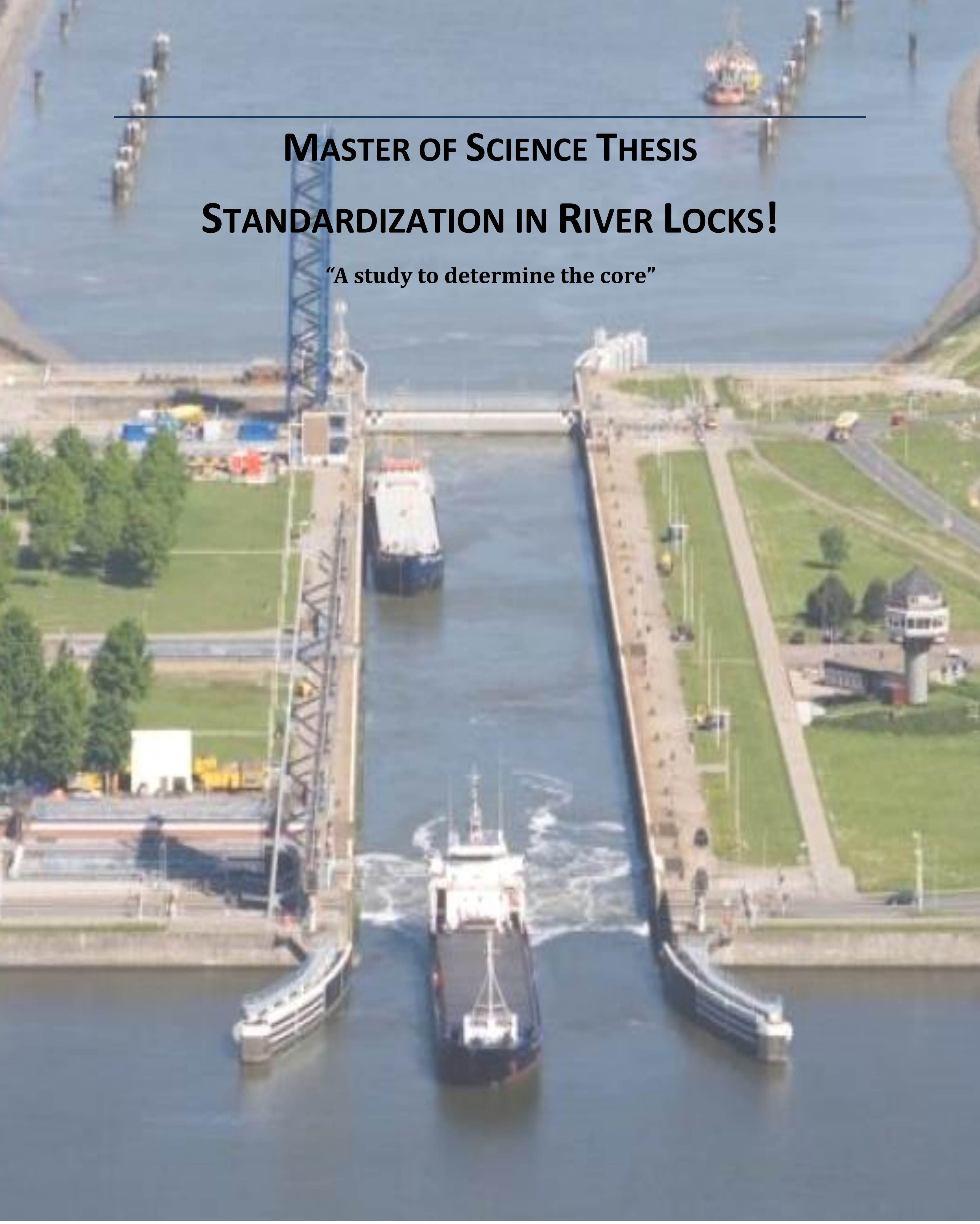
Master of Science Thesis

Standardization in River Locks!

"A study to determine the core"



Technische Universiteit Delft

Lievense engineering the future

Rijkswaterstaat
Ministerie van Infrastructuur en Milieu

This graduation report is part of my master program Construction Management and Engineering at the faculty of Civil Engineering and Geosciences of the Technical University Delft. After finishing my last courses of this master program the search for an interesting thesis began. This search was ended by a conversation with Waldo Molendijk from the engineering office "Raadgevend Ingenieursbureau Lievense". Based on the current developments by Rijkswaterstaat, Waldo came with possibility to investigate the replacements of the river locks that are planned for the next coming years by this office.

Out of this opportunity, it was Jules Verlaan who helped me develop a proper research and to set up the needed committee. As my mentor for this thesis he supported me by contacting Rijkswaterstaat and here the first meeting with Arjan Hijdra was made. Thanks to him the total replacement was narrowed down to the research, which lies in front of you: "Standardization in River Locks".

This title represents the desire to standardize parts of a river lock. As we all know, civil engineering construction almost never the same, with a reason of course. By standardize only parts of the river lock this will be of no difference. Only the elements of a river lock that are suitable for standardization will form the core of the designs and future development.

The main conclusion, based on the literature and case study, is that standardization as a means to reduce the costs will not be very effective. Taking in consideration that the construction costs are a much larger part of the total life cycle costs than the maintenance, the expected benefits will be small or maybe negligible. However when standardization is used as a means to improve the predictability and availability of the main waterways it is a useful tool. Based on the fact that it does not have a negative effect on the financial cost-benefit analysis, it can be assumed that the positive effects of development and implementation of a standard for the replacement of river locks can be advantageous for the economy.

At last I would like to thank the members of my thesis committee for the effort they put into this report, Prof. Dr. Ir. S.N. Jonkman for his critical and scientific attitude towards my research, Drs. Ir. J.G. Verlaan for his involvement in the process, Ir. A. van der Toorn for his technical view and input, Ir. A. Hijdra for his enthusiasm and providing the necessary contacts and information, and at last but definitely not least Ir. W.O. Molendijk for his knowledge, excitement and the daily talks that helped me through the process.

Robert Slijk

Breda, 17 December 2013

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"A study to determine the core"

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Lievense engineering the future

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Preface

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Robert Slijk

Breda, 11 December 2013

Summary

Motivation

Before the year 2040, out of the total of 152 river locks that fall under the supervision of Rijkswaterstaat, 52 have to be replaced. Because of this enormous task, which will be associated with billions of Euro's, it is a real opportunity to optimize the process of design, execution and maintenance. A part of this optimization lies in the increase of predictability, for the total availability and costs. An option for improvement of the economic and financial aspects is the implementation of standards. But not all of the elements that are part of a river lock are desirable for a standard. Therefore this research focus is to determine which of the elements are most desirable for standardization.

Field of Standardization

The world of standardization is huge. All around us is a world that lives and functions by standards that are written and unwritten, even the word standard creates ambiguity among the people. It is a part of control that comes forth out of human nature. For this research the field of standardization is set on the compatibility and variety reduction, based on the functional and technical aspects of a river lock. But not only the consequences are differ from one to another, also the implementation can be set at different levels.

To determine the most desirable element, the level of implementation is set on the national level. With Rijkswaterstaat as the national supervisor and initiator of the replacement they have to take the lead. This national level and the Rijkswaterstaat as chairman of the development makes is a *de jure* standard. Compared to the other variants a standard that is set by law and therefore of use for the total industry.

Search for the most desirable element

Out all of the quantitative and qualitative effects of standards, the ones that can be predicted by formulas are part of this research. These effects can be summarized as the learning curve of handling by developing and manufacturing a product. This comes at handy by the production of series and repetition of the process. These benefits are also a part by the purchase of materials, where the third party can calculate quantity discount on his products.

These effects are taken over the distribution of the transaction costs and maintenance costs. By this subdivision of the life cycle phases of a project the distribution and net benefits can be examined. All to improve the predictability of the costs that are part of the construction or replacement of river locks in the Netherlands. In addition to these higher goals of this research the last criteria that is used, is of quantitative nature and describes the improvement of the availability, or the improvement of the predictability of it.

Findings

The outcome of these models showed a ruler of elements that are suitable and desirable for standardization. The two extremes of this ruler are set by "Standardization" and "No Standardization", which represent the prescription of everything or as little as possible by RWS. From this scale it can be concluded that the movement equipment of a river lock is most suitable, compared to the other elements that are investigated. This conclusion is in line with the expected positive and negative effects of standardization for the elements in a river lock, were the construction costs do not make a difference were the maintenance does.

As a conclusion of the case study it can be presented that for the gates that the positive effects of variety reduction and learning curve offset the negative effect of over dimension. The results shows a slightly positive decrease of the total cost, by 0,3%. This means that the costs for purchase of this particular element is not rising nor falling by the standard. Though the second case study shows that the approach of implementing the standard on all river lock complexes is not financial beneficial, because of the transformation costs that are involved, when the total areaal of RWS has to implement the standard. Based on this case study it can be concluded that it is only financial advantageous to engineer and construct new river locks by the standard.

All together my general opinion, based on the literature and case study, is that standardization as a means to reduce the costs will not be very effective. Taking in consideration that the construction costs are a much larger part of the total life cycle costs than the maintenance, the expected benefits will be small or maybe negligible. However when standardization is used as a means to improve the predictability and availability of the main waterways it is a useful tool. Based on the fact that it does not have a negative effect on the financial cost-benefit analysis, it can be assumed that the positive effects of development and implementation of a standard for the replacement of river locks can be advantageous for the economy.

Recommendations

To set the standards based on the tipping point that is used in the case study all the necessary information has to be recorded. Other, future studies to the feasibility of certain standards depend on the available data. Hence, it is recommended to make sure that all characteristics of all the river locks are known and stored in a standardized format.

Governing is all about anticipation; by this it is meant that the current developments that concern the standardization has to fulfil not only todays needs but also those of tomorrow. With the scenarios for a total Europe is it better to investigate standards on that particular level than the researches that are of today. Therefore I recommend, look abroad and collaborate with other nations to develop a mutual accepted standard.

Further research

As stated before, the world of standardization is huge and based on the literature the effects are divergent. In most conversations the outcome is the same, standards are beneficial but to what extent is unclear. To make the right decisions a lot of these effects should be investigated properly for the construction industry.

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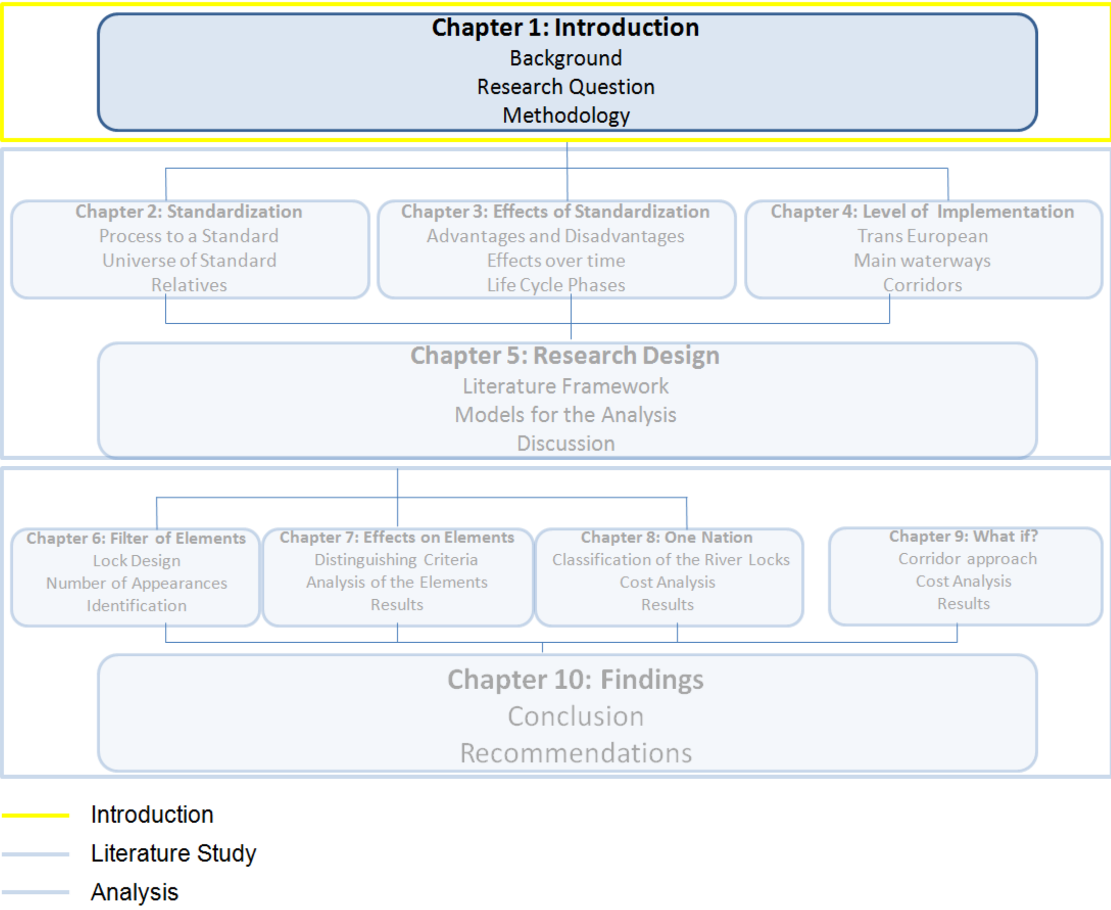
Introduction



1. Introduction

This chapter consist of an introduction to the master thesis research; "Standardization in River Locks". As the figure on the previous page shows, does this chapter consist the background of this research, by means of the replacement of river locks that is planned by Rijkswaterstaat. Secondly, the problem definition and research question are presented and discussed, and last the methodology is elaborated.

1.1 Replacement of river locks

In the past there was a lot invested in infrastructural construction in the Netherlands. Due to aging and increased use, many civil engineering constructions approach the end of their life cycle, making substitution or renovation necessary. The cost of this "substitute statement" in the coming decades is expected to reach several hundred million Euros per year.[1] This means that in the coming decades, a shift will occur in the resources required for management, equipment maintenance and substitution of existing infrastructure in relation to the construction of new infrastructure.

One of the most obvious demands from RWS is the substitution of river locks. With a total amount of 138 river locks in the Netherlands, this group forms a large part of all the waterworks. Almost all of these river locks were built according to the best available options in that time. Based on the location and money the locks were engineered and implemented in the environment. None of them were equal to another and any form of standards in the locks couldn't be derived, let alone that they didn't show any form of uniformity.[2] In the following picture the amount and building period of river locks and other corresponding waterworks built in the previous decades is presented.

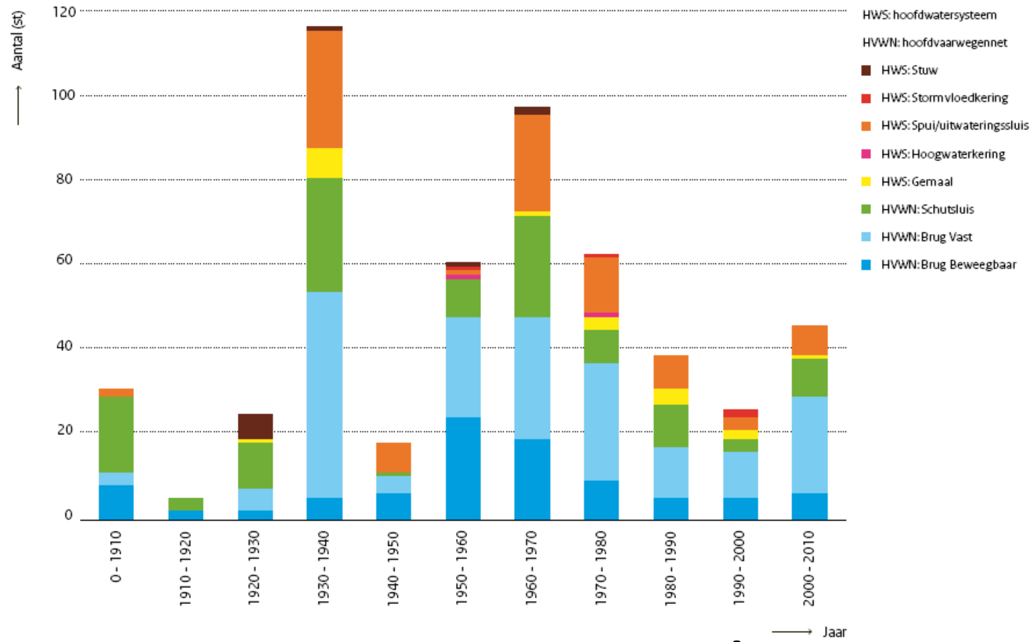


Figure 1: Year of build of the Water Works in the Netherlands[3]

[1] *Ministerie van IenM, (2012); Vervangingsopgave Natte Kunstwerken (VONK)*
[2] *Hoogheemraadschap Hollands Noorderkwartier, (2008); Sluizenboek*
[3] *Deltaprogramma 2013, (2012); Bijlage H: Vervangsopgave Natte Kunstwerken*

Most of the river locks that are part of the substitution by RWS are on this list because they reached the end of life. This end of life is reached when there are such serious structural defects or functional limitations that the intended use is no longer possible or necessary, therefore intervention is necessary. The cause of reaching the end of life may well lie in achieving the end of technical life (aging material), end of service life (use intensity and requirements) or changes in laws and regulations. In figure [2] the total amount of replaced waterworks is shown, according to the different types of waterworks, based on the expected life cycle. As mentioned above the real time of replacement is a combination of the technical and functional state of the river locks. In the paragraphs below these different approaches are elaborated.

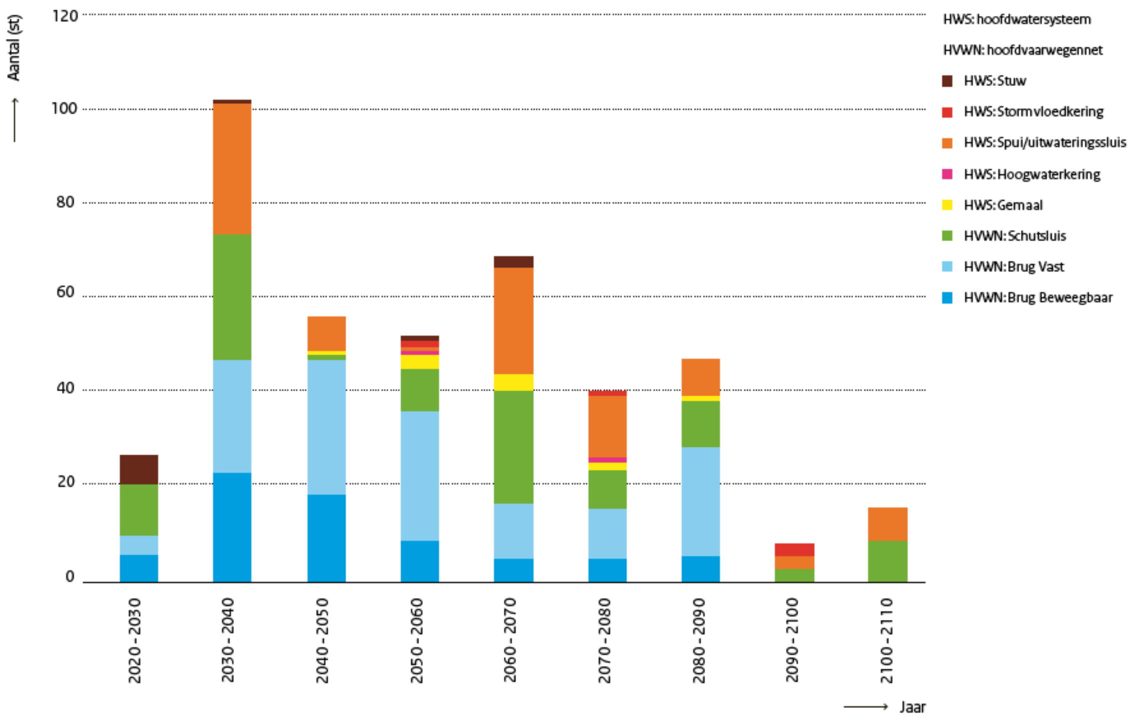


Figure 2: Estimated Replacement of Water Works[4]

1.1.1 - Technical Approach

During the technical lifespan, a lock must meet a certain technical reliability. It is customary to capture this required reliability in a claimed availability. Each lock needs to be regularly inspected and maintained as necessary. These activities obviously affect the availability. That availability is important is shown by certain operating contracts where penalty clauses become active when the agreed availability is not achieved. Therefore it is essential for the principal to get a reliable prediction of the technical lifetime and availability.[5]

A lock is designed on the basis of a mechanical model that is a simplified representation of reality. The model is used to determine the safety of the lock against any form of failure. Therefore the model has three physical uncertainties: water forces, strength (reaction) and model uncertainty. To determine the technical lifespan, it is of importance to have an estimation of the water forces and the strength, during the service life as much as possible. Moreover, it is vital to have insight in the uncertainty of the model.

[4] *Deltaprogramma 2013, (2012); Bijlage H: Vervangsopgave Natte Kunstwerken*
[5] *Blom, C.B.M., Gaal, G.C.M. (2005); Technische levensduur van tunnels*

There is also the awareness that during the completion of construction not only the current state is decreased, but also the question of whether it will go and will continue to operate in the design as expected. Supporting the answer to this question more and more measurement, inspection and monitoring are deployed. Therefore after delivery a constant flow of information will lead to a more accurate picture of upcoming maintenance and therefore reduced availability. It is important that the right information is obtained, that it is interpreted in the right way, that the correct intervention values are established, and that on this basis the maintenance and cost planning strategy can be adjusted. Part of this will always be: "when does an investment in maintenance lead to the best situation?".[6]

The uncertainties in the predictions arise, among others, by the quality of the lock inspections. This is not sufficiently reliable. This will stack your uncertainty upon uncertainty. This makes the inspection data not entirely meaningless, but it's just not the whole truth. A lot of measurements and collecting of data does not automatically lead to the truth, but gives an interesting source of information, provided that you're sensible about it. There are too many variables to put into a model and with that predict the life reliably.[7]

It is expected that, in view of the Life Cycle Costs, the technical lifetime consideration of locks play a very important role. Much energy is spent on making better use of the models, interpreting its results, inspection and monitoring strategies and maintenance aspects. Both at European level and in the Netherlands studies are being carried out that contribute to knowledge about the technical lifetime of locks. This kind of examination is therefore made more difficult by the various aspects within a lock. The rule of thumb hereby is that the civil works have a lifespan of 50 years, the movement will work for up to 20 years and the electrical components have the expectation of 10 years.

It has become clear that the total costs of a lock are not only caused by the construction costs, but also by the costs and revenues during the exploitation for both maintenance and management. Availability for exploitation plays an important role. A reliable prediction of the technical lifetime of a lock, allowing insight into necessary maintenance, repair, availability and costs, contributes to better judgments and decisions about whether a lock needs to be replaced or can be repaired.

Unfortunately, these data on areas occupied by RWS, are partially unavailable for this study by the market advantage that Lievense might have. As could be seen in table [1] on page number [12] only the years are presented. The methods to determine this are unavailable for the same reason. Therefore the parameters are written in this paragraph.

1.1.2 - Functional Approach

The other approach to determine the end of life of a river lock is based on the functional aspects. By functional its meant ability to achieve the functions that are described for a river lock. Especially the functional demands of transit is an important factor. This factor indicates the ratio between the intensity of a river lock and the capacity of it. This number can be expressed on a scale of 0 to 1. This approach is therefore of importance to know which river lock will cause congestions, today and in the future.

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[6] *RWS (2003); Beheer en Onderhoudskosten*
[7] *RWS (2012); Objectbeheersregime Kunstwerken HWS & HVWN*

Scenarios

For today's situation it is quite easy to calculate. By the numbers that are presented by the lockkeeper in his logbook, and the estimated capacity the ratio can be determined, see next paragraph. For the future ratio of intensity and capacity the supervisors use the commonly known scenario's of the CPB. They published a study called: "*Scanning the Future"*, in 1992. This study presented four long-term scenarios for the world economy, based on an assessment of current trends, strengths and weaknesses. These abstract scenarios are transferred to specific markets, which on their term could examine the trends that will come.

The four long-term scenarios that are presented gives an insight in the future until the year 2040. The axes on which the scenarios are examined are: international cooperation and institutional reforms. The researchers chose for these two uncertainties based on trends that they see in the past. The four scenarios are Strong Europe (SE), Global Economy (GE), Regional Communities (RC) and Transatlantic Market (TM), see figure [3] for the distinction and appendix [A] for the background information.

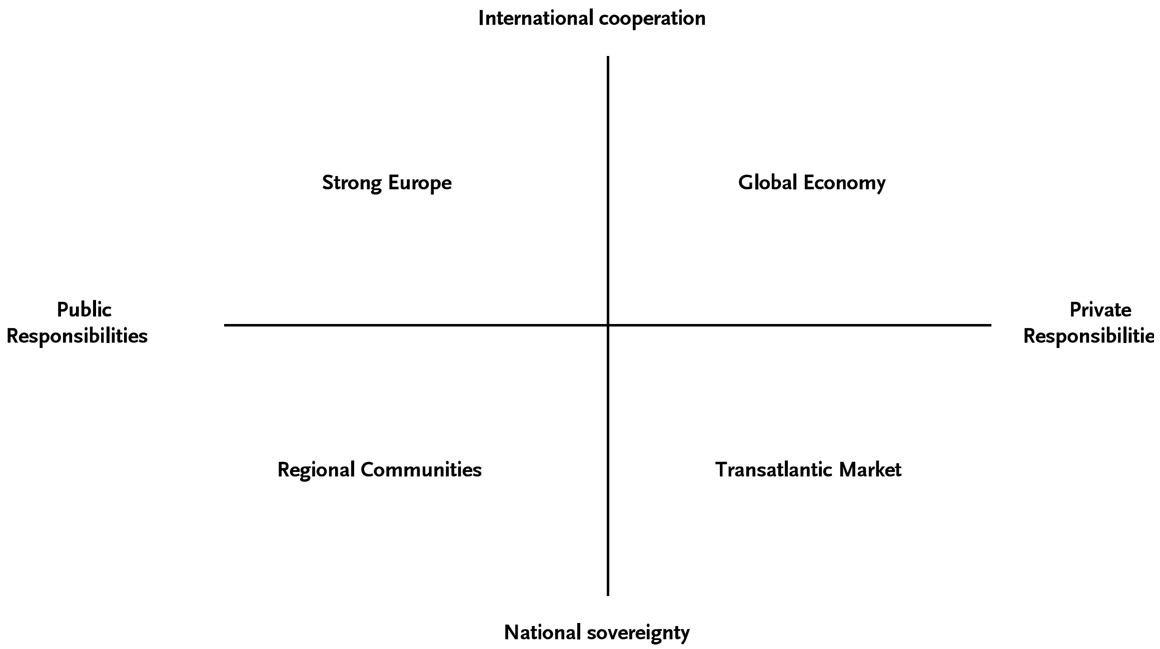

Figure 3: Four Futures of Europe[8]

1.1.3 - I/C-ratio

As mentioned before the I/C ratio plays an important role by the determination of possible replacements. To get a well-based survey of the Intensity/Capacity ratio of the river locks, the analysis made by RWS contains the previous scenarios. The I/C-ratio gives a prospect of the future congestions near the river locks, based on the ratio between the intensity (the amount of ships that are in the locks) and the capacity (the amount of ships that can be in the locks) over a certain period of time. Another criteria that is used by RWS to get a river lock on the list, is the amount of commercial freight. This amount is set by 10.000 freight per year, based on the assumption that a river lock with a minimum of one lock and with the corresponding measures of a CEMT class, must deal with this amount without congestion and additional downtime. With this assumption and the previous scenarios in mind with corresponding increase of the intensity, RWS

[8] *Lejour, A. (2003); Quantifying four scenarios for Europe*

made a list of 52 river locks that has the potential to be renewed, renovated or replaced. See appendix [B]. The next figure shows the Waterway Corridors of the Netherlands. These corridors form an important part of the investigation due to the fact that if one river lock might have capacity congestion, it will affect other locks of the corridor. Also the other way around could be of importance, this means that if there is a long downtime at a certain river lock, the next in line does not have a problem yet.

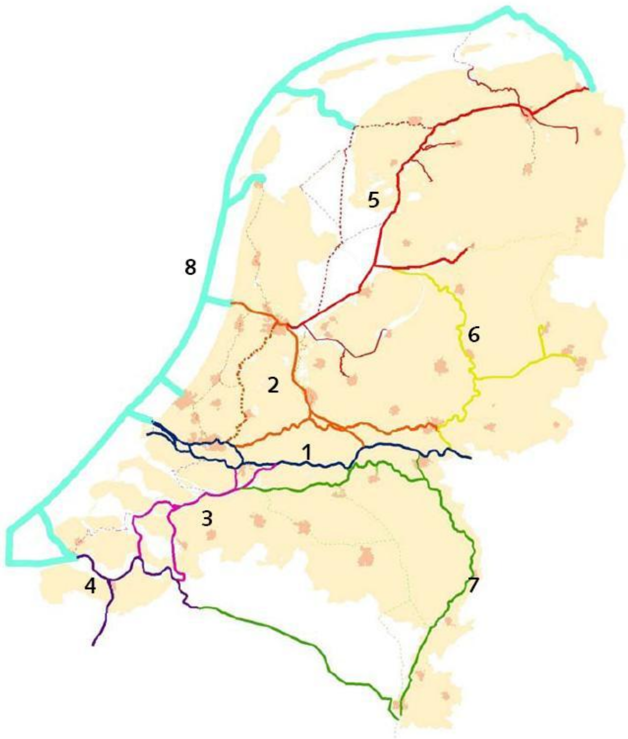

Figure 4: Waterway Corridors Netherlands[9]

Out of this list 17 of the river locks were selected for further investigation. Some of the river locks that are not part of the investigation were not selected because of different reasons. A hand full of them are already part of the MIRT phases and do not need an I/C research, other possible bottlenecks have been offset by temporary or sustainable solutions, and the last group is renewed already.

To identify the Intensity of the river locks in the future, a couple of assumptions have been made.

- Weights of the containers stays the same
- No correlation between different river locks adaption
- No division between regions about the growth
- The impact of climate change is not investigated

[9] *RWS (2011); Deelrapportage Vaarwegen voor de Nationale Markt en Capaciteits Analyse (NMCA)*

The calculation of the I/C-ratio is done by the Kooman spreadsheet. Additional to the I/C-ratio is the calculation of the average passing time of the ships. For this analyses the next technical characteristics of a lock are needed:

- Measures of the locks
- Number of locks
- Opening and operational data per week
- Operational time per usage
- Traffic offering at the lock: random of clustered
- CEMT-classes

In the final stage of this functional analysis made by RWS, the Kooman spreadsheet identifies the river locks that have to be renewed or replaced to fulfill the waterways' future needs. This Kooman spreadsheet is developed and used by the Administration for traffic and shipping *(Dutch: Dienst Verkeer en Scheepvaart (DVS)).* Important parameters for this spreadsheet are the lock dimensions, capacity of freight and increase of scale by the average capacity of freight. The relation between I/C-ratio and the downtime of ships is highly correlative. By an increasing I/C-ratio the downtime will increase exponential. For river locks in the Netherlands an I/C-ratio of 0,5 – 0,6, which is corresponding with 30 min. waiting time, is used as the limit.[10] In figure [5] the goal for the year 2028 is set by the ministry of Infrastructure and Environment. If the I/C-ratio is over the 0,5 a possible bottleneck will come, if I/C-ratio has passed the 0,6 there is a capacity bottleneck, according to the NoMo (Nota Mobiliteit) criteria, see appendix B. As a result of this analysis the following river locks should be renewed or replaced due to the technical and functional end of life, with the estimated year of replacement. See table [1] on the next page.

Figure 5: Map of clean passages of inland waterways[11]

[10] *RWS (2011); Richtlijnen Vaarwegen 2011*
[11] *Minsterie van IenM (2010); Kaart met vrije doorvaart hoofdvaarwegen*

Nr.	Complex:	Reason:	Year:
	Corridor 2:		
1.	IJmuiden	Technical	*2023*
2.	Beatrix	Technical	*2033*
3.	Irene	Functional	*2037*
4.	Marijke	Technical	*2037*
5.	Bernhard	Functional	*2040*
6.	Zuidersluis	Technical	*2037*
7.	Noordersluis	Technical	*2037*
	Corridor 3:		
8.	Volkerak	Functional	*2020*
9.	Kreekrak	Functional	*2020*
10.	Krammer	Functional	*2028*
11.	Hansweert	Functional	*2040*
	Corridor 4:		
12.	Terneuzen	Technical	*2034*
	Corridor 5:		
13.	Oranje	Functional	*2040*
14.	Margriet	Functional	*2020*
15.	Gaarkeuken	Functional	*2028*
16.	Lorentz	Technical	*2031*
17.	Stevin	Technical	*2030*
18.	Oostersluis	Functional	*2020*
	Corridor 6:		
19.	Eefden	Technical	*2031*
20.	Delden	Functional	*2020*
21.	Hengelo	Technical	*2035*

Nr.	Complex:	Reason:	Year:
	Remaining:		
22.	Weurt	Functional	*2020*
23.	Panheel	Technical	*2030*
24.	Sluis 0	Technical	*2031*
25.	Sluis II	Technical	*2016*
26.	Sluis III	Technical	*2016*
27.	Sluis V	Technical	*2035*
28.	Sluis 16	Technical	*2030*
29.	Wilhelmina	Technical	*2033*
30.	Maxima	Technical	*2036*
31.	Heumen	Technical	*2027*
32.	St. Andries	Technical	*2034*
33.	Gouda	Technical	*2034*
34.	Linne	Technical	*2030*
35.	Roermond	Technical	*2030*
36.	Limmel	Technical	*2032*
37.	Bosscheveld	Technical	*2030*
38.	Den Hommel	Technical	*2037*
39.	Ottersluis	Technical	*2035*
40.	Helsluis	Technical	*2035*
41.	Engelen	Technical	*2035*
42.	Grave	Technical	*2035*
43.	Sambeek	Technical	*2025*
44.	Hulsen	Technical	*2032*
45.	Belfeld	Technical	*2026*
46.	Born	Technical	*2033*
47.	Borgharen	Technical	*2025*

Table 1: Replacement of River Locks before 2040[12] [13]

[12] *RWS (2011); Deelrapportage Vaarwegen voor de Nationale Markt en Capaciteits Analyse*
[13] *RWS (2012); Objectbeheersregime Kunstwerken HWS & HVWN*

1.2 Problem definition and research question

The goal of this report is to analyse and conclude which elements of a river lock, corridor or main waterways are suitable for standardization. In this research the main focus is on the financial feasibility of the standardized elements, in relation to the economic, technical and legal effects.

1.2.1 - Objective

The main objective of this research is to investigate which objects, elements or parts of the river lock are suitable for standardization, in order to reduce Life Cycle Costs (LCC) and to improve the reliability and predictability of the costs, nowadays and in the future. In case a positive outcome on one or multiple elements is determined, this could lead to further investigation to the legal implementation and technical optimization.

Therefore it is vital to consider the importance of this research, which is a contribution to the development of a model to design the core of river locks. This means that the presented master thesis has not a goal on its own but has to be seen in the light of a nationwide research to optimize the construction, operation and maintenance of river locks in the Netherlands.

1.2.2 - Problem definition

As a summary of the previous chapter, the Rijkswaterstaat (RWS) will face a challenge to replace several river locks in the next decades. By these technical and functional reasoning of replacement, they see this process as an opportunity to come up with a standardized core inside the river lock, which could solve similar problems throughout the nation and could be developed over time. Another opportunity, which is highly related, is the possibility to standardize some elements or objects in order to gain several financial and economic advantages.

The problems that arise in the ideas of RWS are known as the uncertainty of implementation. One problem is based on the fact that a lot off unknown effects can or might occur during the first phases of standardization, but also over a time span of several years. A second problem lies in the extent in which it will apply. It could possibly be beneficial for small elements or larger subsystems of the river lock, or do these standards become only advantageous on national economic aspect. As a result of this, it can be concluded that the problems are uncertain, to decrease these possible risks this opportunity to create a standardized core of a river lock is an option.

All around the world standardization is seen as a reasonable strategy for risk management. According to the Business Dictionary, risks have the potential for negative impact due to vulnerabilities threatened by future events. Standardization preclude these risks from expected and unpredictable events that forms a danger of the product quality and failure, professional service quality, health and safety, environmentalism, operations, finance, legal rights, political standing or influence, competition, labour and employment, and resource or commodity availability. The most important dilemma in standardization for certain elements in river locks is the balance the societal benefits of competition achieved through encouraging variety against other benefits achieved through reducing variety. The tipping point between these extremes is an elusive question but necessary for this research.

Another problem is the assumption that civil engineering construction depends on the local environment of soils and water levels. Not like IKEA closets or public cars, civil works are custom made for the location it has to fit in. This does not mean that everything has to be engineered, as it is a unique product, because most of the time engineering companies use their knowledge and databases to calculated the dimensions and materials. But as said to copy a construction from one location to another there are certain risks due to the changing conditions. [14]

The last problem that might be of importance is the relative low amount of civil works with high costs per construction, as well as the risks for the surrounding communities. There may be a lot of benefits to be gained from engineered custom constructions. Hence, it is an interesting problem which of the elements is suitable for standardization based on conventional parameters.

1.2.3 - Research question

The background of this research, in combination with the problem definition, made it clear that despite the variety of elements within a river lock a functional and technical standard might create advantages for different parties. These advantages can be derived on financial criteria such as construction costs, but also on economic ground by the possible improvement of the availability. That is the motivation for the following research question:

Which elements of a river lock are most suitable for standardization by the replacements of river locks in the Netherlands, based on the balance between financial/economic benefits and competition benefits?

By elements it is meant the subdivision of a river lock based on the database of RWS. This subdivision is called the conservation level of river locks. The reason for this level is because of the available data and the expected effects on the total construction of a river lock. A higher level means a clustering of elements, which are too comprehensive and therefore hard to execute. A lower level is too detailed and some of these elements are already subject to standards. Hence, the best choice is to investigate the conservation level of river locks.

By a river lock its intended that the scope stops and ends by the physical entrance and exit of the river lock. The harbour parts that help navigate the ships into the lock are not part of the scope, these elements are too dependent on external factors. This is also the case for the intersecting traffic of cars, bicycles and pedestrians.

One has also chosen to compare the elements of a river lock with each other. As possible result for this research might be that all elements are suitable for standardization, based on all kind of criteria. By adding the word "most" the elements will be compared and can be put on a scale from "no standardization" to standardization.

The word suitable is chosen because of the fact that whether or not an element of the conventional level turned out to be desirable, other criteria that aren't used in this report are of importance for the decision-making. Political and legal aspects are just a few of the multi criteria that can play a part in the final decision-making. As Phil Whitehouse ones said: "If standards represent peace, then formal standardization can be war!"

[14] *Wegberg, M. van, (2004); Standardization Process of Systems Technology*

1.2.4 - Hypothesis

Elements with a high ratio of maintenance vs. construction have the potential to become a standard. With the proper subdivision of these elements, a financial and economic benefit is possible at the end. The reason for this hypotheses is that the financial percentage of maintenance will be much larger than the construction costs, over the total life cycle of a river lock for certain elements. This includes the variable and fixed maintenance of elements. For the economic part of this hypothesis it is thought that a decrease of different parts within the river locks that falls under the supervision of RWS will contribute to the availability, as well as the predictability. This is based on the idea that if an element is used more than ones, the characteristics are better known.

1.2.5 - Position of this report in the current developments

In the past almost all the contracts in the construction industry were awarded on a low-bid basis. The design and engineering was already made by an engineering office, public or private. In case of RWS, most of the time, their own Engineering office, called Bouwdienst, made the drawings and technical specifications that served the tendering for the low-bid basis. When a contractor submitted the lowest bid for the project, the execution of the construction was given to this company. This low-bid procedure has served the public parties for a long time. It promotes an open competition between the contractors and enjoys the necessary legal precedence. Especially the first condition is a major concern for the public parties as well as for their industry partners. The disadvantage of the low-bid procedure is the fact that it provides contractors with an incentive to lower their prices to the maximum extent possible. This could result in a lower price at the expense of quality. As a result, the low-bid system may not result in the best value for money expended or the best performance during and after construction.

Nowadays, the construction industry and public parties are finding themselves under growing pressure to increase the project’s performance, time and cost. Even so are there recent developments like European Tendering, Electronic Tools and the parliamentary commission that investigated an optimization in the process. In response to these pressures and developments, the industry has experimented with alternative procurement and contracting methods.[15] In essence, best-value procurement incorporates factors other than just price into the supplier selection process to improve performance or achieve other specific project goals.[16] [17]

The development of best-value procurement and supplier selection methods in the public sector have been employed under traditional design-bid-build contracting and has to some extent borrowed ideas and approaches used to procure products and services in the private sector. This change in the tendering made it hardly possible for the RWS to hold on to their engineering partner, the Bouwdienst. The entire standard engineering work they were used to, had stopped, and was switch to a new principle: “Market, ... unless” (Dutch: “Markt, ... tenzij”). This change in engineering and tendering made it that the market is now learning and developing. By this it is meant that the companies are developing standards to engineering by themselves because they cannot rely on the Bouwdienst anymore.

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[15] *Gransberg, D.D., Ellicott, M.A. (1996); Best---Value Contracting: Breaking the Low-Bid Paradigm*
[16] *GCH International (2004); Design and Construct; De overheid gaat Lumpsum!*
[17] *Minchin, R.E., Smith, G.R. (2001); Quality-Based Performance Ration of Contractors for Prequalification and Bidding Purpose*

This principle of RWS means that tasks which are traditionally performed by RWS itself in the field of construction, management and maintenance of roads and waterways, be transferred to the market. RWS dictates how everything should work, but leave the design and solutions to the market. The standards of the Bouwdienst had been translated to implicit standards by RWS in the form of guidebooks and manuals. This method of tendering requires close cooperation between the government and the market.

To implement this form of cooperation between the public party of RWS and the private parties, a new construction has been made. This so-called Public-Private-Partnerships (PPP) is a possible solution. PPP is the most extreme form of cooperation between the government and the market. The direction of a project and the end result, such as maintaining or building a road or a bridge, remains in the hands of the government. The realization is done as much as possible by market. Sometimes the contractor is fully responsible for design, construction, management and maintenance and financing of the project. This type of contract may have a duration of 20 or 30 years. [18] The question is, can the implicit standards of RWS be converted to explicit standards through the involvement of market participants in the process?

1.2.6 - Relation with other researches

This research cannot be seen as a stand-alone investigation for the replacement of the river locks in the Netherlands. Prior to this research some meetings with RWS were held to take notice about missing spots or links by the replacement. The following models and project group have a strong link with this research and are therefore elaborated.

RINK (Risico Inventarisatie Natte Kunstwerken)

The main goal of RINK is to give an overview of the maintenance condition of the entire set of hydraulic structures, regarding risks on economic and safety grounds and the visualization of the remaining lifetime. Another target is the evaluation of the performance of the hydraulic structures on the basis of a network level. This so-called Service Level Agreement creates an understanding in the functionality of the hydraulic structures and could therefore serve a tool to prioritize the need to take measures or modifications on the total network level.

VONK (Vervangingsopgave Natte Kunstwerken)

As a result of RINK some hydraulic structures are pointed out to be replaced in the near future. The goal of VONK is to give guidance to this multi billion project. Due to the large amount of Euro's that have to be spend in the future, VONK has been created to investigate all kinds of alternatives. This includes one-on-one replacements, but also different corridor routes, etc. Bearing in mind what is best for the Netherlands.

MWW (MultiWaterWerk)

Part of this VONK program is MWW. A project team that represents the four elements of the market: Government, Commercial Parties, Knowledge Institutions and Users. This team is searching for the best methods to replace the river locks. This includes all aspects of civil engineering tenders.

[18] *RWS (2011); Ondernemingsplan 2015*

Brug- en sluisstandaarden van RWS

Parallel to this MWW program, RWS is trying to develop a standard for bridges and locks. This standard consists of documents that the organization of the processes and the functional and technical requirements for bridges locks describe, in relation with the legislation, policies and network management. These documents relate to the use, operation and control of movable bridges and locks, with a focus on objectives, organization, primary work and the functional and technical equipment used in them.

1.2.7 - Limitations

As already mentioned in the explanation of the research question, that this research focuses on the river lock itself. This means that the scope stops and ends by the physical entrance and exit of the river lock. The harbour parts that help navigate the ships into the lock are not part of the scope, these elements are too dependent on external factors. This is also the case for the intersecting traffic of cars, bicycles and pedestrians. The reason for this is the fact that a new matrix has to be developed with the axes: CEMT-class and Traffic-class, this could lead to multiple designs.

This thesis focuses only on the elements that are desirable for standardization. Other measures that could create benefits to the construction industry are not part of this scope. This does not mean that standardization is a goal for this research but a means to improve the construction industry.

Political and legal aspects are not part of this scope either. As a recommendation it could be that the possible elements should not be fully issued but rather described as functions with technical limitations.

1.2.8 - Standards that already exists in river locks

Standards are not a new phenomenon in the construction world that we live in. In fact, written standards date back to the first years of the Industrial Revolution in 1782.[19] From this day, when James Watt introduced the steam engine, the mode of low-level production turned into a mechanized production, which, in turn, went to standardized equipment and tools. This can be represented by the standardization of bolts and nuts in the year 1800 by Henry Maudslay.[20] A British mechanical engineer who made the applications of interchangeability principle to both bolts and nuts. Before this invention, they had to be made one by one separately. Over time these technical standards are evolved to dozens of organizations, which are involved in standardization of physical and non-physical assets. Some of these standards have a relation with the river locks as we know them but are sensitive for changes.

Physical standards

- Connection parts by measures and strength
- Concrete classifications by strength
- Steel classification by strength
- Location and strength of bollards, stairs and fenders
- Measures of ships by the CEMT classification

[19] *Ping, W. (2011); A Brief History of Standards and Standardization Organizations*
[20] *Bradley, I. (1972); A History of Machine Tools*

Non-physical standards

- Safety
- Procedures
- Communication
- Asset Management
- Machinery guidelines/NEN1010

1.3 Methodology

The main question of this master thesis is: '*Which elements of a river lock are most suitable for standardization by the replacements of river locks in the Netherlands, based on the balance between financial/economic benefits and competition benefits?'* To answer this question this report is divided in different phases, see figure [6]. The other chapters next to this presented core are needless to explain.

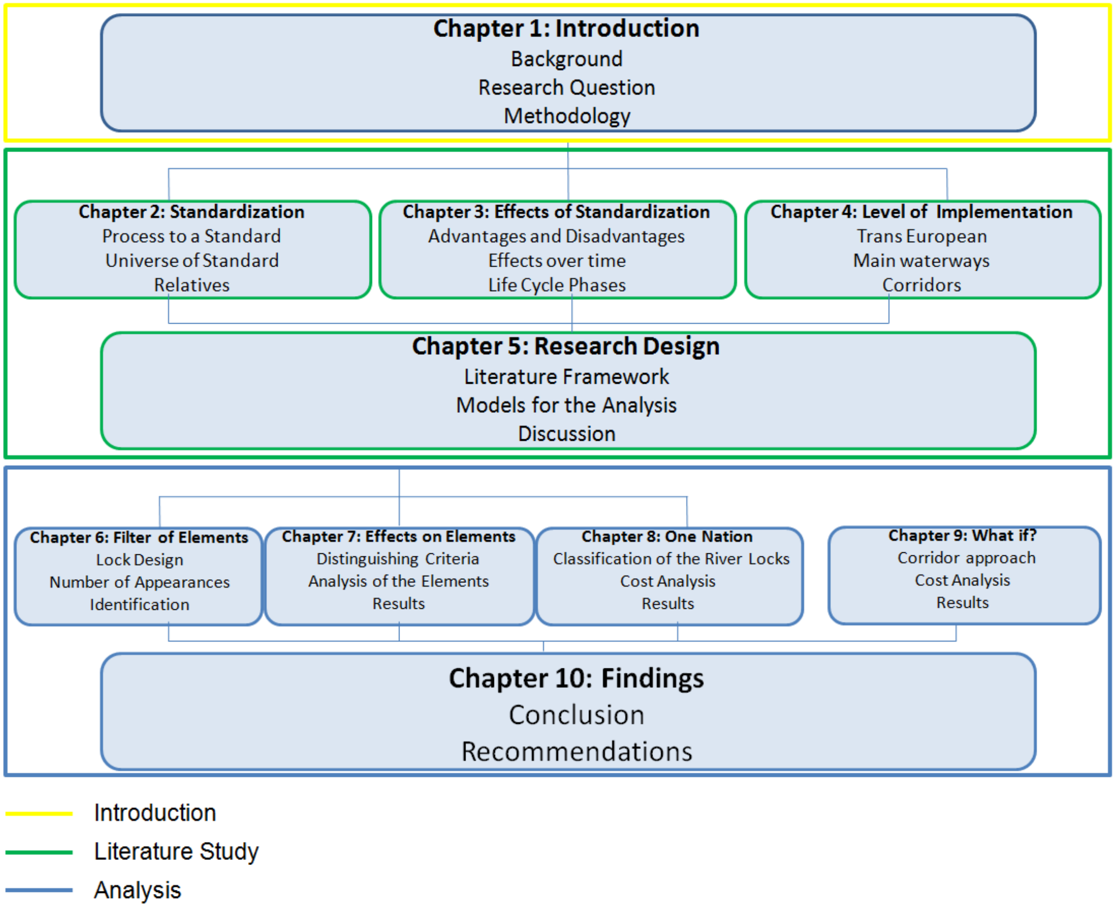


Figure 6: Total Research Structure

1.3.1 - Introduction

To give an answer to the question why the river locks should be replaced Chapter 1 is inserted. It gives a clear view on the opportunity for RWS and their motives for a change. These are needed to answer the main question. As also could be read in this chapter that the scope has been defined, the problem stated and a brief explanation of the method that is used in this research.

1.3.2 - Literature Study

Chapter 2 is the literate study about standardization. This literature part is useful for me as a researcher and for the readers to have an understanding of the different standards and which of them are used in this research. The choices on which forms are relevant and what are the advantages and disadvantages, based on:

- Activity
- Level
- Field

Chapter 3 describes the effects of standardization of elements of these types of standardization:

- Advantages and disadvantage
- Specific for the river locks
- In general over the total Life Cycle

Chapter 4 shows the relations between the level of implementation and the numbers that are involved. This includes a categorization of all the river locks in the Netherlands that are under the supervision of RWS. This categorization has the potential to select the major part of the river locks for further investigation.

Chapter 5 is a summary of the literature that is studied in order to give a brief conclusion, which will form the input for the case study and the used models. These models are presented and discussed in this chapter.

1.3.3 - Analysis

Chapter 6 is a decomposition of a river lock. Is gives a clear view on the specific elements and subsystems and there interdependencies. It also elaborates which of the objects or elements are largely dependent on external factors and are therefore excluded from further investigation. In combination with the previous chapter, certain elements that are selected will form the basis of the analysis.

Chapter 7 is the analysis of which elements/subsystems are suitable to standardize, based on the quantitative effects of variety reduction and learning curve. The criteria that are used to determine the most desirable element are the costs in all life cycle phases and the improvement of availability.

After some of the elements are identified as desirable for standardization, one has decided to present a case study about the gates. In Chapter 8 a matrix is formed which gives a clear understanding about the financial and economic benefits that comes with the standardization of these specific elements for the whole nation.

Chapter 9 is the reverse research to the effects of standardization. By this it is meant that an answer will be given to the question: "What if?". By this pragmatic view on the problem it is thought that difficulties and choices will arise when it is decided that the core of river locks will be standardized and implemented a corridor.

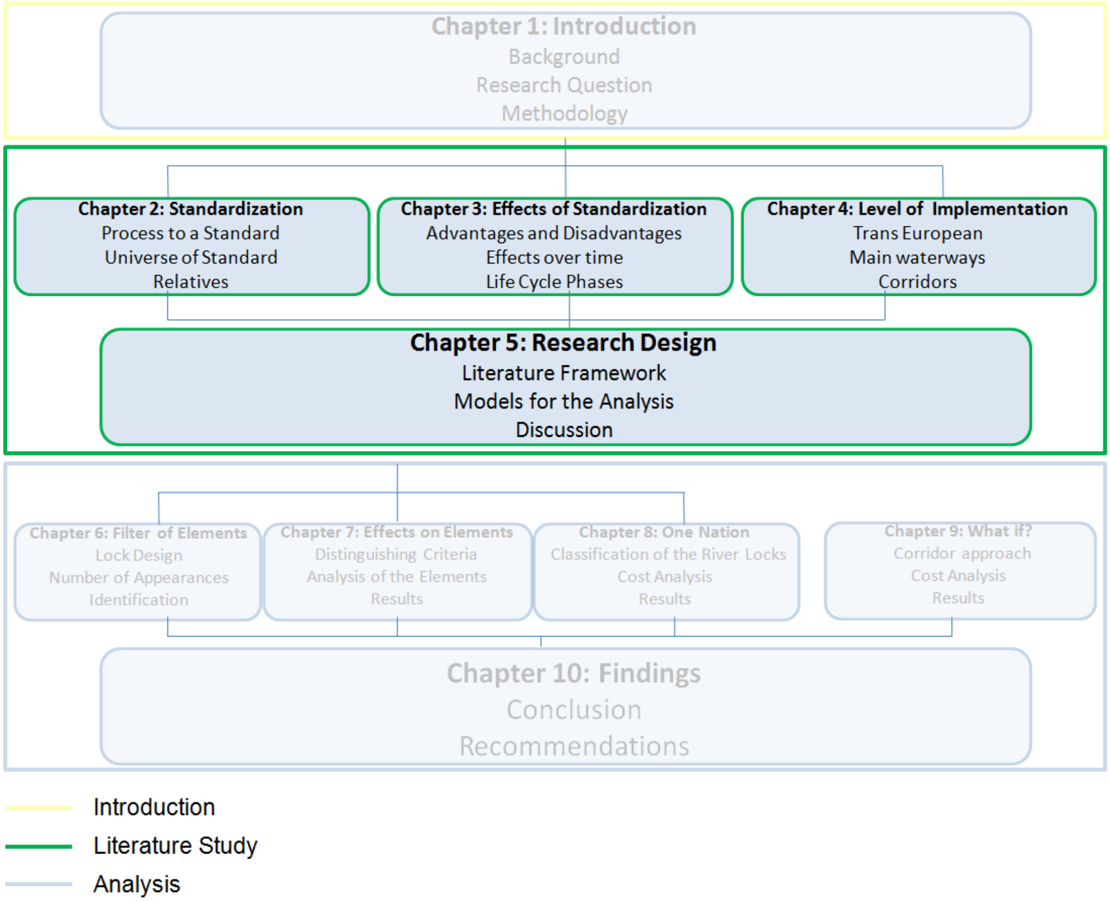
The last chapter of this research contains the conclusions and recommendation that comes forth of this report.

MASTER OF SCIENCE THESIS

STANDARDIZATION IN RIVER LOCKS!

"A study to determine the core"

Literature Study



Standards are essential for different stuff made by different companies in different countries to work well together. Whether it is bananas of chocolate, application forms for terrorist training, or the size of people's rear ends (critical for airline seats), standards are an essential part of life today.

Don Norman, 2009

2. Standardization

A lot has been written about the verb and the noun standardization. In articles, researches, books and even presidential speeches this word creates a mutual understanding between author and reader. But as all this literature is combined different theories and descriptions arise. This chapter is meant to create a clear view about standardization and to take away vagueness on this topic. For the same reason there is also a paragraph included which describes the relatives of standardization and the differences between them. At the end of this chapter the assumptions and choices that are needed for this research are elaborated and discussed.

2.1 Process of standardization

The word standard can be used in several ways regarding emerged and converged technologies. The standardization process can divide a standard into three or four major categories. The first one is the so-called *de jure* standard, which means "by law" or "concerning law" in Latin[21]. This *de jure* standard describes a public technology that is determined by an agreement reached through negotiation in a standardization body. A standardization body works as a mediator that facilitates voluntary consensus-building about conflicting requirements from multiple stakeholders of a technology.

By contrast are the second standardization processes, called *de facto,* consortia and Voluntary Consensus Standards (VCS) standards which are much like the private law of contracts, they impose compliance only on voluntary participants. The phrase *de facto* means "in practice but not necessarily ordained by law" or "in practice or actuality, but not officially established".[22] This standard describes a technology that wins market competition, and the technology is handled like an authorized *de jure* standard. It is a standard formed in a market without mediation by a standardization body. Therefore, if a differentiated proprietary technology is broadly accepted in a market, it can be considered a *de facto*, consortia or VCS standard. These types of standards differ in terms of openness to the market, where participation is not always desired, see figure [7].

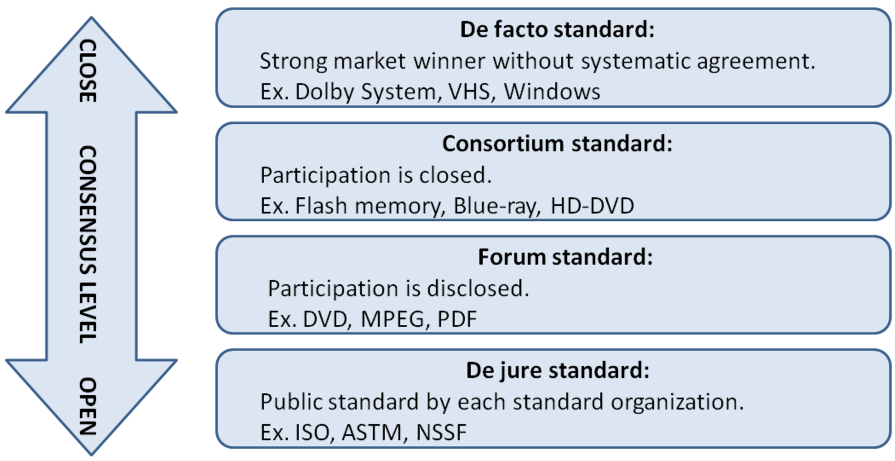


Figure 7: Different standards with corresponding consensus to the market

[21] *http://en.wikipedia.org/wiki/De_jure_standard (seen on 04/23/2013)*
[22] *http://en.wikipedia.org/wiki/De_facto_standard (seen on 04/23/2013)*

2.2 The Universe of Standardization

The universe of standardization is the collection of different dimensions in which standardization occurs. As already mentioned in the previous paragraph, standardization can be divided in a lot of different categories that all have its own purpose. By this elaboration it becomes clear in what framework the standardization of elements that are part of a river lock can be identified.

2.2.1 - Level

The level of a standard is based on the area in which the standard is used, or in which area the standard should be used. This part of the universe is of importance because of the fact that the river locks that are part of this scope are used by different types of users and organizations, see figure [8]. In chapter [4] it becomes clear that the total network of waterways is subject to standards and regulations, on the other side a company can set a standard that will influence the designing of the river locks. It should always be remembered that it is on the company level that the actual implementation of standards takes place.

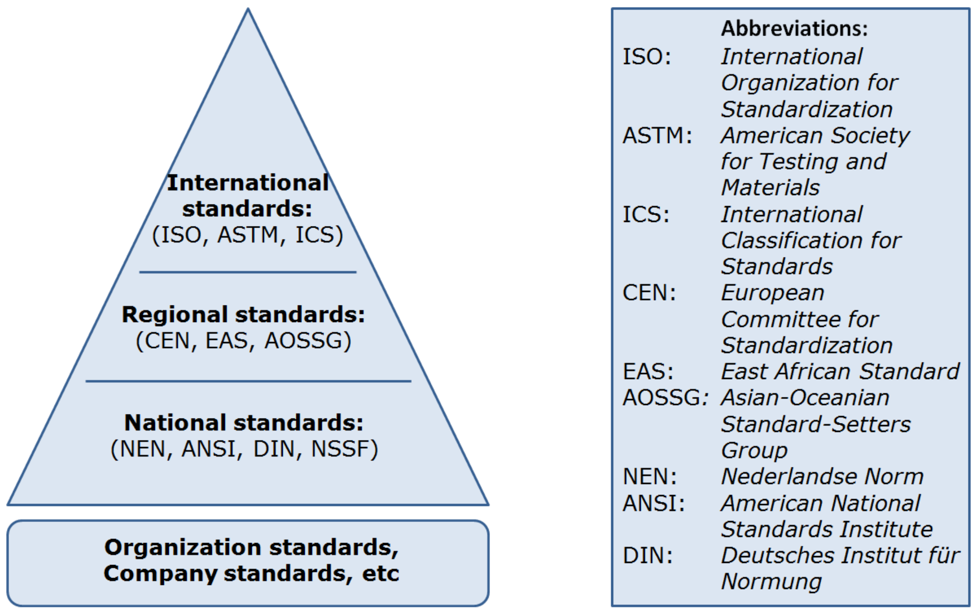


Figure 8: Level of standards

International Standards

International standards are standards developed by international standards organizations. International standards are available for consideration and use worldwide. One prominent organization is the International Organization for Standardization (ISO). Other example of a global operation organization is the American Society for Testing and Materials (ASTM).

International standards may be used either by direct application or by a process of modifying an international standard to suit local conditions. The adoption of international standards results in the creation an equivalent, national standards that are substantially the same as international standards in technical content, but may have editorial differences as to appearance, use of symbols and measurement units, substitution of a point for a comma as the decimal marker, and differences resulting from conflicts in governmental regulations or industry-specific requirements caused by fundamental climatic, geographical, technological, or infrastructural factors, or the stringency of safety requirements that a given standard authority considers appropriate.

International standards are one way of overcoming technical barriers in international commerce. The technical barriers are caused by differences among technical regulations and standards developed independently and separately by each nation, national standards organization, or companies. Technical barriers arise when different groups come together, each with a large user base, doing some well-established business that between them is mutually incompatible. Establishing international standards is one way of preventing or overcoming this problem.

Regional Standards

Next to the international standards are the regional standards. These are standards developed by regional institutions, which can be seen as political boarders. Nations agreed with each other to develop certain standards in order to gain benefits, economic or financial by trade barriers, manufacturing processes, health issues, etc. Only the participating countries mostly use these standards.

In some examples, international standards set by the ISO are transformed to regional standards because of different reasoning. One of them is the knowledge of various cultures and the corresponding behavior of the people. What can be seen as a success in a country, does not have to result in a success abroad. That is why certain ISO standards are set with the opportunity to be modified for regional implementation.

National Standards

As mentioned in the regional standards, the world is divided into several regions, which on their terms can be divided into nations. This division has a long history with battles and wars. The outcomes of those battles are known as countries that have their own politics and rules. These laws are the basics of the majority of standards. Not only that a country strives for their economic advantages over others, uniqueness of cultures and clear communications makes it that all nations have their own standards.

The implementation of national standards is therefore less difficult compared to regional or international standards. Especially for national use an regional of international standard is not necessary to implement. It saves a lot of time and the outcome just only has to fit in the needs of the country.

Organization standards

The last level of implementation is quite different than the others written above. This organizational standard is, as the word already says, set by an organization or likewise a company. These standards are developed to control and increase the efficiency within an organization. Another option for organizational standards are the financial advantageous over competitors. As can be seen in figure [8] some of the examples of organizational standards are known by the use of them. Because of the fact that the majority of the market uses these standard, the company that has this technological lead can exploit this by an organizational standard that covers the market. In some cases an organizational standard will be promoted to a national standard.

2.2.2 - Activity

Standards vary by the nature of the information contained in them. For instance, some standards define the meaning of words; other specify the strength of certain materials, and others indicate the appropriate dimensions of one product so it will fit with another product of standardized dimensions. The character of a standard implies a certain technical outcome, if the necessary information is used as presented. By technical outcome its meant a result that can be described in physical terms. After reviewing existing literature on standards and looking at specific standards themselves, the following six basic types of technical outcomes are identified. [23] [24] [25]

Terminology standards

The technical function of terminology is to establish a common language for products, product characteristics, units of measurement, components, and patterns of behavior. The following description of a terminology standard is the best example for this standard: "a standard that is concerned with terms, usually accompanied by their definitions, and sometimes by explanatory notes, illustrations, examples, etc." Most of these standards of terminology are written in the documents of ISO/TC 37, a committee within the International Organization for Standardization (ISO).

Measurement method standards

To encourage the quantitative measurement of the physical characteristics or properties of object in a specified manner, the technical function of measurement method standards is developed. These measurement method standards provide a common language for the communication of the results of measuring. They may be used in technology development, in conjunction with other types of standards, or development production. It gives guidelines as to what should be measured for various parts of the construction process. It allows for estimators to measure works in a standard format for easy preparation of a Bill of Quantities and easy comparison of tenders.

Test method standards

For evaluating the characteristics, properties or performance of a product a test method standard specifies the procedure. The standard generally includes directions regarding conditions of tests, documentation, observations and conclusions. To determine whether a product meets a particular quality standard, the test method standard is often used. If the prescribed procedure includes making certain calculations, it will often refer to a measurement method standard.

Compatibility standards

The characteristics of properties that a product should have in order to be compatible with a conjoint product are specified by compatibility standards. An industry wide compatibility standard allows a product made by one manufacturer to work with a conjoint product made by another, and the replacement of either product by similar products of other manufacturers. In everyday surroundings compatibility standards are numerous and their effects are quite visible. Examples of conjoint products that are compatible in the industry wide through standardization include nuts and bolts, bulbs and lamp sockets, etc. A product can be standardized to be compatible with itself. The size of bricks and the gauge of railroad tracks are standardized for this purpose.

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[23] *ISO Standards*
[24] *Reamer, A.D. (1981); The Role of Industrywide Voluntary Product Standards*
[25] *ASTM International - Standards Worldwide*

Variety reduction standards

A variety reduction standard prescribes a limited and discrete variety of production characteristics in order to achieve lower per-unit production costs, the so-called economies of scale, and ease consumer transaction costs in comparison shopping. Many variety reduction standards were written by industry associations in the 1920's in response to the urgings of the demand. From that period a lot of examples can be found in the optimization of construction and communication; bricks, nails, files, paper, etc. A the same time a standard may have a variety reduction function and a compatibility function. For example, standard file folder sizes have a variety reduction function and are compatible with standard size of letters, typing paper and legal pads.

Quality standards

A quality standard attempts to ensure an acceptable level of product performance along one or several dimensions. Possible dimensions of product performance include output/outcome, reliability, durability, efficiency, and safety/environmental impact. Quality standards come in a number of forms; performance criteria, design criteria, materials specification, recommended practices. Through the use of measurement and test method, acceptability is often determined.

2.2.3 - Field

The field is an category which indicates the different aspects that are all needed for the usage of constructions.[26] These field have a mutual relation from the top to the last, see figure [9]. All of them are of necessity to create a safe, reliable and proper system of civil engineering constructions. This paragraph will show these different categories and explains which of them are used in this report.

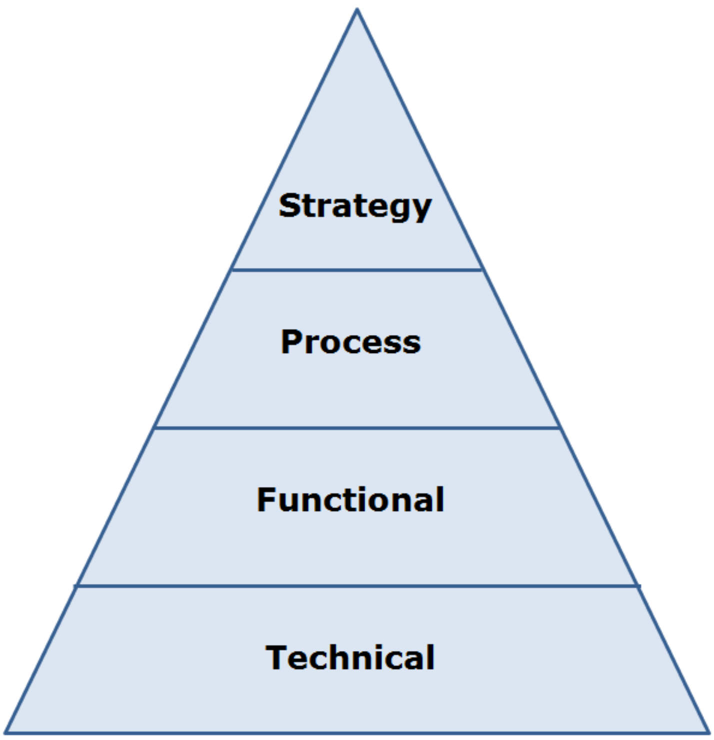

Figure 9: Pyramid of the Field of Standardization

[26] *RWS (2012); Topkader gebruik, bediening en besturing schutsluis en beweegbare brug RWS*

Strategy

The strategy can be seen as the set of basic principles and guidelines as a framework for the operation of river locks and the necessary information and structure. These documents are required to apply in the development of underlying levels of the field in which it will take place. This could include the organization of services and processes, the design of command and control systems and contract formations. The main people that are involved in these comprehensive and abstract thoughts about standards in the construction industry are the administrators and identifiers of this framework. This research could be of influence in the decision-making but will not change the strategy.

Process

The next level in the field is the implementation of the strategy. This includes the process description of the work, the organization, the tasks and responsibilities of employees and the associated procedures. These descriptions are required to apply in the design of work processes and in the implementation of operational activities. This documentation of process within the company about standardization is already written. Hence, it is of no importance for this report to investigate the effects of this category.

Functional

By the description of the information and equipment, which is needed to perform the processes, written in the upper level. Hereby is also of importance the trade-off between the costs and benefits of a particular need. These documents are useful to apply in the design of control systems, retaining structures and other elements. Also the organization of work processes are part of this level. For this report the designing of elements, based on the functional needs, are taken into account for answering the system.

Technical

The lowest level of this field contains a description of the conditions and requirements for the system functionality and technical equipment. These documents are required to apply in the design of control plants and objects. Not only the functional aspects are of importance for this research to determine which element is most desirable, these technical conditions are too. Hence, this level will be part of the further investigation.

2.3 Relatives of Standardization

Over the years a lot of terms and strategies are used in all kind of industries to encounter the number of products, processes or a combination. Some of these terms are difficult to compare while others have a huge overlap, in relation with standardization. For the sake of this research it is important to have a clear view and framework of the different strategies and terminology.

2.3.1 - Differentiation

The largest contrast of the above mentioned standardization is differentiation. Technically it is the reverse process of standardization, to create more products out of a standard to compete with each other. [27] This ends up with an increasing variety of products and eventually higher costs for the consumer by an increased demand of this customized product in the niche market, where the manufacturer has the benefits out of a monopolistic position.[28] [29]

2.3.2 - Adaptation

The terms of standardization and adaptation are difficult to compare based on the *de facto* standards. These industry-supported standards are in many ways open for adaptation. The market demands, in fact, that companies adapt to these standards by innovative solutions to current and local problems. Even so is the environment in many cases crucial for the end product and therefore subject to adaptation. It is more viable to have a construction tailored to the individual needs of each location due to the inherent complexities and dissimilarities involved in operating in the civil engineering.[30]

On the other side does adaptation conflict with standards. These fixed and established standards should be difficult or in most ways impossible to adapt, otherwise the approved standard by law or market is neither complete nor correct.[31] It is believed that if such a standard is approved the key success lies in the development of the technology and the corresponding economies of scale for the region, nation or worldwide.[32]

To encounter this problem of standardization vs. adaptation a new form has been introduced: Adapted standardization. It is a procedure which uses a combination of standardisation and adaptation, and which responds to the infamous slogan: "Think global, act local". It is about the degree in which adaptation will take place.[33] [34]Referring to the replacement of the river locks it is based on a standard concept (the core of the lock) to which minor or single changes are made to alter it to the specifications of the local rules, environment and surroundings. It is on us to determine where this line of degree is situated.

2.3.3 - Modularization

Nowadays a lot of difficulties that influence the business conditions are experienced by public and private companies. At first there is the increasing demands of different and customized products by the focus on customers' needs. This results in an increase of the variety of products. The competition among the companies is the second difficulty. Due to this factor they strive for an optimized business chain. This includes the efficiency of adaptation to renewable products as well as increasing of quality and reduction of fixed costs. At last, the dynamic environment, which implies that public and private companies have to tune their products to the latest regulations, demands and needs.[35]

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[27] *Adachi, S. (2006); The Strategic Choice between "Standardization" and "Differentiation" in R&D*
[28] *Perera, H.S.C., Nagarur, N., Tabucanon, M.T. (1999); Component part standardization: a way to reduce the LCC of products*
[29] *Beuth Verlag (2000); Economic benefits of standardization*
[30] *Douglas, S.P., Wind, Y. (1987); The Myth of Globalization*
[31] *Rau. P.A., Peebles, D.E. (1987); Standardization of marketing strategy by multinationals*
[32] *Kindleberger, C.P. (1983); Standards as Public, Collective and Private Goods*
[33] *Chin, A., et al. (2008); Standardization promotes flexibility*
[34] *Choi, H.J., et al. (2003); Towards a Standardized Engineering Framework for Distributed, Collaborative Product Realization*
[35] *Miller, T.D., Elgard, P. (1998); Defining Modules, Moldularity and Modularization*

For handling these seemingly conflicting demands modularization is often mentioned as a means, and frequently in connection with the manufacturing concept of mass customization.[36] The idea is that combining a limited number of modules can produce a broad variety of products. In this way modularity balances between standardization with customization and flexibility. Modularization, on the other hand, is invented to allow the manufacturers to reuse parts of programs that already work. By dividing everything up into modules, you break everything down to the basics. If you already have an element that works well for a particular function, you do not have to reinvent the wheel.[37]

What the term module really covers, seems to be some indication of confusion about. In some part of the literature, modules are defined as a physical building block, while others refer to them as non-physical objects like software. Some focus on structure and others on functionality. It is assumed that modularization, in comparison to the standardization, is more focussed on the functionality of building blocks in order to create a variety of products with a limited amount of elements. With this in mind, the modularization is a start of standardization, if and only if, these functionalities are transferred into a standard.

2.3.4 - Variety reduction

The distinctions of the two terms are quite difficult. Both are concerned with the elimination of unnecessary diversity in any sphere of company operations. Standardization is most commonly used in the sense of reducing a series of items all serving the same purpose to one item or a very few items, for example all office notes and prints are on A4 paper. Variety reduction is widely interpreted as a reduction in a range of items all serving the same or similar purposes by removing the least profitable and those with least user appeal. There is a huge overlap between the input and output of both the strategies. [38]

2.4 Results and Discussion

Based on the above mentioned, one is decided to take the following standards into account by answering the main question.

2.4.1 - *De jure*

In this research, only the *de jure* standard is assumed to be an option for the initial standardization of the river locks by RWS. This assumption is made because of the prescribed innovations, environmental issues and stakeholder approach. As mentioned in chapter 1, RWS has the desire to build a smart river lock, continuously improving itself due to open market competition and external support. This can be complicated by the *de facto* standard, which holds back the process of improving due to the Intellectual Property of the companies.[39] On the other side could this be a major problem in the development of the standard. Many companies have concerns about the open standardization because of leakage of technology in the process, which might be beneficial for companies that do not contribute to the process. This form of leakage is part of the abandonment of Intellectual Property Rights of companies, in order to create a widely based standard throughout the market.

[36] *Droste, M. (1990); Bauhaus 1919-1933*
[37] *Gamma, E., et al (1995); Design Patterns: Elements of Reusable Object Oriented Software*
[38] *Tassey, G. (2000); Standardization in Technology-based markets*
[39] *Tay, J.S.W., Parker, R.H. (1992): Measuring International Harmonization and Standardization*

2.4.2 - National

The selection for the national standard is chosen because of the fact that some of the advantages are partly feasible if these standards are implemented on the national level. Economic benefits are wider in terms of regions and the total country. Another reason for this national standard is that an implementation of a *de jure* standard is not common on a company or organizational level and for an international or regional standard this research is insufficient. On the other side does this topic relate to regional and international standards. For example is the CEMT classification of importance for the standards that might be beneficial. Because of the scope of this research it is chosen to investigate the standards only on the national basis but it is not excluded that widening the standard to a European one might result in higher economic benefits.

2.4.3 - Compatibility

The compatibility standard is known as the standard that will influence the availability of the river locks. Hence the economy will benefit from it. This standard is therefore an important one to insert in the scope of this research, besides the financial benefits created by efficiency and synergy in maintenance it might be crucial for the availability of the river locks and on their term the total corridor.

2.4.4 - Variety reduction

Together with the compatibility standard the reduction of variety is useful in achieving economies of scale. This short term benefits of standardization might be valuable in convincing the decision makers. On the other side could this standard have disadvantages if the elements are over dimensioned by the fact that everything has to meet the quality requirements.

2.4.5 - Functional and Technical

Based on the compatibility standard the elements that will be suitable for standardization should be described as functions in the total system of a river lock. This will also create less market competition but for the operation and maintenance it might create a huge profit. The technical standard is needed to fulfill the quality and functions of an element. The fact that some of the elements will be compatible due to variety reduction, they have to meet certain technical rules and standards that it will create new standards.

The development of a standard can be steered quite well in its early stages; at that time the knowledge to determine why, where and how to adjust is lacking. When a standard is widespread in society we finally know all consequences of it. Control and steering of that technology, however, had become quite difficult by that time

David Collingridge, 1980

3. Effects of standardization

Implementing a standard into an industry effect that industry and perhaps it will also influence other industries. In the literature on the topic of standardization most of the effects are for that specific industry on an abstract level. In this chapter it is intended to elaborate the commonly known effects of standardization and their corresponding effects on this research. Because of the fact that a project can be divided into life cycle phases, which on their terms have different effects, this division is elaborated in paragraph 3.

3.1 General effects of Standardization

In this paragraph the market's effects of standardization will be elaborated. As could be read in the previous chapter a lot has been written about standardization and its components. This also included the positive and negative effects of them. Some of these effects are scientifically investigated, but most of them are based on expert judgement and the overall opinion of standards.

3.1.1 – Advantages

International and Governmental agencies see a lot of potential in the development of standards because of the growing simplicity and uniformity of daily life processes, which creates important benefits.[40] These positive effects of standardization are most of the time an incentive for the investigation of a standard, including this report.

Economy of scale

The most common advantages of standardization are the economy of scale. By creating products that are compatible, markets/companies will have economic/financial benefits.[41] Because of the manufacturing process, the variety will be reduced and the process optimized, which will continue in the operation and maintenance. This is also the case for processes, when these are standard, the effectiveness and efficiency will improve.

Combination of knowledge

When the process of standardization starts, the latest technology will come to the surface. Experts within the field can join their experiences and knowledge to create a flawless standard that can fit into the purpose and is compatible among the products of different manufacturers.[42] In this way, it helps the market to invent a new technology, rather than create a competition where all participants hold back their intellectual property. [43]

Improving efficiency

Having a standard eliminates redundant technology and unnecessary rivalry in a market, by simplifying the classification and categorization of a technology and by sharing information about the technology. It can also contribute as a coordinator between industry requirements and market needs. It enables higher productivity and allows companies to concentrate on truly necessary technological innovations. [44] [45]

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[40] *ASTM International (2009); Mission statement*
[41] *Besen, S.M., Farrel, J. (1994); Choosing How to Compete: Strategies and Tactics in Standardization*
[42] *Farrel, J., Saloner, G. (1985); Standardization, compatibility, and innovation*
[43] *Katz, M.L., Shapiro, C. (1985); Network Externalities, Competition, and Compatibility*
[44] *NSSF (2007); National Standardization Strategic Framework*

Comparison of results

Because a standard defines the quality and measures of a product, it helps the demanding party to compare the products among each other based on the costs and results. This will improve the confidence in the quality and reliability of the suppliers who use the particular standard. It might end up in a broader choice of products and increases competition among suppliers. [46]

Reduction of failure

Next to improving the efficiency of labour is the reduction of failure. This means that the effectiveness of the labour is rising. By repetitive work, people who are involved will learn from their mistakes, which will end up with a reduction of the amount of failure during the process. [47] [48]

3.1.2 - Disadvantages

In contrast are the negative effects of standardization.

The long process

Before a standard is widely accepted all kind of processes have to start. Non-governmental bodies that serve the public would lead all these processes. To make sure a standard will be adopted, multiple companies and other contributors must willing to pay a lot of money to defeat the competitors. Instead of collaborating they fight against each other. Hence, this process will take a lot of time.

Decreasing of research

When a standard is used by totality of the industry and market, it might discourage others to enter this market and competition. This could end up in preventing research developers from finding other methods or products, which could be more valuable then, the current standard.[49] In other words it will slow down the innovation in the industry on the total system, but could speed up the development within the standard.[50]

Decrease of flexibility by rules

A standard requires its adopters to comply with its specifications. It may reduce the flexibility of use of a technology and prevent producers and users from taking the best combination or usage of technologies. It may also cost time and effort to understand and comply with the specifications.

Risk of failure in series

After the standard has been set by organizations, it does not mean that the standard is perfect. Due to the fact that people are involved in the process of standardization, errors might occur. If a failure is integrated in a standard, it means that it will be part of that market. This will end up in higher risks of failures on the total series that involves the standard.

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[45] *WSV (2011); Standardisierung von Schleusen*
[46] *Bahke, T. (2000); Economic benefits of standardization*
[47] *Sered, Y., Reich, Y., (2005); Standardization and modularization driven by minimizing overall process effort*
[48] *Bagby, J.W. (2010); Role of Standardization in Technology Development, Transfer, Diffusion and Management*
[49] *Tassey, G. (2000); Standardization in technology-based markets*
[50] *Farrell, J., Saloner, G. (1985); Standardization, compatibility, and innovation*

3.2 Effects

The general effects that came forward out of the studied literature are translated because this research' focus is on the elements of river locks. The main question for this paragraph is: "What will happen if an element is subject to standardization?" Because some of the effects will come to the surface in an earlier stage and some of them after a couple of years, the possible effects are divided in time frames.[51]

3.2.1 - First order effects

These first order effects are a direct result of the standardization process and the intended use of the standard.

High costs for the development

If it has been decided that an element out of a river lock should be standardized it could take a long time before the actual standard is developed, because of all the different interests and powers.[52] In fact RWS is the initiator of this process and would therefore lead the dance. On the other side does the construction companies have the knowledge and experiences in building these elements. At last but not least is there also the large group of users that wants to influence to outcome. As a conclusion, public and private parties have to collaborate. They need to share their knowledge and must see the benefits for their own assets. Hence, this process could take a long period of time and cost a lot of money.

Over dimensioning

The functional and technical standards are developed over the normative river locks. This means that an element develops according to the most extreme parameters of the vulnerable element of the total series. Or in fact to the most vulnerable element that could be necessary today or in the future. For example when the gates will be standardized the height and width of the river lock with the greatest forces is used as normative, and is therefore the standard. Based on scenario thinking and the possibility of expansion this normative river lock could also be developed over years. All the other river locks, which are smaller in size and difference between the water heights, will be over dimensioned. This extra amount of materials and labour could case serious disadvantages for the financial part of a single project. The total extra costs must be outweighing by other benefits.

Higher predictability of costs and availability

After the standards are set the predictability of an element, and on their term the total river lock will increase. Nowadays models are developed to indicate the strength and failure modes of constructions. These models have uncertainties within them based on the unknown factors that come with custom-made products. These models calculate the total failure mode by multiplying the risks,[53] so if only one of these elements is standardized the total risk of failure will decrease, or in other words the predictability of the availability will increase. This also applies to the costs, which can be estimated more accurate because the standardized elements are known. This effect will not immediately have a financial advantageous but will eventually be economic beneficial due to lower to lower risks of failure and the higher availability of the river lock.

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[51] *Brumsen, M., et al. (2011); Philosphy, Technology Assessment and Ethics of Civil Engineering*
[52] *Wegberg, M. van, (2004); Standardization Process of Systems Technology*
[53] *Ghoshal, S., et al. (1998); Multisignal modeling for diagnosis, FMECA, and reliability*

Less market competition

If an element is set by a framework of standards based on the quality, measurements and interfaces with other elements, the manufacturers are bound to these rules that create a reduction of choices. This could lead to a market competition where the top manufactures, which helped developing the standards, have a huge advantage towards the others. With the corresponding opportunities for long production runs and automation of these manufactures lead will continue and there is less market competition. This might create a market in which prices will increase because of the lack of competition in the market. On the other side doesn't this mean that other companies are not able to compete with the top manufactures of a certain element.

Fewer parts to deal with in inventory & manufacturing

Economy of scale could be beneficial after the standard is implemented, based on the price and number of elements that are part of a river lock. For instance a hinge is a small percentage of the total cost, but you need plenty of them. On the other side, there is the wall of the river lock with a high construction cost but has a small amount of appearance. Generally speaking does standardization have a positive effect on the manufacturing due to economy of scale and the total inventory costs of an element.[54] Based on the costs of storage per m2. If the variety is reduced the number of spare parts will decrease and have a positive outcome for the inventory costs.

Reduced training costs and time, efficiency in O&M

Major benefits are expected from the routine that will come with standards. If the elements between river locks are the same, the handling of them and especially the maintenance will become more and more efficient. A reduction of these costs might be of importance for the decision-making of a standard. To benefit from this occurrences of reducing the employment costs the following conditions plays a part:

- Something has to be toughed; with other words standardization has to be a cause for the learning curve.
- The learned experiences must be used quick; this means that the time span between the subsequent events is not to long and it has to influence the productivity of labour.

Increasing the ease of asset management

Besides the efficiency in operation and maintenance the estimation of the total Life Cycle Cost can become easier. The documentation of inspections and the expected failures are the same over all the river locks. They can be compared between each other, which will give a clear image on the total value of the assets that are falls under the supervision of RWS.[55] This form of asset management is already set by existing standards of ISO and creates a proper estimation of the future costs and benefits.

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[54] *Perera, H.S.C., Nagarur, N., Tabucanon, M.T. (1999); Component part standardization*
[55] *Vanier, D.J. (2001): Why Industry Needs Asset Management Tools*

3.2.2 - Second order effects

The second order effects are matching with changes in human behaviour as a result of the introduction of the new standard, and the effect that comes over time due to earlier made decisions and construction.

New players in de market

Besides the traditional companies that are in the market of river locks, new players might enter. The framework that is set by the standards of an element creates opportunities for new, or existing, companies to develop total different elements within the boundaries. As an example is the upcoming usage of 3D-printers which might be useful in the construction industry for manufacturing specific elements, if and only if these new method will fall inside the boundaries of the standard.

On the other side is it also possible that a company will develop its own *de facto* standard, based on the national standard of an element. Off course they are bound by the limitations that comes with a standard, but it creates a production of series. In that case the economy of scale will turn out to be beneficial for the company and eventually for the principal.

Availability increases

Because the possible standard for an element is entirely conceived for its purpose, earlier made errors will fade out of the designs and constructions. In combination with the higher predictability and increased ease of asset management the total availability will become higher.[56] This will end up in an economic benefit for the user as well as for the nation/region.

Less flexibility

The new philosophy of RWS, which indicates that the market should develop the design and technology, will be held back. The standards that will give guidelines and framework to the functional and technical design of the elements ends up in a combination between the old and new methods. This makes the design and construct of new river locks less flexible compared to the contracts used nowadays.

This is also the case when it turned out that an implemented standard is not optimal. Because the standard is already absorbed by the public and private companies, a change will be relative costly, in relation to the continued use of the standard.

Working towards a total system

If it turn out that standardization of the core in river locks is both financial and/or economic beneficial, than it is quite possible that more elements will be subject to standards. Especially when the control systems make use of the same software and network, the interaction between the river locks could have a huge boost. In that case the operation between river locks optimize, which create benefits for the user and economy. For the users it means faster maintenance and smooth running from one lock to the other.

[56] *WSV (2011); Standardisierung von Schleusen*

3.2.3 - Higher order effects

These higher order effects about the standardization of elements of a river lock are thought from different perspectives. As could be read in the following effects the possibility that it might occur is low but it is worth to have a notice of what might happen.

Change of the industry

If the line of standardization will continue towards all the elements of a river lock it might turn out to a fragmented industry in which the principal purchased all the different elements by different manufactures. In fact the lowest-bid tendering comes back. The functional and technical aspects prescribe all the elements, and are therefore easy to tender and purchase. This could lead to a high market competition, which can be compared with the supermarket, an industry in which you can buy all you need and fits to the purpose.

On the other side could it be that private companies will take over the supervision of the river locks. Everything is already been thought so the private companies do only have to maintain the river lock. In that case the operation will be in the hands of the private companies and they will compete over the availability of the corridors.

Standards are transferred

As read in the second order effects there is a possibility that the amount of standards will increase due to the fact that it is, financial and economic worth to do it. This could lead to an upgrade of the national standards to the regional standards of Europe. By then the economic availability will be expand over many more rivers and canals and benefits of the standard will grow.

It is also possible that the standards will expand over to other constructions. The nearest construction, which is also part of an investigation by RWS, are the bridges. Also for this counts that the control systems could be combined in order to achieve financial and economic benefits out of the operations. But of course not all only the bridges can be subjected to standards, in fact it is possible for the total construction industry.

Standardized elements can be recycled

A major benefit from standardization of elements in a river lock is the possibility that they can be recycled into new river locks, by the replacement or construction of a new one. All the standardized elements are compatible among the river locks but not only by todays constructions but can also be used for the future river locks.

3.3 Life Cycle Phases

As could be read in the effects of standardization for the elements that are part of a river lock, is that the wanted and unwanted effect not occur in the same time span. It is even truth that the effects differ between the known phases of a construction.[57] In this paragraph the different life cycle phases of a construction, see figure [10], are elaborated by the major costs components of the particular phase.

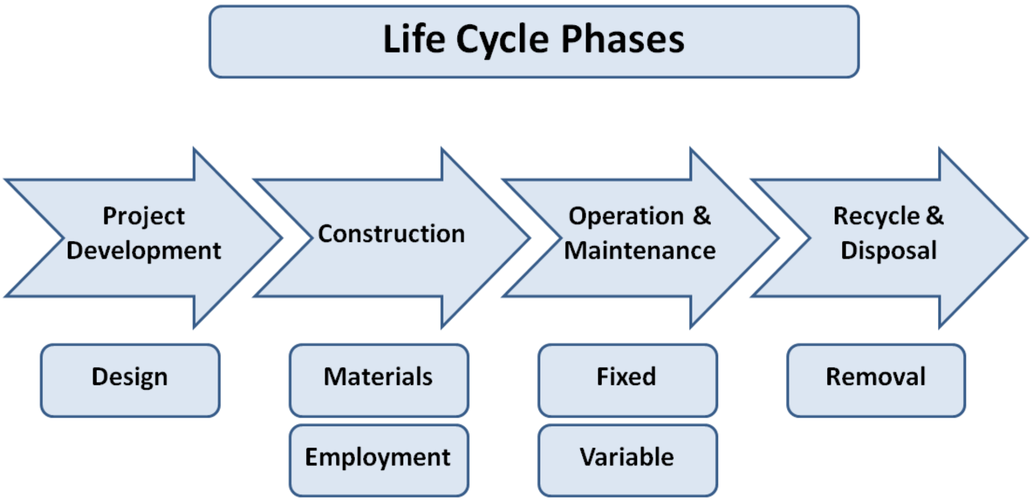

Figure 10: Life Cycle Phases of a project

3.3.1 - Product development

Before the real execution of a construction can start, there is the product development. This phase is characterized by designs, engineering, drawings and eventually contracts.

Design Costs

In this research the focus is on the design costs of the construction. Use of the standardized elements in multiple constructions, or in the same construction reduces all the single design costs by replacing duplicate designs by one development effort.

3.3.2 – Construction

In the construction phase of a project, several cost components are indentified. This is done based on the fact that benefits are different one the cost components.

Material Costs: Purchasing and producing of elements

By reducing the variety of purchased and manufactured elements through standardization it is possible to reduce the costs. In this component it is of importance to make sure standardization of materials is carried out to far. In that case the benefits gained through the reduction of material costs may be offset by the excess processing costs.

[57] *Perera, H.S.C., Nagarur, N., Tabucanon, M.T. (1999); Component part standardization*

Employment Costs: Construction Costs + Overhead Costs

Next to the material costs is the employment costs, which is a sum of the construction costs and overhead costs. The construction costs are based on the transport cost and execution costs. The overhead costs can be seen as procurement costs and facility costs that comes with offices etc.

3.3.4 - Operation & Maintenance

After the construction is build it will be subject to operation and maintenance. In this report these costs are not separated between operation and maintenance but because of the available data one has decided to split this life cycle phase into fixed and variable costs.

Fixed Costs: Operation + fixed maintenance

The fixed component of the O&M phase is a sum of the operations and fixed maintenance. The operations are the control of the river lock. This could be the lockkeeper and the usage of electricity. The fixed maintenance means the daily and annual maintenance, such as breakdown maintenance, lighting, cleaning, lawn mowing, etc.. All of these operations and fixed maintenance are planned over the remaining life cycle of a construction.

Variable Costs: Variable maintenance + Upgrading

Variable maintenance is maintenance that can be planned and performed to maintain the quality of the functions in and possible extend life of a construction. These costs are predictable based on experiences and comparison with other river locks. If the cost for the performance of maintenance is relatively high it may be cheaper to replace the element in question and to bring the initial condition, return the condition of the element to extend through it in place of the service life of the element performing maintenance.

3.3.6 – Recycling and Disposal

When the river lock reaches it technical and functional end of life it has to be removed or replaced. Because of the different expected duration of elements some of these could be used in other constructions or in the replacement. Because of the long time span between the implementation of the standards and the recycling or disposal of the elements this will not be part of the further research.

3.4 Results and Discussion

As a result of the literature study to the effects of standardization of certain elements in a river lock, table [2] is presented. As could be noticed is the division, or in some case overlap of effects between the different phases of a construction life cycle.

	First order effect	Second order effect	Higher order effect
Product Development	- Higher costs for the development - Fewer parts for the manufacturing - Collaboration between Private and Public parties - Less market competition - Higher predictability of costs	- Lower costs for the development - Different or new player in the market - Less flexibility in design	- Change of contracts - Use of recycling material from earlier build locks
Construction	- Less market competition - More routine - Over dimensioning - Reduce of failure	- Reduction in costs due to the learning curve	- Combining the different elements on site - Use of recycling material from earlier build locks
Operation & Maintenance	- Higher predictability - Higher availability - Fewer spare parts - Exchange with other river locks	- Interrelations between river locks - Maintenance program is designed on Corridor level - Overall asset management	- One control system for the HVWN - Interrelated maintenance program
Recycling & Disposal			- Exchange with other river locks - Predictable rest value

Table 2: The effects based on the different Life Cycle Phases

3.4.1 - Results

For answering the main question, some of these effects are taken into account. One has decided for the following effects, based on the expected importance of an effect. Reasons for not taking an effect for further research is the fact that some of these are difficult to quantify, and for that reason necessary information is unavailable. Hence, for the further investigation to the elements that are desirable for standardization the following effects are chosen:

Change of construction costs (financial)
The reasoning for this effect is because of the differences between the elements on this part. The economies of scale are different for every element, based on the learning curve, variety reduction and the ratio between materials and construction. Another reason is the over dimensioning of the elements, which could lead to an increase of the realization cost.

Change of maintenance costs (financial)
Based on expert judgement, this effect will be substantial for some of the elements. Especially the interaction between river locks can be advantageous for the costs of a maintenance program.

Improvement of availability (economic)
The chain is as strong as the weakest link. By this one-liner it is meant that in waterway corridor, the availability for the shipping industry depends on all crucial elements of a river lock. Hence this effect is important for the regional or national economy, but is not applicable on all the elements.

3.4.2 - Discussion
First order effects are generally easy to predict. Second- and higher order effects are much harder to foresee, but can have effects which are much more important than the first order effects. Unexpected negative or positive consequences of standards often have higher order effects, which are a direct consequence of the behaviours generated by the people, involve with it. Hence, this analysis of the possible effects cannot be considered as complete or truthful. It is meant to give an impression of the effects that a standard could have by its implementation on an element of a river lock.

Other forms of cost reduction could be possible but are not part of this scope. Therefore, the effects that are mentioned are only based on standardization and not as a combination with other measurements to improve the construction industry. By this is meant that new construction methods, materials etc. could also change the outcome of the effects.

The overall predictability of the construction costs, maintenance costs and availability is a major goal for RWS. By this effect the future costs managed and controlled. Therefore this effect is of importance but due to the fact that it is hard to express in time this effect is excluded from further research. On the other side can be said that the predictability increases by the percentage of a river lock that is standardized, based on the total failure modes of a construction. Unfortunately is this assumption not scientifically proved.

4. Level op implementation

The impacts of standards are highly dependent on the level in which it will be implemented. This means that if the amounts of river locks are increasing, the effects will be stronger, both positive and negative. Now the European Union is becoming closer and the trade between the countries is improving, it is not unthinkable that a standard will be transferred to a higher level than it is set on. As an example is the CEMT-class, a classification of ship measures that is used in Europe. This chapter is therefore meant to give an informative insight in the levels of implementation. It is build up as a top down approach in which a lower level is subordinate to the prior level.

Figure [11] depicts a schematic representation of the total network. It can be seen that the top level is the Trans-European Network of Transport. As will be elaborated in the next paragraphs is the EU trying to combine the next levels, so an economic boost can be created. Under this top level the national levels of all the countries that are involved in the TEN-T are presented. All of them has their own rules, regulations and of course standards. In some of these countries the government set out corridors, which are routes from one place to another with the same characteristics. Like in the Netherlands exist a corridor of multiple river locks. As will be presented in the last paragraph, this doesn't mean that every river lock is part of a corridor.

Parallel to this decomposition of the Trans-European Network are the CEMT-classes. As stated in the introduction this standard is about the measures of vessels. This division of CEMT-classes is elaborated in this chapter.

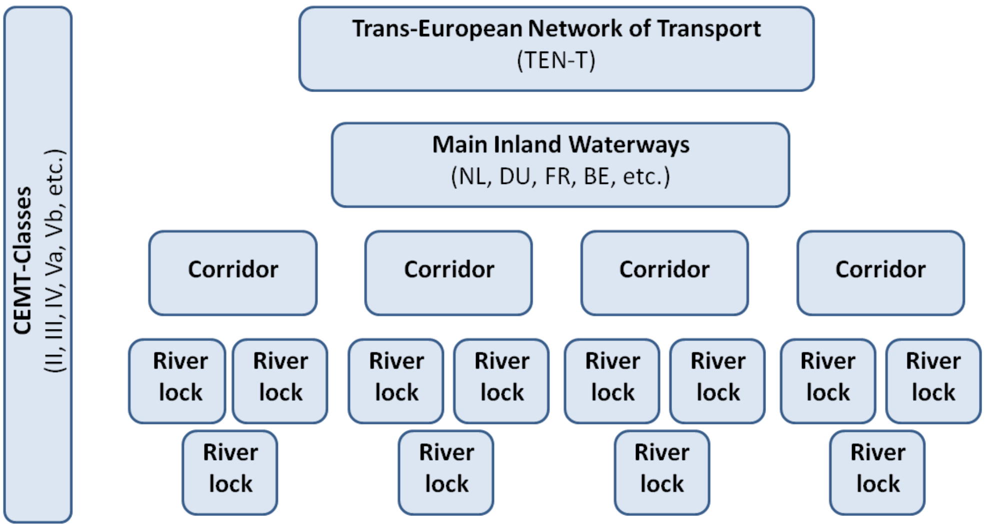

Figure 11: Decomposition of the TEN-T

The decomposition of the TEN-T can be seen as a total system of inland waterways where the performance requirements that are established primarily to the total network are translated to the nations, and on their term into the level of objects.[58] The performance requirements of individual locks and bridges are derived from performance requirements on network and corridor level. The basis for this is the Network Vision of RWS in which the performance requirements for (parts of) the network are made.

[58] *ProRail and RWS (2007); Leidraad Systems Engineering*

4.1 Trans-European Network of Transport

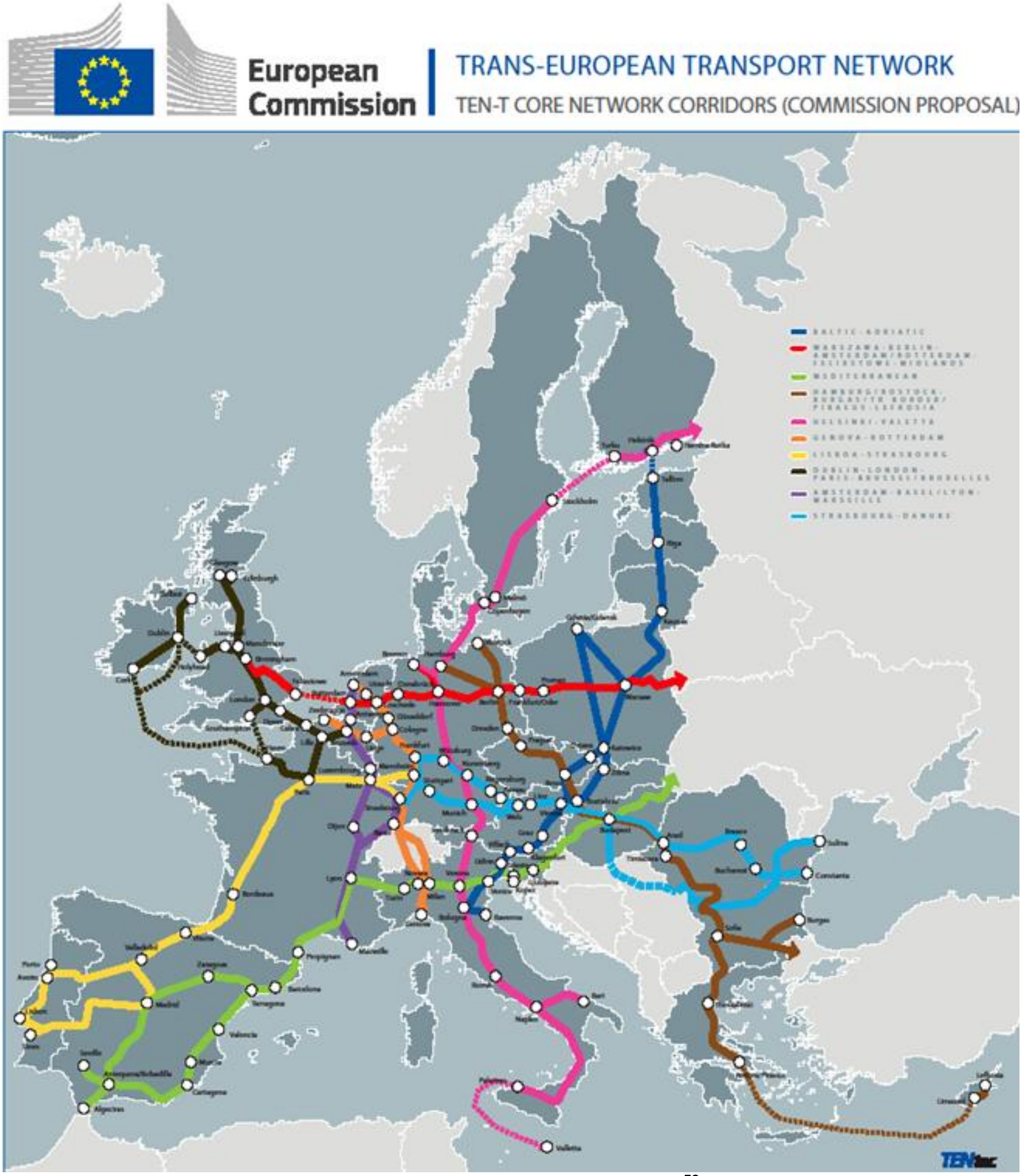

Figure 12: Trans-European Transport Network of Inland Waterways[59]

The Trans-European Network of Transport (TEN-T) in the waterway sector consists of 51.700 kilometres. This large amount of kilometres contains the main canals and rivers, and around 276 river lock complexes. A large part of this network is situated in the north west of Europe. Especially in Germany, France and the Benelux. By this comprehensive network of inland waterways one can reach a lot of endpoints. From the harbour of Rotterdam it's possible to make it to the Mediterranean Sea, or from Amsterdam to the harbours at the Black Sea. With freight ships you can bring goods and persons anywhere deep into the hinterland of Europe.

[59] www.ec.europe.eu *(seen on 27/06/2013)*

This extensive transportation between the European countries asks for collaboration. In the Netherlands is RWS for instance also working internationally. Our waterways must be well connected with the waterways of Germany and Belgium. These partnership focuses on infrastructure, transit and safety. By these forms of collaboration between countries is Brussels willing to help the projects with financing a large part of it.

In The Northern part of the Netherlands RWS and Germany are working closely with each other in the Eems-committee. In East Netherlands frequent consultation with the Germans on the Rhine corridor. In the south RWS works with the Belgians in the Westerschelde Commission. And there is consultation on the improvements in the corridor Ghent-Terneuzen. With Germany, Belgium and other European countries, they work together on the international implementation of RIS (River Information Services).[60]

4.2 Main Inland Waterways (HVWN)

Figure 13: Main Inland Waterways of Holland[61]

The main inland waterways of the Netherlands (Dutch: Hoofdvaarwegennet (HVWN) consists of 5.046 kilometres waterways. Almost all of these kilometres are suitable for freight shipping. The main transport axed, the blue and light blue lines in figure [13] are approximately 1.400 kilometres long and consist around 140 river locks.

[60] *De Commissie van Europese Gemeenschappen (26/10/2006); Oprichting van het uitvoerend agentschap voor het trans-Europees vervoersnetwerk krachtens Verordening (EG) nr. 58/2003 van de Raad*

[61] *CBS (2009); Vaarwegen in Nederland, based on a figure of RWS DVS*

Waterways have always been present and are not only used as waterways, but also for the discharge of water. With these two major functions they together form a system of water. Because of its location at the delta of several major European rivers such as the Rijn and Maas, the Netherlands is a transit location for the countries in the hinterland. Next to these rivers the Netherlands has many canals and lakes that connect the main cities. Because of this the Netherlands has a good and extensive network for the transport of goods by water.

That's why RWS wants to form an integration of different networks. The aim is to provide an optimal service to the user of the waterways. This means that cooperation with other administrators should be sought, both internationally and regionally. This also means to identify where the interests of recreational, freight ships, inland freight ships go together and where not. This also means to guarantee the different use of water, keeping in mind the different user functions interrelated to each other and the relationship between the modality shipping and other modalities. The point is to offer a solid and responsible service in all these relations to all the users of the various infrastructures.

4.3 Corridors

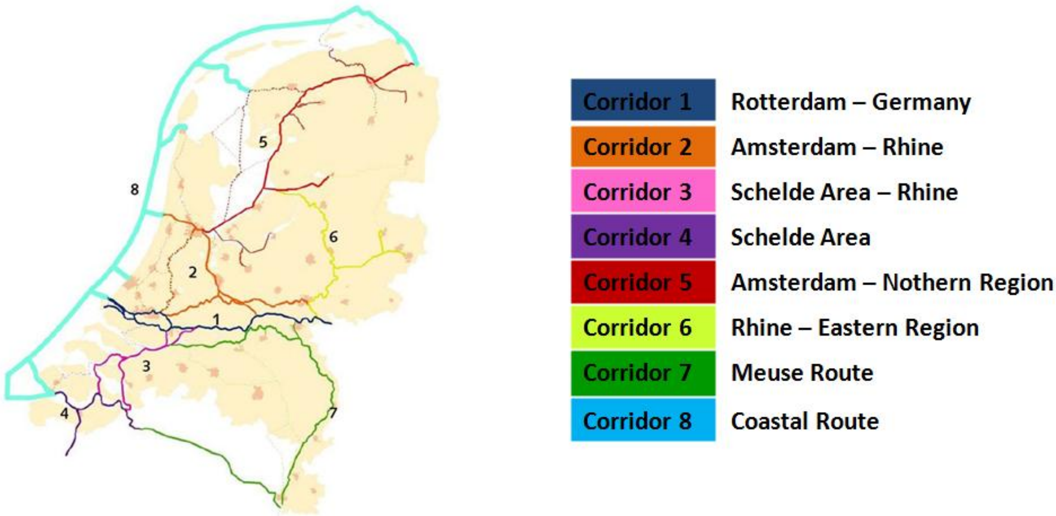

Figure 14: Waterway Corridors Netherlands[62]

The policy focuses on a reliable and predictability door-to-door service. The reliability must improve so that freight ships can deliver on time. Therefore an integrated network approach is necessary. Such a network consists of corridors and routes. Shipping in all its forms cannot be seen from the other social use of water, such as supply and drainage, drinking water, nature and recreation.

To create a robust network, further inter-administrative agreement on the accessibility of the various destinations along the waterways must take place. An important aspect is the connection to other modalities and coordination and prioritization in infrastructural junctions. In the pursuit of a corridor and route approach a national coordination and regional coordination is essential. Based on the above analysis and formulated policy RWS has chosen a corridor-/route approach.

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[62] *RWS (2011); Deelrapportage Vaarwegen voor de Nationale Markt en Capaciteits Analyse (NMCA)*

RWS considers it useful and necessary to make a distinction about the role of the route in a distinguished corridor. Service levels should be determined per route. This is particularly true for the freight ships but the Beleidsvisie Recreatietoevaart Nederland gives likewise the main connections for recreational boat trips. Service Levels apply to an entire route from A to B. In this, reliability, security and availability play a large part (see Chapter 1). In order to fulfil the service levels, traffic measures and asset management are used.

In the following table the different CEMT-classes for the main waterways and corridors for Europe, and therefore also for the Netherlands are shown. This division has it origin in the need to find standards for waterways. By creating a standard in the vessels that make use of these waterways, standard measures can be inserted.

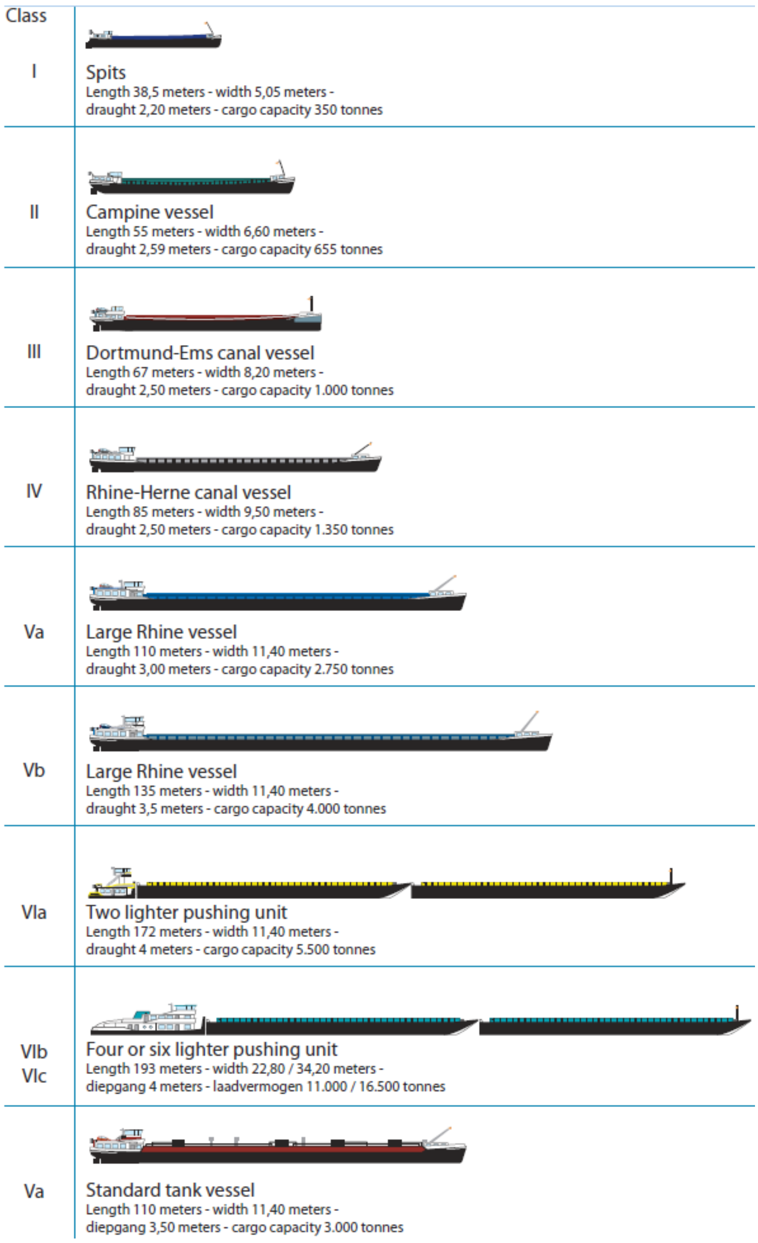


Figure 15: CEMT-Classes[63]

[63] *CEMT (1992); RESOLUTION No. 92/2 ON NEW CLASSIFICATION OF INLAND WATERWAYS*

4.4 River locks

Figure 16: All River Locks under the Supervision of RWS[64]

The river lock itself is an element in the system of the Trans-European Network, the inland waterway network and the corridor network. On the other side the river lock is a system on its own, see chapter 6. All of these river locks have the same functions in order to call themselves a river lock.

These basic functions of a river lock are:

- Control of the water levels on both sides

- Discharge of water

- Separation of fresh and salt water

- Passing vessel

- Retaining high water conditions

[64] *Deltaprogramma 2013, (2012); Bijlage H: Vervangsopgave Natte Kunstwerken*

4.5 Results and Discussion

The following table of the level of implementation is a summary of the above-elaborated structure of inland waterways, nationally and internationally. It gives insight in the impact that a standard might have if it is implemented on a certain level.

	Length:	River Locks:
TEN-T	51.700 km	552
HVWN	1.400 km	140
Corridor	110 – 240 km	2 – 20

Table 3: Impact on the Level of Implementation

For this research it has been decided to investigate the outcome of standardization on the national level. This is because of the amount of river locks that are present on the national level. As mentioned in the first chapter, the problem of standardization in civil engineering structures lie in the ratio between the low amount of constructions and the high construction costs. By the choice of the HVWN level, the amount is relatively high compared to the corridor level. Thereby the research question of this thesis is to determine the most suitable element for standardization, by that, and also elaborated in the introduction, it is meant to investigate all locks.

The reason not to implement on the corridor level is based on the fact that RWS, as the main operator of the river locks, will eventually search for an integral system that controls all river locks in the Netherlands.[65] Even so, this is of no influence for the operations but also for the maintenance. Hence, for this research it is chosen to find an element on the generic level, and further researches can specify this on a lower level.

To investigate the implementation on a pragmatic level it is chosen to do this on the regional, or corridor level. By this comparison to the national level other effect might become visible. In chapter 9: Case Study (II), this implementation is analysed.

The implementation of standards in the core of River locks has the highest influence on all effects when it is implemented on the TEN-T level. As elaborated in chapter 2, it is possible that the possible standards will be transferred to an international standard. When this is the case it is a huge benefit for the Dutch market and economy. It means that the standard, which is used for years, will be exported to nearby countries.

[65] *RWS (2012); Topkader gebruik, bediening en besturing schutsluis en beweegbare brug RWS*

5. Research Design

After the literature framework is set, this report will continue with the analysis of the available data that concerns the standardization of different elements in river locks. The models that will be used are elaborated and explained in the last paragraph of this chapter. But before the start of this analysis, it is necessary to summarize the framework that will be used during the next phase. In the discussion paragraph of this report, some of the assumptions are discussed in order to create a mutual understanding about the problems that arises during this research.

5.1 Summary of literature framework

As shown in chapter 2 of this report, the word standardization has different outcomes based on the one who writes about it and the one who reads it. Standards plays a huge part in our daily life, we are surrounded by products and procedures that are fixed in standards that were set by recognized organizations, on international and regional levels. These standards may describe quality, language, procedures, etc. and are of huge value to our society. For the analysis part of this research, one has decided to include standards that have a technical outcome on; a nation level, compatibility, variety reduction, technical and functional design.

Besides the positive effects of standards, as seen in chapter 3, there are also negative effects that arises when the standardization process takes place or when the community absorbs a standard. To encounter the problem that is stated in the introduction about the value of a standard, which is based on the tipping point between the benefits of competition in the market and the benefits of variety reduction, one has decided to investigate the crucial criteria's, costs and availability.

In combination with this research to find the most suitable element within a river lock, based on cost and availability, the research level of is set on the national level, the HVWN. This level contains all the river locks that fall under the supervision of RWS. These river locks forms the heart of all the main corridors and commercial routes through the Netherlands. To gain the most benefit or loss, this level has been chosen as a case study for the implementation of a standard.

5.2 Models for the Analysis

To answer the main question: 'Which elements of a river lock are most suitable for standardization by the replacements of river locks in the Netherlands, based on the balance between financial/economic benefits and competition benefits?' the models that give a substantiated motivation are elaborated in this section. At first, one has decided to reduce the number of elements by diminishing the total database with a filter. From this point it becomes clearer whether or not an element is necessary to standardize. After the reduction of elements, the effects on costs and availability are inserted over these particular elements. This creates an image of the outcome of standardization on one element or a combination of them. At last two case studies are presented in which, a model is created to categorize most of the river locks that are under the supervision of RWS and the implementation of the standard a corridor.

5.2.1 - Filter of elements

In this first analysis it is all about the core of the river lock. As the explanation of the titles in the introductions shows, it is not only the heart of a river lock but also of this research. By this core it is meant the physical combination of elements that can be used in every river lock, independent from the location it has to come.

A river lock is a complex structure with all kind of elements that are combined in order to fulfil the functions and characteristics, which are of necessity to be classified as a river lock. In the first paragraph of chapter 6 an overview is shown of all the element that part of, at least one river lock in the Netherlands. All these elements fulfil a specific function is this construction, but based on the location, environmental and principal differences between the river locks, not all the elements are needed or used.

With in mind the knowledge that all locks have gates, chamber, etc.. this filter is needed to subdivide the different elements by their appearances. This is needed to indentify the core of river locks. By this filter the elements that are rare in the river locks might are not further investigated. This does not mean that they are not beneficial to standardize but based on the assumption that the core consist of elements that are frequently used in the designs this line is set. It is recommended for further research to determine whether or not one of these excluded elements could possibly be part of the core.

This formula below shows the filter of commonly used elements in all river locks that fall under the supervision of RWS. The filter that is used to determine the core of the river locks is as followed:

$$\frac{n}{N} * 100\% < c$$

Where:

n = number of appearances

N = total number of river locks

c = filter criteria [%]

5.2.2 – Cost estimation of elements

Next to the filter of elements, the results will be transferred to the next model. In this model, the quantitative effects, written in chapter 3 are linked to these elements. As mentioned in the same chapter, it is impossible for this research to take all the effects into account based on the available time. The transaction costs of the particular elements are drawn from the estimated construction costs of the new river lock of Terneuzen, which are calculated on fixed indicators used by Lievense and Arcadis. The maintenance costs are drawn from the maintenance costing used by RWS and transferred to the new river lock of Terneuzen, based on the materials and measures.

In table [4], an empty scheme is shown. It contains the different costs of all selected elements before and after standardization. In the last column, the differences between the two values are shown. Below the different phases of the project, a percentage is shown, which will indicate the amount of contribution to the total LCC of this element. This is done for both the costs before and after standardization, and the difference between these two values, displayed in percentages. Based on these outcomes a conclusion can be drawn about the elements that are desirable for standardization.

	Before:	**After:**	**Difference:**
Product Development [%]			
Material Cost [%]			
Employment and Overhead Cost [%]			
Transaction Costs [%]			
Operation and Fixed Maintenance [%]			
Variable Maintenance and Upgrading [%]			
Maintenance Costs [%]			
Total			

Table 4: Summation of Costs

The life cycle phases are structured and completed as follows:

Product Development Costs (Cd)

The costs for product development are set at 15% of the total construction costs. One has decided to set this percentage at 15% for all the elements, because of expert judgement and personal experiences. The construction costs are the basis of this criterion are a combination of the material costs and execution costs. To determine whether or not this assumption has an influence on the outcome of this research as sensitivity analysis is made for the engineering costs of 20% and 25%.

Material Costs (Cp)

This criterion contains the purchase of all the materials that are involved for that particular element. In some cases the materials are manufactured by the combination of other materials, in that case the material costs as it is used in this research are the total costs of materials and manufacturing.

Employment and Overhead Costs (Ce)

The total amount of employment and overhead costs are given according to the following formula:

$$Ce = \left((Cp + Cc) * Ci * (Cg + PR)\right) - Cp$$

With:

Ce = Employment and Overhead Costs

Cp = Material Costs

Cc = Construction Costs

Ci = Indirect Costs of the execution [%]

Cg = General Costs [%]

PR = Profit & Risks factor [%]

To estimate the employment and overhead costs in this research the percentage for indirect costs of execution is set by 12%. This percentage is a generally accepted value for indirect costs, which are an enumeration of one-time costs of a project and execution costs over the different aspects such as dredging, concrete works and ground works.

The percentage for general costs is set by 8% and the percentage for profit & risks by 4%. The general costs are basically the costs for the use of offices, electricity, etc. The profit and risks is a factor that is used by companies to make any profit because of the potential risks they take for the execution. These factors are based on expert judgement and personal experiences.

Construction costs (Ct)

This one in inserted because of the division between initial costs and the costs over the time span of the construction. This can be seen as a total of the previous costs:

$$Ct = Cd + Cm + Ce$$

With:

Ct = Transaction Costs

Cd = Product Development Costs

Cm = Material Costs

Ce = Employment and Overhead Costs

Operation and Fixed Maintenance Costs (Cf)

This combination of costs is drawn from the data given by RWS. This data includes the yearly costs of fixed maintenance, which are on their turn also the operational costs of the element. For the estimation of the expected total costs for the lifetime of the construction it is chosen to set this for 100 years. This assumption is made due the technical lifetime approach set by RWS for new civil engineering structures.

The discount rate for this project is set on 2,5%. This number is based on the letters send by the minister of Finance to the senate in the Netherlands. [66] [67] Generally known is the fact that an Euro in your pocket today is worth more than an euro tomorrow. This seemingly vague equation is a reality based on the interests that can be earned immediately[68]. Hence, the total amount of costs for operation and maintenance is not the yearly costs times the number of years.

The following formula transformed the yearly costs in the total costs of an element:

$$Cf = \sum_{t}^{0} (Cf,0 * (1+i)^{t})$$

With:

Cf = Operation and Fixed Maintenance Costs

Cf,0 = Yearly Operation and Fixed Maintenance Costs

i = Discount Rate

t = Time in years

Variable maintenance and Upgrading Costs (Cv)

For the variable maintenance and upgrading the same database has been used. In this database the two can be separated but for this research it is chosen to combine these for a clearer view on the distribution of the total costs. As it counts for the fixed operation and fixed maintenance the lifetime for this costs is the same, 100 years. Also the financial discount rate that is used is the same in this criterion. The following formula is used:

$$Cv = \sum_{t}^{0} (Cv,t * (1+i)^{t})$$

With:

Cv = Total Variable maintenance and Upgrading Costs

Cv,t = Yearly Variable maintenance and Upgrading Costs

i = Discount Rate

t = Time in years

[66] *Ministerie van Financiën, Holland (2007); Advies Werkgroep Actualisatie Discontovoet*
[67] *Mr. drs. J.C. de Jager, (2011); Kamerbrief reële risicovrije discontovoet*
[68] *Brealy, R.A., Myers, S.C., Allen, F. (2008); Principles of Corporate Finance*

Maintenance Costs (Cm)

The total maintenance costs is, as well as the transaction costs, inserted to give a wider view of the distribution of the costs. It is the total of all the operation and maintenance costs that are derived of the time span of 100 years, with the following formula:

$$Cm = Cf + Cv$$

With:

Cm = Maintenance Costs

Cf = Operation and fixed maintenance Costs

Cv = Variable maintenance and Upgrading Costs

5.2.3 - Effects on elements

In this part of the analysis, the impacts of standardization on the costs and availability are presented. These effects are a summary of the discussions in chapter 2, 3 and 4. The initial costs that are needed to calculate the effect on the elements are already presented in the previous paragraph. By calculation the effects of standardization a differences can be made between the costs before and the costs after standardization. This is done by the estimation of the costs before standardization, based on the construction of the lock near Terneuzen, and the estimation of the costs after standardization, based on the costs before + effects. By presenting this difference in a percentage of the initial costs, it is possible to compare the element that comes forward out of the filter analysis. The following costs effects are used in this model:

1. Learning curve

2. Variety reduction

3. Second order effects (Availability)

Learning curve

To determine the benefits of standardization the learning curve, elaborated in chapter 3, will have its influences on the employment costs. Estimating a regression factor, which indicates the ability of learning for specific tasks, can do quantifying this effect. This factor is for the construction industry generally between 0,65 and 0,95, based on the following learning effects:

- Decrease of failure due to machinery
- Feeling confident of the employees with the machinery
- Decrease of the preparation time

The other factor that is important for the total effect on the element is the extent in which a series can be produced. The next formula is used for this research to examine the effects on the different elements in some of the phases of the construction: [69] [70]

$$Ca(d,e,f) = (1 - f\text{^}\log{(G * H)}) * \ Cd,e,f$$

With:

[69] *Globerson, S., Levin, N. (1989); Incorporating forgetting into learning curves*
[70] *Thomas, H.R., Mathews, C.T., Ward, J.G. (1986); Learning Curve Models of Construction Productivity*

Ca(d,e,f) = Difference is costs after standardization of Cd, Ce and Cf

f = Regression factor

G = Size of the series, with respect to the current situation

H = The percentage of learning abilities of the costs

Cd,e,f = Costs before standardization of Cd, Ce and Cf

The regression factor that is used to determine the different values after standardization, different number for the elements between 0,65 and 0,9 are used, based on the amount of machinery and expected learning abilities for that certain element for that life cycle phase.[71] For the size of the series, the estimate amount of 140 is used. This is based on the amount of river locks that are part of the HVWN, elaborated in chapter 4.

The percentage of learning abilities that is used for the factor "H" plays a part when the estimated benefits of employment and overhead costs are calculated. The minimum amount for this phase is 12%, there shall be added the percentage of execution costs over the total employment and overhead costs. The number of 12% is based on the standard indirect costs as a result of the execution, as an example is the construction of a lock chamber. The total amount of execution costs are 8,3 million Euro's over a total of 24 million Euro's for the employment and execution costs. The total percentage of "H" will be: 12% + (8,3/24)*100% = 47%.

Even so, the estimation of the benefits of operation and fixed maintenance will be calculated by this factor "H". Because not all the fixed maintenance will be subject to the learning abilities of the employees. As could be seen contains the fixed maintenance the use of materials as well. The estimation of "H" for this calculation is based on the data from RWS that contains the division of maintenance.

For the material costs and variable maintenance and upgrading costs the learning curve will not play a part. This is because of the fact that the purchasing of material costs will not be influenced by a learning effect for the constructor. This is also the case for variable maintenance and upgrading of an element, where the purchase of elements plays a large part. Another reason to exclude this phase from the learning curve is the fact that variable maintenance is the uncertainty of the work and can differ over time.

Variety reduction

The occurrence of variety reduction as an effect of standardization can be clarified using the following formula, in which the reduction of costs is presented in a percentage over the initial costs.

$$Ca(p,v) = (e * m) * \ Cp,v$$

With:

Ca(p,v) = Difference of costs after standardization of Cp and Cv

e = Engineering factor [%]

m = Amount of finished products

[71] *Vos, Ch. J., Jager, H.C. (1995); Uitvoeringstechnologie van betonconstructies*

Cp,v = Costs before standardization of Cp and Cv

As already identified, the Engineering factor is set by 15% of the material costs, which is based on expert judgment and personal experiences. The amount of finished products depends on the element that is investigated. This amount of finished product is calculated according to the following ratio: handling/purchase. For the sake of this report the following numbers that are used are presented in table [5]:

	Purchase	Material Costs	Amount of finished products	Effect on the Cp and Cv
Mechanics	19,6	32	61%	9%
Command and Control System	5,3	7,5	71%	11%
Bed Protection	1,6	8,6	19%	3%
Gates	11	14,8	74%	11%
Lock Head	25	89,5	28%	4%
Lock Chamber	31	53,5	58%	9%

Table 5: Effects of Variety Reduction

Availability

As elaborated in chapter 3 creates the increasing of the availability a financial benefit for the user as well as an economic benefit for the region. This makes the effect of availability improvement a criteria that has to be considered in order to conclude the most desirable element(s) within a river lock.

To determine the availability improvement, one has decided to take a closer look at the element, and the function of this particular element. Even so is a risk register from river locks investigated.[72] The quantification of the availability is not worth trying, because of the difficulties in the system of a river lock and the uncertainties that comes within. Therefore, its decided to scale the element as presented in the following table.

	No effect	Small increase	Large increase
Mechanics			
Command and Control System			
Bed Protection			
Gates			
Lock Head			
Lock Chamber			

Table 6: Effects of Availability Improvement

The scores are based on the failure of the main process, the passage of ships. This plays a major part in the economic feasibility, and reliability of the river lock. Therefore the availability is one of the most important effects that can play a part when standards are developed. This does not only count for a river lock itself but also for the total corridor. As the one-liner says: "the cable is as strong as the weakest link". By this idea the availability is inserted to determine the most desirable element of a lock.

The scores that are given to the different elements are from the risk registers that are used by the plan development phase of lock Terneuzen. In this risk register and the corresponding FMECA all sort of scores, a combination of change times the impact, are bound together to see which of the elements scores high on the availability level.

[72] *RWS (2012); Inspectierapport Kreekraksluizen*

5.2.4 – Determine the most desirable element

After the criteria are set and the models are filled with the available data, one has chosen to determine the most desirable element on the basis of the outcomes. To combine these different outcomes the following method is used:

- The highest score receives a: ++

- The lowest score receives a: 0

- The scores in between receive a: 0, + or ++ based on the percentage of the difference between the highest score and the lowest. A score between the 0 and 33% receive a 0, the scores between 33% and 66% receive a +, and the scores between 66% and 100% receives a ++.

The first reason for this approach is the comparison of the elements against each other. This is done because of the main question, which is called the most desirable element of a river lock. This is only possible by comparing the elements with each other and not on the absolute figures. The second reason for this approach is to combine the qualitative and quantitative scores. As could be noticed in the models the effects of learning curve and variety reduction are real numbers, where the effect of availability improvements in on a scale. Together one has decided to use this multi criteria approach for the analysis to the most desirable element for standardization in a river lock.

5.3 Discussion

For the filter that is used to determine the most common elements, the assumption is made that a standard will have more benefits if the standard is subject to a large amount of appearances of elements.[73] By the 80% factor, it appears that the other elements are not desirable to standardize, as stated in the main goals of this research. In fact it is for further research interesting to take all the elements into account. On the other side is this distinction in the selection of common elements not just happened. It is quite interesting to know why certain elements are not part of all the river locks, or in some cases why a certain element is only part of one or two river locks. In my defence, the 80% line is chosen to reduce the amount of elements by a well founded assumption, that the benefits of standardization rests on the idea of economies of scale.

The same discussion can be held over the system level of a river lock. A could be seen in the models, this research focus is on the conservation level of a river lock, this is a decomposition used by RWS. The fact that a lower system, the inspection level, contains a lot more elements that might be desirable for standardization is out of this scope. On the other side are the elements of the inspection level, most of the time negligible compared to the total costs of a river lock. Therefore, one has decided to investigate the conservation level, based on the available data and the meetings held with RWS.

The estimation of the initial construction costs that are used for this research are based on a single river lock, Terneuzen. This river lock will also be used for sea transport and might therefore be larger and more expensive than river locks. Even so is the use of one river lock not enough to get a well-founded estimate of the construction costs, but only an indication. In the defence of this report it has to be said that a combination of more

[73] *Harmon, R.L. (1992); Reinventing the Factory II*

locks will not end up in a better estimate because of the fact that every lock of another CEMT-class is different.

For the maintenance cost the overall estimate data from RWS is used, based on an investigation by the Bouwdienst in 2001. The figures that were presented are on the price level of 2001 and had to be adapted to today's price level. This is done by multiplying all the maintenance cost over 1,25, based on the figures of CBS. The estimation of the yearly maintenance costs are therefore not up to date and are taken over the all river locks in the Netherlands, while the construction costs are only estimated by one lock.

Formula for the variety reduction is made out of the assumption that the engineering costs can be dispersed over the purchased materials. This is off course only the case when the materials actually have to be engineered. In the formula the amount of finished products is used as a factor, which indicates this part of the costs that have to be engineered. As could be seen in the outcome of this effect, the amount of finished products is higher when it comes to the mechanical and electric elements. The lowest score is for the bed protection, which has a lot of raw materials and are therefore not subject to variety reduction. Hence, the benefits are low. Unfortunately was it not possible to find a scientifically proven formula for this effect. The only guidelines that are found on the variety reduction effect is set by Simons and de Vries, which indicates the quantity discount in the construction industry is between 4% and 8%.[74]

The effects on the availability of the elements are only set by an scale between 0 and 2. This is done to give an impression of the increase of the availability. This is only done by an investigation at the risk register of river locks and expert judgement. The problem with this effect is the quantification of it. While it is probably the most important effect for RWS, to provide the country with reliable construction that helps the economy, the effect is hard to predict. As mentioned before the failure mode of the total system will decrease but that is not always the case when standards are implemented. Certain elements will always have a high failure mode, the only thing that will change is the predictability of it. For the sake of this report this effect of predictability is not mentioned in the analysis due to the fact that the predictability increased for all the elements that will be standardized. Even so is the availability included as a criteria because it gives a understanding of the high risks elements of a river lock.

Another point of discussion is the fact that not all the gates are the same. In most of the cases there are 3 different gates to be distinguished. Those are the roller, lifting and miter gates. In this research all the gates are seen as the same to simplify the models. This means that additional costs for the transformation to the same standard are not taken into account.

As a conclusion of this discussion part, the model for the identification of the most desirable element is well founded by the available data and gives a clear view on this topic. For the decision-making it is interesting to see what will happen, based on the financial effects if an element will be standardized.

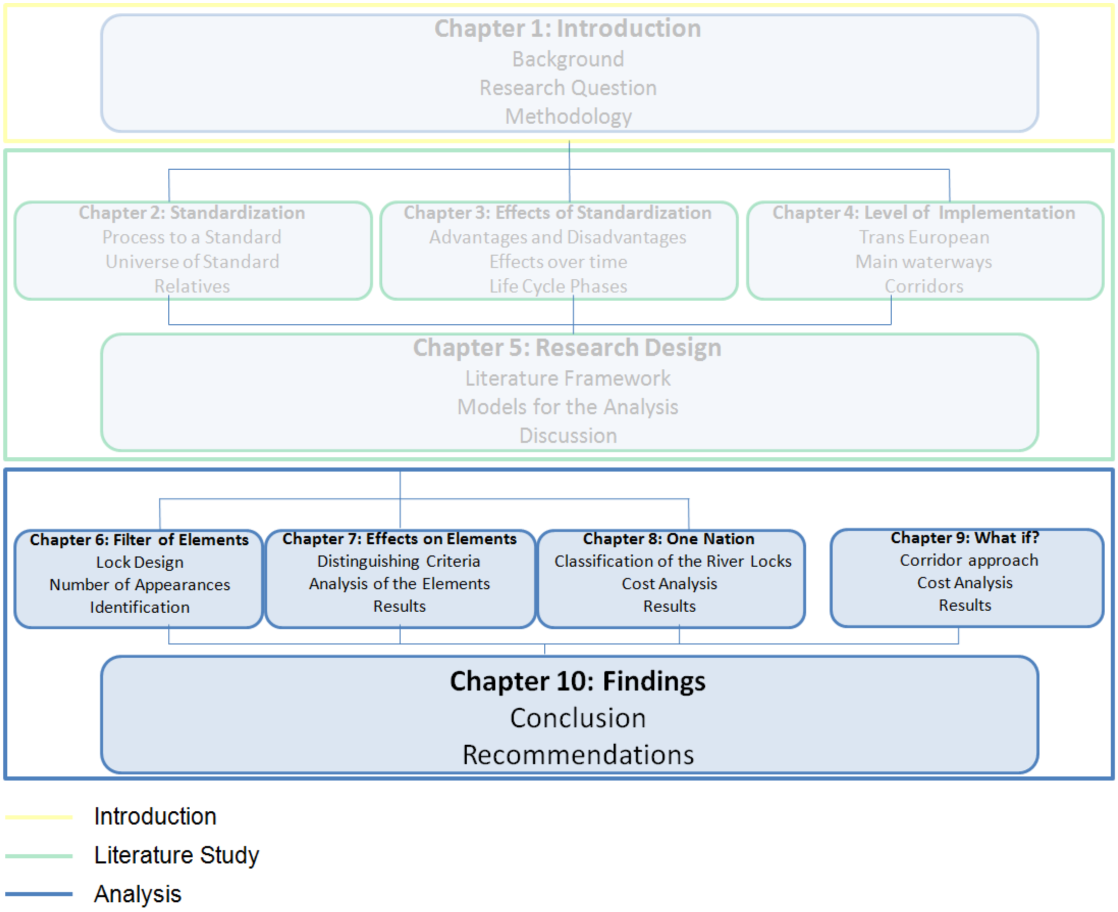
[74] *Simons, C.A.J., Vries, H.J. de (1996); Standaardisatie en normalisatie*

MASTER OF SCIENCE THESIS

STANDARDIZATION IN RIVER LOCKS!

"A study to determine the core"

Analysis



6. Filter of Elements

To determine the elements that are desirable for standardization it is wise to give an impression of a river lock and how this civil engineering construction is decomposed into the elements. As mentioned in the research question in chapter 1 the level of elements is based on the conservation level used by RWS. In the first paragraph the conventional view of a river lock has been elaborated. The second paragraph contains the analysis of all these elements according to the model described in the previous chapter. The last paragraph is a summary of this analysis and a discussion of the results.

For the rest of the research this decomposition of the elements is used. At first for the determination of the most desirable element in chapter 7. Based on the outcome of this analysis the most desirable element is investigated when it is implemented in all the river locks in the nation. The last case study is about what certain elements will do and what if those are standardized. For all these researches the elements that are chosen will come from the decomposition in this chapter.

6.1 Lock Design

Before it can even be determined which of the elements is the most desirable for standardization it is good to give an impression of a river lock. In the figure [17] a picture of the sea lock near Terneuzen is presented. In this picture not all the element scan be recognized, mostly because they're under water or under the ground.

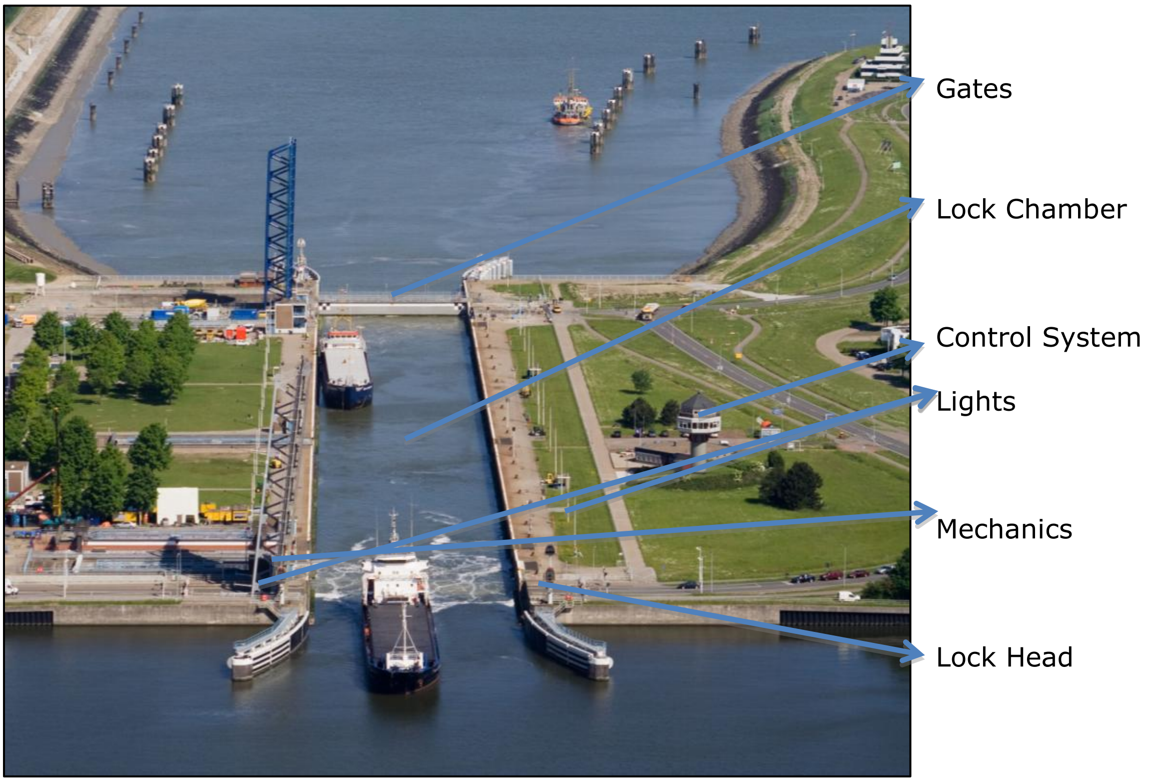


Figure 17: Picture of the Sea Lock near Terneuzen[75]

[75] *Website: www.standaard.be (on 11-22-2013)*

The lock design can be divided into the three major parts, see figure [18]. The reason for this subdivision is made according to the work fields in which they take place. At the end all these work fields has to fit into another but generally spoken are these parts made by different expertise and is it a system on its own.

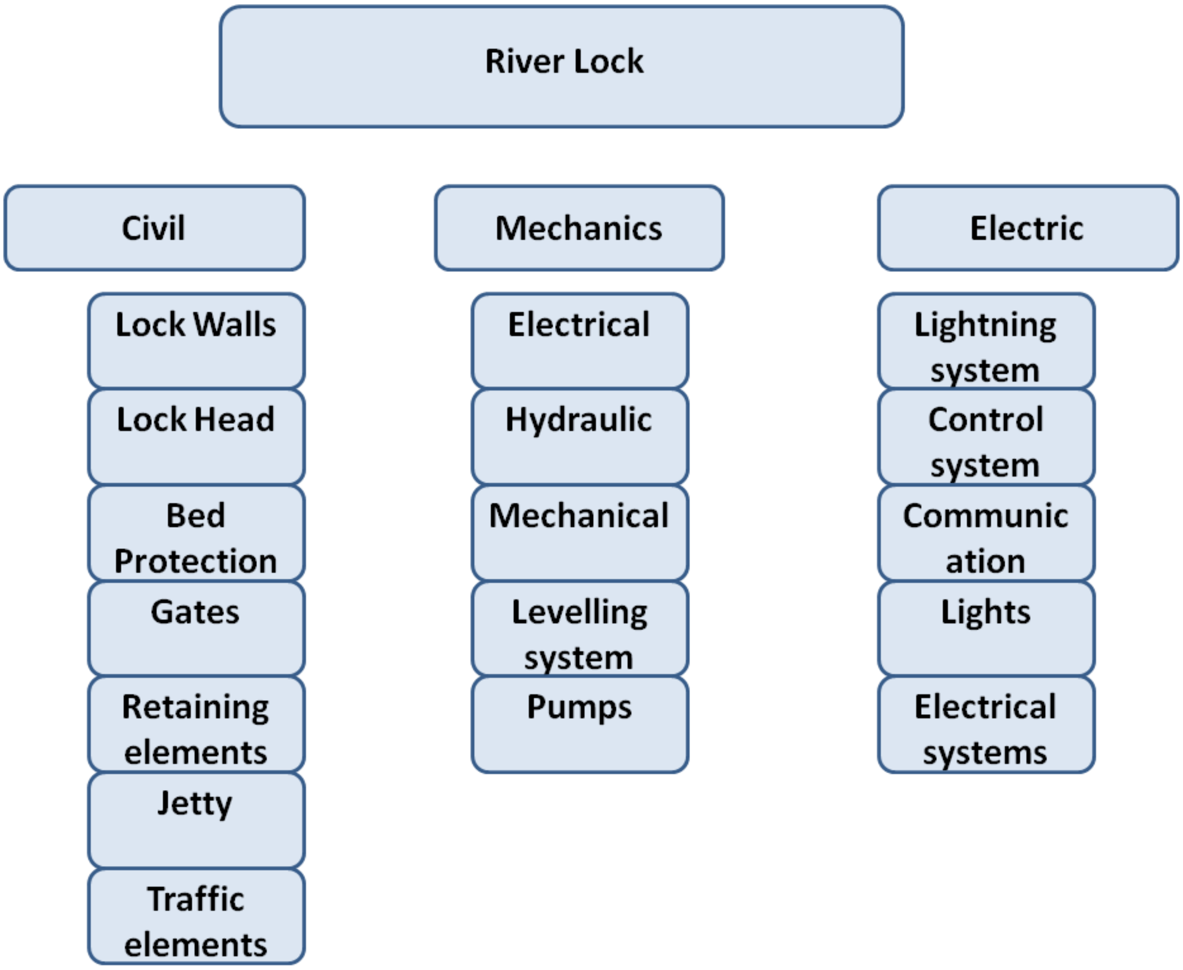


Figure 18: Schematic Decomposition in elements on the conservation level

6.2 Analysis

The first part of this analysis is to identify the core of a river lock, as the subtitle of this research mentioned. This core can play an important factor by the standardization of river locks in the Netherlands. It is the heart of the construction and might possibly be copied or adapted to others. It is a concept of how a river lock should be engineered, from the same basis with a modifications to the environment it has to fit in.

Now the different elements of a river lock are known it can be determined which of these elements are used most of the times by the construction of a river lock. For this analysis 38 river locks are examined by 78 elements on the conservation level, see appendix [D] for the total excel sheet. Most of the 38 river locks are part of the river locks described in chapter 1, which should be replaced before the year 2040. As described in chapter 5 the following formula is used:

$$\frac{n}{N} * 100\% < c$$

Where:

n = number of appearances

N = total number of river locks

c = filter criteria [%]

For the filter criteria an 80% appearance is used. As stated in the discussion part of chapter 5 the reason for this filter criterion, is the knowledge that the amount of appearances of an element influences the benefits from it. The following table shows the 11 elements that appeared over more than 80% in the investigated river locks. Because of the fact that all the elements have to be compared on the same level, one has chosen to combine the different methods of mechanical drive.

Nr.	Name:	Appearances:
1.	Movement equipment	38
2.	Grounding and lightning protection system	34
3.	Command and control system	33
4.	Bedprotection	34
5.	Retaining structure	33
6.	Low Voltage Installation	35
7.	Object lighting	32
8.	Shipping signal istallation	35
9.	Gates	38
10.	Lock Head	38
11.	Lock Chamber	38

Table 7: Appearances of Elements in River Locks[76]

[76] *Rijkswaterstaat (2013); Data Informatie Systeem Kunstwerken*

6.3 Identification of elements

In order to give a better insight in the division of the costs, at first is presented the elements that are indentified as possible for the core, and all others. By this figure [19] it can be seen that by far the largest part for the costing are the civil engineering constructions. As can be seen in the conclusion of this chapter for the maintenance this the other way around.

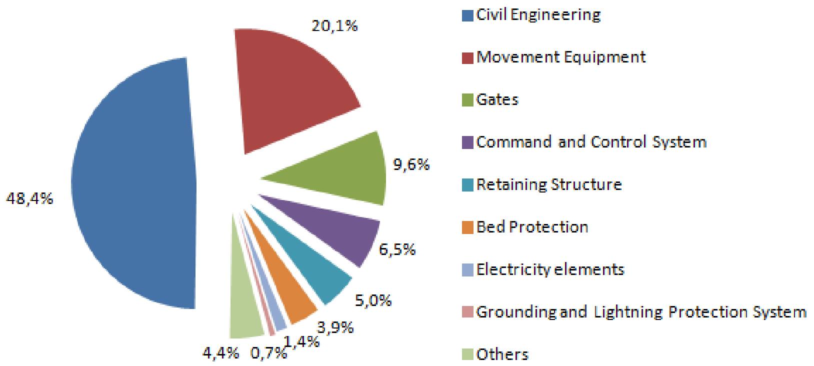
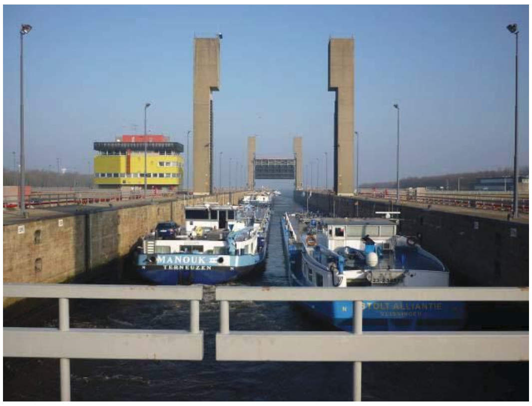


Figure 19: Division of Costs

Now the elements, which appeared in more than 80% of all the river locks, are known this report focus is on some of them. In this paragraph it is explained why. The corresponding pictures are taken by RWS of the Kreekrak River Lock East.

Civil Engineering, (48,4%):



The following elements have the same pros and cons and are therefore combined:

- Lock Chamber

- Lock Head

Pros:

These civil engineering structures form a major part of the construction and material costs. This assumption made of expert judgement makes these elements interesting for standardization.

Also the seemingly ease of the work and design can make these elements perfect for standardization.

Cons:

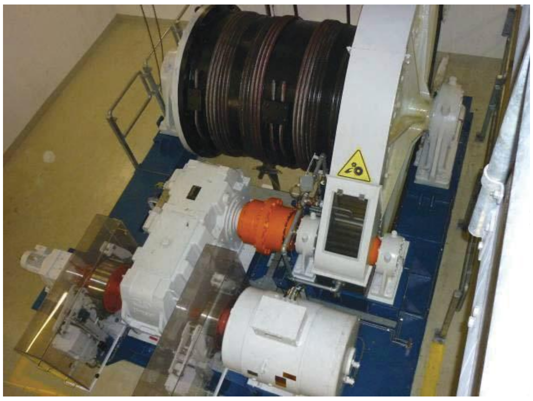
On the other side are these elements subject to environmental parameters, such as the ground conditions, water level and forces from the ships. This could make standardization difficult.

Result:

Based on the above-mentioned pros and cons this element is: Included.

Movement equipment, (20,1%):

Pros:



According to expert judgement this element is subject to a lot of maintenance. As elaborated in chapter 3 this could lead to a large decrease of costs due to the ease of operation and the various parts of maintenance.

The availability of the lock depends heavily on these elements. The gates that will close the river lock so the levelling system can be turned on are the most important elements that should always work. If this fails the river lock will be out of order, which can create an economic loss for companies and the nation. Hence, the availability of these elements is crucial for the river lock.

In contrary to electro, hydraulic movement equipment is seen quite more often and according to the experts it is way better due to environmental aspects. Hence, the implementation for a standard with electro mechanics is more sustainable and should therefore be investigated.

Cons:

The movement equipment is dependent of the type, size and material that is used in the gates. The river lock as a complex system with a lot of interfaces between the elements. If the size of the gates is larger this element should be adapted to handle the new forces that are subject to it.

Result:

Based on the above-mentioned pros and cons these elements are: Included.

Gates, (9,6%):

Pros:

The gates of a river lock are relative easy compatible with nearby river locks. They all have the same function and if standardized the same measurements. Also the high maintenance on this element makes it a good one for further investigation.

The next pro is the fact that the availability of the lock depends heavily on this element. In fact if the gates are not functioning anymore, by function is meant the retaining of the water, the process of passing vessels will stop.

Cons:

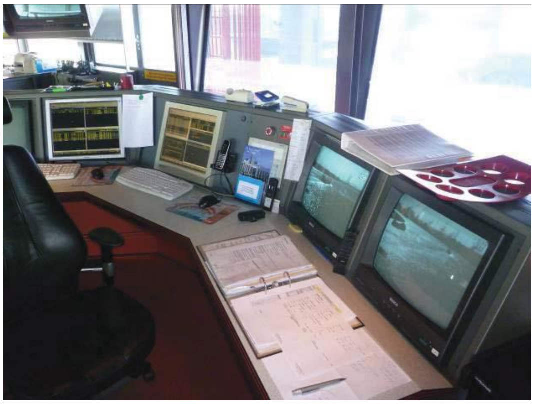
Size of the elements is depending on the heights of the water level and waves. This is an important fact because it can create over dimension of this element, and so high costs. This is because they do not only have a function to hold the water from flowing in the lock chamber but also to protect the surrounding area.

Result:

Based on the above-mentioned pros and cons this element is: Included.

Command and Control System, (6,5%):

Pros:



According to expert judgement this element is subject to a lot of maintenance. As elaborated in chapter 3 this could lead to a large decrease of costs due to the ease of operation and the various parts of maintenance.

The availability of the lock depends heavily on this element. The mechanics, which will close the gates so the levelling system can be turned on, are the most important elements that should always work. If this fails the lock will be out of order, which create an economic loss. Hence, the availability of this element is crucial for the river lock.

This element is suitable to combine with other nearby river locks. As a matter of fact it is not excluded that the command and control system will fall under one control centre. In that scenario this element must be standardized to create the most benefits.

Cons:

The development of these systems is exponential which could lead to new technologies before a standard is born. This can lead to a lot of upgrading and adaption to new systems.

Result:

Based on the above-mentioned pros and cons this element is: Included.

Retaining Structure, (5,0%):

Pros:

Because of the fact that a large part of the costs for this element are from the engineering and materials it might create a lot of financial benefits when this is standardized.

Cons:

On the other side does this element highly subject to environmental parameters such as soil and water condition. Plus the fact that this element is crucial for the safety of the surroundings communities it is useful to be designed for every unique situation.

Result:

Based on the above-mentioned pros and cons this element is: Excluded.

Bed Protection, (3,9%):

Pros:

This element is not subject to environmental parameters. The height of the water or the width of the lock does not influence this element, only the forces of the ships are taken into account.

It is an easy element to standardize because of the guidelines that exists. It has to be placed on the bottom of a river lock and contains in almost all the river locks the same amount and quality.

Cons:

If it is standardized on a basis of a normative vessel a lot of river locks it will be over dimensioned, with higher material costs as an outcome.

Result:

Based on the above mentioned pros and cons this element is: Included.

Electricity elements, (1,4%):

The following elements have the same pros and cons and are therefore combined:

- Low Voltage Installation
- Object Lighting
- Shipping Signal Installation

Pros:

The low voltage installation, object lighting and shipping signal installation are elements that are not subject to environmental parameters. The location, ground conditions, etc. does not play a part in the design and development of this element. Therefore these elements are also very suitable for compatibility standards, which create a higher availability.

The low voltage installation provides the lights, signals and command and control system of the necessary electricity. These functions make this element important for the availability of the river lock and standardization could help providing this.

Cons:

The amount of these costs, related to the total costs of a river lock is negligible. The benefits that it will create make these elements not worth to investigate.

There is insufficient data available for these elements.

Result:

Based on the above-mentioned pros and cons these elements are: Excluded.

Grounding and Lightning Protection System, (0,7%):

Pros:

It is not subject to environmental parameters. This means that this element can be inserted on all river locks in the Netherlands without any adaption for the local surroundings.

It is an easy element to standardize because of the guidelines that already exists by the national standard organizations.

Cons:

There is insufficient data available to determine the benefits of standardization of this element.

Result:

Based on the above-mentioned pros and cons this element is: Excluded.

6.4 Results and Discussion

As a result of the filter analysis and the identification of the elements the following table shows which of the elements will be investigated. The reason why some of the elements that are excluded for further research is because the impact on the costs are too low. Even so is the environmental impact on some of these elements too high that any standard for this has to adapt to the location it has to fit in.

Nr.	Name:	Costs [%]:	Result:
1.	Lock Head	48,4	Included
2.	Lock Chamber		Included
3.	Movement Equipment	20,1	Included
4.	Gates	9,6	Included
5.	Command and Control System	6,5	Included
6.	Retaining Structure	5,0	Excluded
7.	Bed Protection	3,9	Included
8.	Low Voltage Installation	1,4	Excluded
9.	Object Lighting		Excluded
10.	Shipping Signal Installation		Excluded
11.	Grounding and Lightning Protection System	0,7	Excluded

Table 8: Identification of Elements for Further Research

As might notice in appendix D: "Element x River Lock Matrix" some question marks could be set by some of the data. The information that was received for this research is still under construction by RWS. This means that the data is not complete and not all reliable. Even so is this selection of river locks made by the availability of the data. Hence, this filter to select the most desirable element could end up with different elements if the database covert all river lock that are under the supervision of RWS.

Another discussion point is, as stated in the discussion part of chapter 5 the assumption is that the number of appearances influence the total benefit of the standard. In this research is it chosen to set the line at 80%, which is quite arbitrary. Because of the available data on the costs of construction and maintenance the filter was set high so a lot of the element does not made it through. In the defence of this report it is about the model that is create to determine the most desirable elements and not the assumptions that are made. To give an clear view of the element that appeared in more than 50% but are not part of further research the following table is presented.

Nr.	Name:	Appearances:
1.	Mooring Facility	20
2.	Closed Circuit TeleVision Installation	25
3.	Building	23
4.	Rainwater drainage	24
5.	Cable Support Structure	21
6.	Railing	23
7.	Maintenance Facility	27
8.	Fender and Guiding Facility	29

Table 9: Elements that Appeared between 50% and 80%

Last discussion point is that the choices for the elements are made before the investigation, while there is a possibility that the elements could be beneficial if standardized. As example the Grounding and Lightning System and the Object Lighting. Unfortunately is not all data available and must this element be further examined.

7. Standardization Effects on Elements

In this chapter the elements that are investigated in the previous chapter are examined by the effects that will take place after standardization. The effects that are examined for answering the main question are elaborated in chapter 3: "Effects of standardization". In chapter 5 the models that are used for the determination of the most desirable elements of a river lock is stated.

7.1 Criteria

For the determination of the most desirable element the following criteria are used:

7.1.1 - Construction costs

This overall costs for the construction of a river lock is a sum of the investigated phases that are part of it. The reason for this criteria is the fact that the principal for this research is interested in the financial benefits that comes with the standardization of certain elements. Therefore it is quite interesting to see what part of the river lock, or element is spent on the construction of it. Based on this question, the costs for the construction are investigated by:

- Design Costs

- Material Costs

- Employment and Overhead Costs

7.1.2 - Maintenance costs

The maintenance costs are sum of the fixed and variable maintenance costs and the use of the elements. The reason for this criteria is based on the goals set in the introduction to have a notice about the distribution of the costs. With other words, which element has the most maintenance costs, relatively and in percentages. Even so is the prediction that the maintenance costs will decrease if an element will be standardized. To give an insight in this criteria the distribution is set by the earlier mentioned phases of the life cycle:

- Operation and Fixed Maintenance Costs

- Variable maintenance and Upgrade Costs

7.1.3 - Availability

The availability of an element is expressed on a scale between 0 and 2. This is done to give an understanding of the benefits that are part of the effects. The reason for this criteria is the necessity that a river lock becomes more reliable in the sense of availability. By standardization, the initial thought is that it will reduce the risks and failures of element and are therefore interesting for the total availability.

7.2 Analysis

After the model is filled with all the needed and available data out of the indicators and references from Lievense, Arcadis and RWS, the following effects on the specific elements can be shown. In this paragraph the costs distribution before and after standardization of the elements are combined into a graph. To give a proper view on the benefits and possible loss the graph is explained.

7.2.1 - Distribution

In figure [20] the distribution of the five financial criteria is shown, in percentage of the total costs of an element. In appendix [F] the table with all the data is shown. Based on this figure, the following can be concluded:

- The total costs for command and control system of a river lock depends heavily on the variable maintenance and upgrading phase.
- The costs for movement equipment and gates are distributed in the same way, and do not depends heavily on a certain criteria.
- The civil engineering constructions: Bed protection, Lock head and Lock chamber are situated on the right side, which means that the material costs is the main cost component.

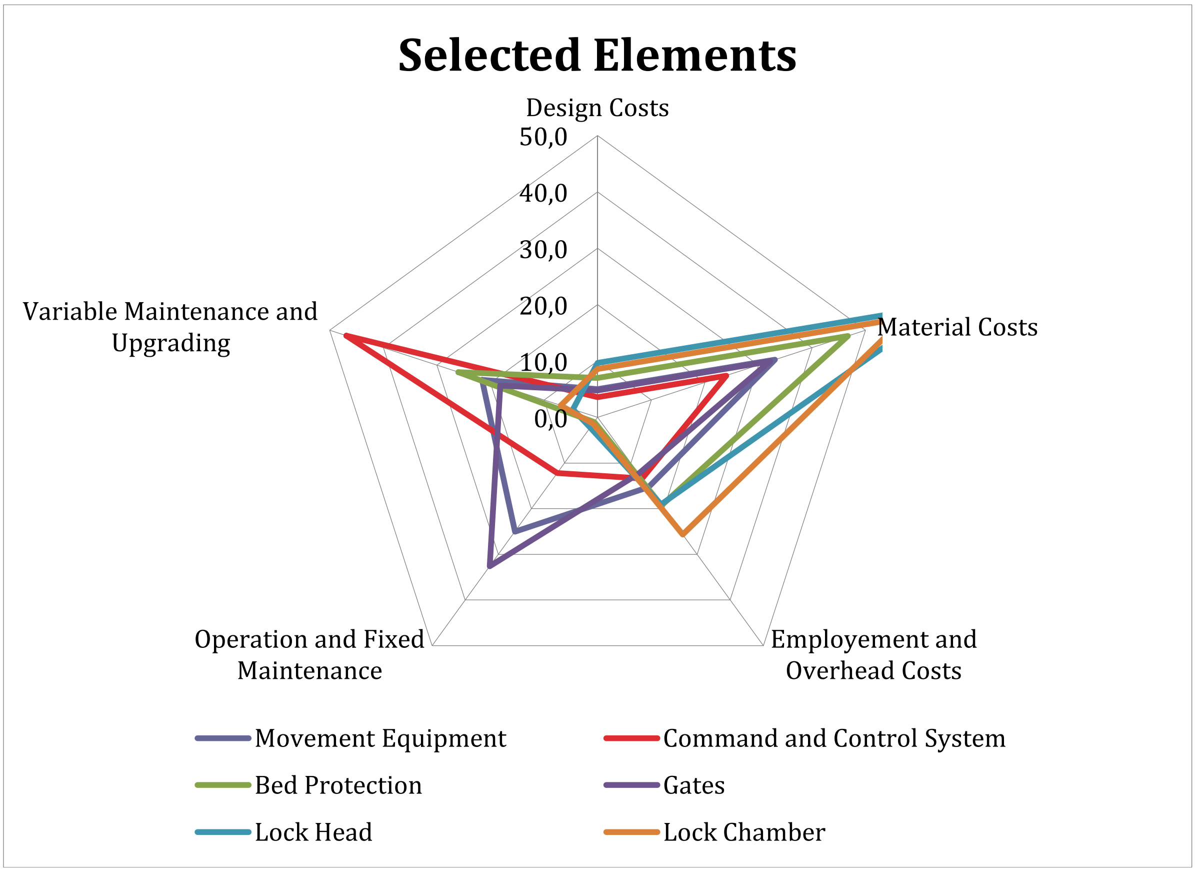


Figure 20: Distribution of all Selected Elements in [%]

7.2.2 – Cost effects

The effects of standardization that occur when an element is subject to standardization is presented in the following figure. The graph shows the percentages of difference between the costs of transaction, maintenance and total before and after the standardization. The last is a combination of all the elements, with other words, when the total river lock, or in this case the selected elements are standardized.

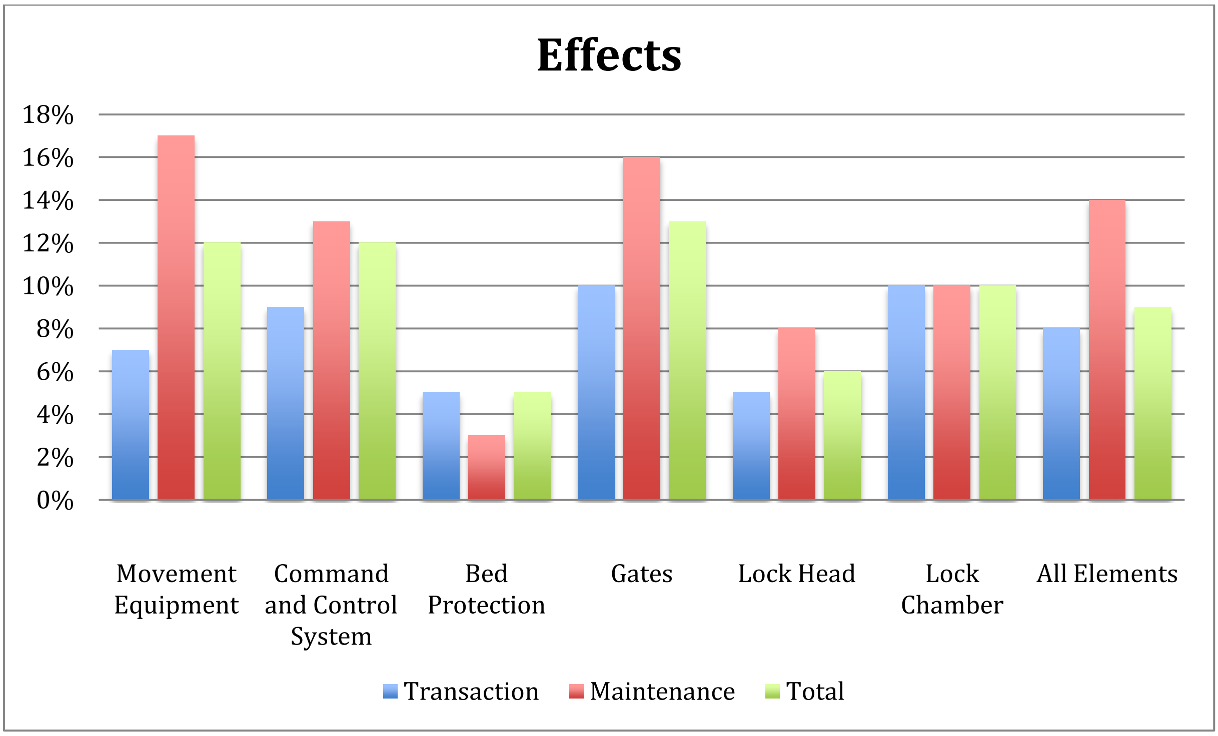


Figure 21: Effects of Standardization on the Elements

As could be seen in figure [21] the benefits on the costs are different between the elements. From this graph the following order can be made, on the basis of costs:

Nr.	Element	Construction	Maintenance	Total
1.	Gates	10%	16%	13%
2.	Movement Equipment	7%	17%	12%
3.	Command and Control System	9%	13%	12%
4.	Lock Chamber	10%	10%	10%
5.	Lock Head	5%	8%	6%
6.	Bed Protection	5%	3%	5%

Table 10: Effect on the Costs

As mentioned in the discussion part of chapter 5 about the engineering costs of an element one has decided to carry out a sensitivity analysis. By this analysis one has decided, based on the knowledge of ir. A. Hijdra, to increase the percentages of engineering costs to 20% and 25%. In the following table the results are presented. Out of this table it can be concluded that the financial benefits for the Command and Control System are increasing, compared to the change of the other elements. As a result for the investigation to the most suitable element it can be seen that it does not make any difference.

		Engineering Costs [%]		
Nr.	**Element**	**15%**	**20%**	**25%**
1.	**Gates**	13%	15%	17%
2.	**Movement Equipment**	12%	14%	15%
3.	**Command and Control System**	12%	14%	17%
4.	**Lock Chamber**	10%	12%	14%
5.	**Lock Head**	6%	7%	8%
6.	**Bed Protection**	5%	5%	6%

Table 11: Sensitivity Analysis of Engineering Costs

7.2.3 – Availability effects

To determine the availability improvement, one has decided to take a closer look at the element, and the function of this particular element. In combination with the risk register from RWS the following table can be presented:

	No effect	**Small increase**	**Large increase**
Movement Equipment			X
Command and Control System		X	
Bed Protection	X		
Gates		X	
Lock Head	X		
Lock Chamber	X		

Table 12: Effects of Availability Improvement

This table shows that not all the elements will improve the availability of the river lock. As could be seen lie the distinction by the subsystems of a river lock. The civil engineering part scores low on this effect, while the electric and mechanical parts are subject to this effect.

7.3 Results

As a result of this analysis the most suitable element can be selected. As mentioned in the model description in chapter 5, the criteria are all costs components in this selection. The following table shows the outcome of this model:

	Construction			Maintenance		
	Design	**Material**	**Employment**	**Fixed**	**Variable**	**Availability**
Movement Equipment	0	++	0	++	++	++
Command and Control System	0	++	0	++	++	+
Bed Protection	++	0	+	0	0	0
Gates	0	++	+	+	++	+
Lock Head	++	0	0	0	0	0
Lock Chamber	++	0	++	0	+	0

Table 13: Results of Standardization

When these scores are combined an order can be formed over these elements. In figure [22] this is shown. Here it can be seen that the highest scores are determined as most suitable for standardization. The lowest scores are labelled as the "No standardization". This label means that these elements do not show enough benefits, compared to the other elements, for standardization. This does not mean they are not suitable for standardization but are not most desirable.

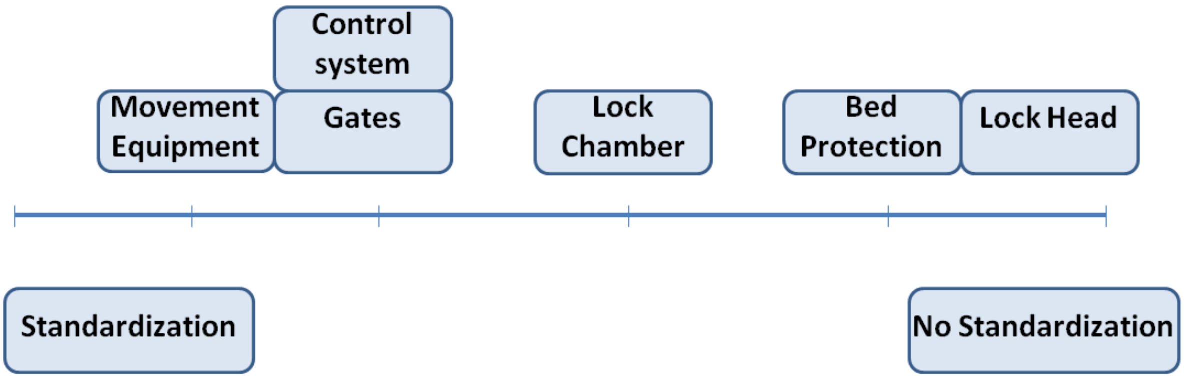


Figure 22: Scale for the Most Suitable Element

8. Standardization on National Level

In addition to the conclusion from chapter 7, one of the elements will be tested by the implementation on a national level. As seen in chapter 4 the national level contains 140 river lock complexes, which fall under the supervision of RWS. As the leader of this standardization process and principal for this research they are interested in the large scale implementation, where the effects are generic over all the river locks in the Netherlands. Hence, this case study will contribute to the overall effects of standardization, in the field of life cycle costs. The value of this case study is to give a high accurate estimation of the effects, both economy of scale and over dimensioning, when the materials are encapsulate from all other costs and market effects. The benefits are already calculated in the previous chapters, hence this case study is only about the additional costs of standardization. The motivation for this approach is to give handles for further research to the optimize process of standardization in river locks.

To start with this case study one has assumed that all the lock complexes in the Netherlands will be transformed into the new standard, expect for a numerous locks that are not fit into the classification. This assumption is made in order to show what the effects are if, and only if, the standard will be implemented in the whole country. In that case it is also assumed that RWS will operate and maintain the river locks all together, as one nation. As a contradiction to these assumptions in the second case study this is not part of the analysis, which might create a total different outcome.

For this case study to the implementation of a standardized element in the replacement of river locks, one has decided to use the gates for this. The first reason is based on the conclusion from chapter 7, where the gates scored high on the scale of suitable elements for standardization. The second reason for this element is because of the simple engineering, based on the costs and measurements. According to the experts by Lievense the parametric characteristics of a gate is based on some information which can be withdrawn from literature and databases. These facts are the CEMT-classes of a river or channel and the water head on both sides of the lock. By this simple method for calculation of the gates measures a major part of the national river locks will fit in.

To determine the real benefits of a standard, by this its meant that the negative effect of over dimensioning is added to this study, it is of importance to take a closer look at the river locks in the Netherlands. By this classification of the river locks the most important parameters are used. These are the heights, based on the water levels and CEMT-class of a corridor and thus for a river lock. After the classification a distinction is made according to these parameters. This is of necessity when the over dimension of the river locks has to be determined. At last the benefits from the previous chapters and the loss of over dimensioning are drawn together.

8.1 Classification of river locks

As described above the first analysis contains the classification of river locks. In the previous period towards this research MWW already made a classification for the river locks in the Netherlands. This was based only on the CEMT-classes and contains 5 different types, from S to XXL. In the attended discussions with experts the majority concludes that this classification is a good start but in a lot of cases to expensive, due to over dimensioning. Hence, a new model for the classification is created with the experts of Lievense. In this model not only the CEMT-classes are part of it, but also the heights of the water level and soil. By adding these parameters to the classification model a more accurate distinction can be made in order to prevent over dimensioning. This emerges when lock complexes does not need the same gates.

Before this model can be used a standard identification of the river locks is needed to determine the amount of gates that are present in the river lock complexes. Nowadays some locks do have a roller, lifting or miter gates, all with their own advantages and numbers. As the assumption describes all the locks will have the same gates, and in this case study the miter gates. This means that the locks, which have not miter gates, will be transformed into one, which does have it. The costs for this transformation are not part of this case study. Even so is the option for gates in the middle of a lock not in this research.

For the classification of the river locks the following steps are made:

1. At first a 2x2 matrix, which categorizes the river lock, will determine the amount of gates in a river lock, with on the axes: retaining and ratio length/width. See figure [23] for the top view and figure [24] side view.

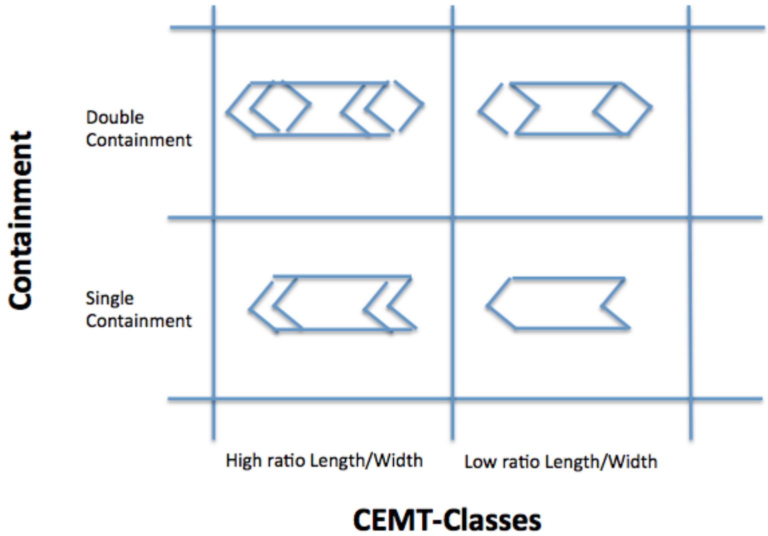


Figure 23: 2x2 Matrix for Categorization

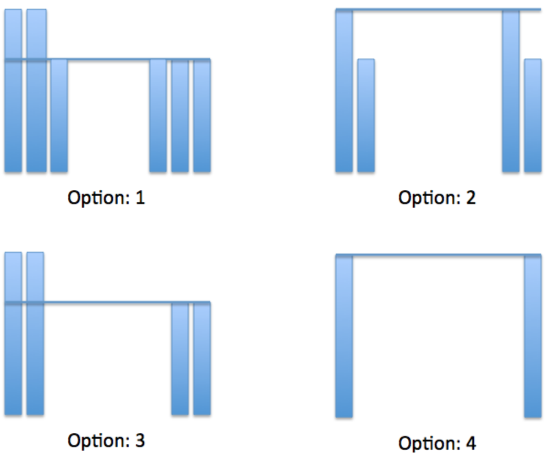


Figure 24: Side View of the 2x2 Matrix

The choice for double or single retaining depends on the water levels on both sides of the river lock. In certain case a river lock has to work both ways, by this it is meant that the water level on one side fluctuates on the water level on the other side.

The ratio length/width is based on the CEMT-Class that is used in the corridor, in which a certain lock is located. For this classification, table [14] is used and extended with the ratio and classification. The decision for a high of low classification is based on expert judgement and investigation of the current situations.

CEMT-Class	Length	Width	Depth	Ratio L/H	Classification
Class I	38,5	5,05	1,8 – 2,2	7,6	Low
Class II	50 – 55	6,6	2,5	7,6 – 8,3	High/Low
Class III	67 – 80	8,2	2,5	8,2 – 9,8	High
Class IV	80 – 85	9,5	2,5	8,4 – 8,9	High
Class Va	95 – 110	11,4	2,5 – 4,5	8,3 – 9,6	High
Class Vb	172 – 185	11,4	2,5 – 4,5	15,1 – 16,2	High
Class VIa	95 – 110	22,8	2,5 – 4,5	4,1 – 4,8	Low
Class VIb	185 – 195	22,8	2,5 – 4,5	8,1 – 8,6	High
Class VIc	193 – 200	34,2	2,5 – 4,5	5,6 – 5,8	Low
Class VIIb	195 – 285	34,2	2,5 – 4,5	5,7 – 8,3	Low/High
Sea Locks	>285	>34,2	>2,5	<8,0	Low

Table 14: CEMT-Classes and the Ratio Length/Width[77]

2. The second step is the calculation of heights for all the gates that are investigated. This height is based on a model, which contains the retaining height and fall height of a gate, see figure [25] where option 2 from step 1 is presented. This model can be expressed in the formulas on the next page.

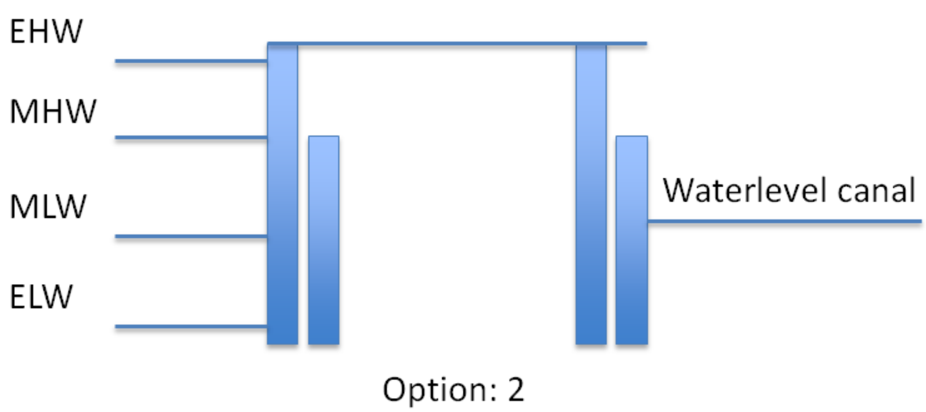


Figure 25: Water Levels around a River Lock

[77] *CEMT (1992); RESOLUTION No. 92/2 ON NEW CLASSIFICATION OF INLAND WATERWAYS*

These formulas describe the heights of each gate, with the maximum of 6 gates, starting from left to right. The benefits of this model is that gates might be different within the river lock. In the classification that is used by MWW all the locks are the same, including the heights of the gates. When this classification is the standards, the costs are lowered because of the "tailor-made" gates of each river lock. The heights in this model are measured in relation to the NAP. This prevents flaws in the classification of the river locks.

As a description of this model the formulas are elaborated:

$$\Delta H1 = |EHW - Hcanal|$$

The first gate is the same for all the river locks, the Extreme High Water (EHW) minus the height of the canal. These are the first defence of the river lock.

$$\Delta H2 = |MHW - Hcanal| \;\; or \;\; |Hcanal - MLW|$$

The second gate is based on the outcome of a river lock in the first step. This means that if it is option 1 or 3, the Normative High Water (MHW) minus the height of the canal measures this delta height. In case it is option 2 the model describe a calculation of the height of the canal minus the Normative Low Water (MLW). The last option will not have this gate.

$$\Delta H3 = |Hcanal - MLW|$$

The third gate is effective only when option 1 is the outcome of step 1. Then the height of the gate will be determined by the formula of Height canal minus the MLW. In all other options there is no gate number 3.

$$\Delta H4 = |MHW - Hcanal|$$

The fourth gate has the same conditions as the third one. Only when option 1 is the outcome of the first step this model will be used. The formula as it is used contains the MHW minus the Height of the canal. All other options will not have this gate.

$$\Delta H5 = |EHW - Hcanal| \;\; or \; |MHW - Hcanal|$$

In case of option 1 or 3, the height of the fifth gate can be determined by the formula: EHW minus the Hcanal. When option 2 is the outcome of the first step the formula of MHW minus Hcanal is used. The last option does not have a fifth gate.

$$\Delta H6 = |EHW - Hcanal| \;\; or \; |MHW - Hcanal| \;\; or \;\; |Hcanal - ELW|$$

For the sixth gate multiple formulas are used, depending on the option that comes out of step 1. If it is option 1 or 2 the formula is EHW minus Hcanal. In case of option 3 MHW minus Hcanal is used as the formula to calculate the height. For the last option the formula Hcanal minus Extreme Low Water (ELW) is used.

On the following page the meaning of all abbreviations are listed.

With:

ΔHd = Height of Gate number 1 - 6

EHW = Extreme High Water

MHW = Normative High Water

MLW = Normative Low Water

ELW = Extreme Low Water

Hcannal = Water level of canal

3. The third step of classification is to insert all data in a 3x6 matrix, with the ΔHead and CEMT-Class as the parameters, see figure [26]. In fact the width and depth are been deployed against the height of fall. The extreme values are excluded from this matrix, based on the assumption that standardization is beneficial when it comes to numbers. Also the river locks that are smaller than the CEMT-class of IV are excludes. The few that fall under the supervision of RWS not worth mentioning. It will only become interesting when all river locks, including the smaller regional ones are part of the standardization.

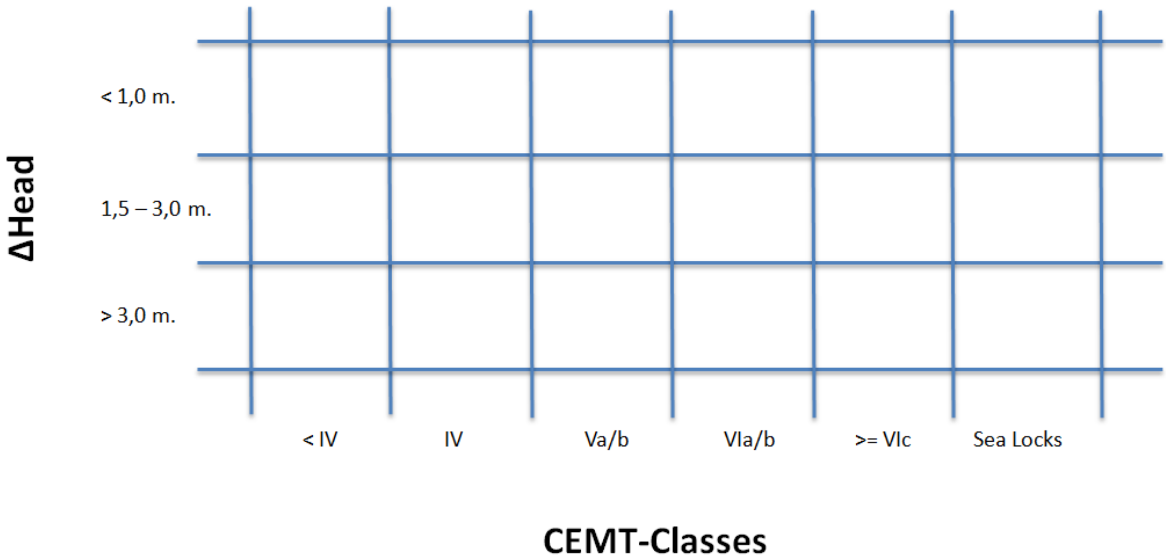


Figure 26: 3x6 Matrix for Classification

The combination of Va/b and VIa/b is based on the width of the CEMT-classes. As could be seen in table [14] the width is the same for these classes. Hence, the combination is justifiable because the height and width of a river lock are of importance in calculating the division of gates.

As also could be noticed is the distinction of classes lower than IV and larger than VIc. Based on the data there are just a handful of river locks that fall under the supervision of RWS that they can be excludes. In other words, it could be beneficial but the amount is so low, compared to the other classes that standardization that it is out of this scope.

4. At last the amount of over dimension can be calculated. By the division of the gates, based on the ΔHead different scenarios can be presented. Out of these scenarios the best option can be decided, on a basis of m2. The heights of all the gates are known and the division is set, so every extra ton of steel can be determined, compared to the current situation. See table [15] For the costs of a gate the price of 4.025 €/m2 is used, which is also used in the calculation of chapter 7.

CEMT-Class	< 1.0	1.0 – 2.0	2.0 – 4.0	Width	M2	Costs
Class IV						
Class Vab						
Class VIab						
Total						

Table 15: Cost of Over Dimension

8.2 Analysis

In the previous paragraph the steps that are needed to determine if the standardization of gates are beneficial are elaborated. In this paragraph the outcome of these steps are shown and analysed. The total excel sheet, which is made for this case study is presented in appendix [H]. Out of this database the following figures can be made. These first figures give a clear view on the scatter of all gates. This means the variety based on the height. By this division a cluster can be made of gates, based on the heights, in order to reduce the over dimensioning. This means also that the gates that are not beneficial, based on the assumption of large numbers and the extreme heights, will fall out of this model. Therefore a well-founded classification of the gates is presented.

Figure [27] is a summary of the gates with an interval of 0.5. In this figure it can be seen that between 0 and 0.5 the largest amount of gates is located. The next 3 clusters are quite the same and after a height of 2 meters the amount is rapidly declining. The last cluster is set by all the gates that have a height that is over 5 meter. This is done because of the small amount, mostly 3 or 4 in the single clusters.

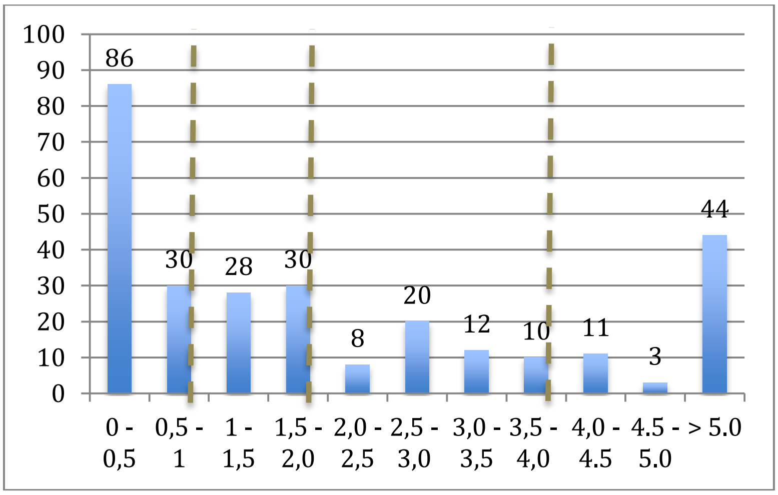


Figure 27: Total Amount of Gates by a ΔH interval of 0.5

In the next figure [28] the interval is set by 0.25. The reason for this small interval is because of the outcome it might have, especially for the first 4 clusters out of figure [27]. As can be seen in figure [28] the amount of the first 0.25 is still the highest. Another remarkable outcome is the fact that the three clusters of 0.5 to 2 meters, from figure [27] have a (much) larger amount in the last 0.25 meters.

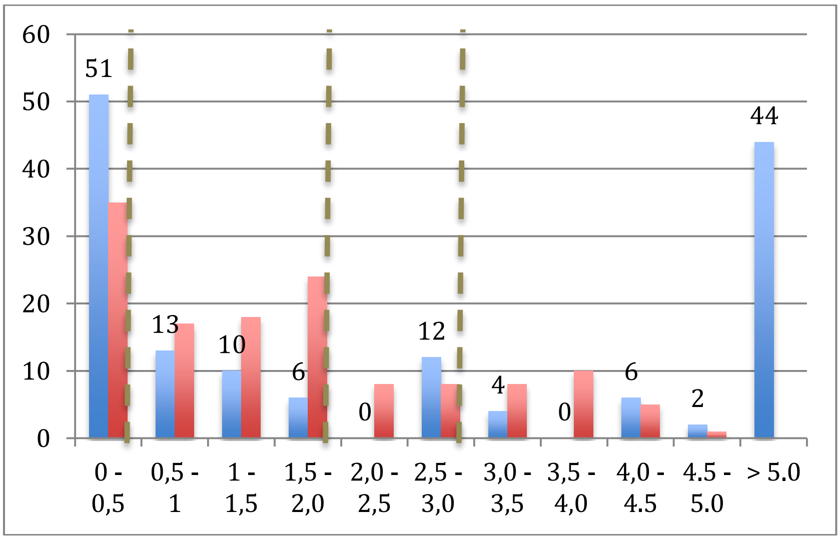


Figure 28: Total Amount of Gates by a ΔH interval of 0,25

To reduce the over dimension of the gates, a proper line has to be set for the clustering of the gates. Based on the figures [27] and [28] it can be determined where the lines for this clustering have to be set. Because of the fact that the clustering is quiet arbitrary one has chosen to compare two classifications. By this approach of selecting of these two clusters, an interpolation between the two outcomes can determine the best classification for the standardization of river locks. The following table showed the clusters:

	Cluster 1	Cluster 2
Line 1	0 – 1.0	0 – 0.5
Line 2	1.0 – 2.0	0.5 – 2.0
Line 3	2.0 – 4.0	2.0 – 3.0
Line 4	>4.0	>3.0

Table 16: Clustering of the gates

Based on these clusters the classification of all the gates in the Dutch river locks can be presented. The table [17] en [18] on the next pages shows this division. They have on the x-axis the CEMT-classes, which represent the width and height of the river locks. On the y-axis is the ΔHead that represent the fall of the height, and thus the additional height to the CEMT-class prescribes measures. It can be seen that, based on the chosen clustering and knowledge of all the CEMT waterways that the high percentages in the groups are located in the first meters.

ΔHead	CEMT-Classes					
	< IV	IV	Vab	VIab	> VIc	Sea Locks
0-1.0	8	4	47	52	1	4
1.0-2.0	0	0	37	18	1	2
2.0-4.0	0	0	28	20	2	0
>4.0	0	0	46	6	0	2

Table 17: Division of the Gates (Cluster 1)

ΔHead	CEMT-Classes					
	< IV	IV	Vab	VIab	VIc/VIIb	Sea Lock
0-0.5	8	4	28	44	1	1
0.5-2.0	0	0	56	26	1	5
2.0-3.0	0	0	16	12	0	0
>3.0	0	0	62	14	2	2

Table 18: Division of the Gates (Cluster 2)

To determine the financial effects of this clustering both the classifications are calculated, based on the over dimension. These effects are only interesting for the CEMT-classes of Vab and VIab. All the other classes do not have the amount that is worth to investigate. In the tables [19] and [20] the costs for over dimension are determined, where the width is calculated by the goniometric functions, based on the angle of 18,7°[78]. The costs for a m2 gate is set by € 4025,--. This number is a combination of the weights per m2 and costs per kg. According to calculations of Lievense this is 1150 kg/m2 * € 3,50.

CEMT-Class	< 1.0	1.0 – 2.0	2.0 – 4.0	Width	M2	Costs
Class Vab	23,9m	20,8m	39,2m	12m	1006,8 m2	€ 4.052.000
Class VIab	33,4m	5,2m	38,0m	24m	1838,4 m2	€ 7.399.000
Total					2845,2 m2	€ 11.451.000

Table 19: Cost of over dimension (Cluster 1)

This first table of the costs for over dimensioning shows a total amount of 2845,2 m2 extra steel that is needed for all river locks in the CEMT-classes Vab and VIab when this clustering is chosen. Based on the price of steel the costs are € 11.451.000.

[78] *This angle is the average of all miter gates that known by Lievense.*

CEMT-Class	< 0.5	0.5 – 2.0	2.0 – 3.0	Width	M2	Costs
Class Vab	6,3m	39,9m	9,8m	12m	672,0 m2	€ 2.704.000
Class VIab	9,4m	30,2m	37,4m	24m	1848,0 m2	€ 7.438.000
Total					2520,0 m2	€ 10.142.000

Table 20: Cost of over dimension (Cluster 2)

In this second table the total amount of m2 is less than the first. This is mainly because of the exclusion for all the 30 gates with a ΔHead higher than 3.0. But this is not only the reason for the smaller amount of m2, the first line is set by 0.5 and creates a smaller cluster, which results in a little over dimensioning. All together will this clustering costs € 10.142.000 extra because of the over dimensioning.

To see the difference between the positive and negative effects of standardization, these extra cost due to over dimensioning need to be presented in percentages over the common costs. Also based on these percentages it can be derived which of the classification is less disadvantageous. In the tables [21] and [22] this is done for both the clustering.

CEMT-Class	Number of Gates	Costs	Per Gate	Purchase Before	Purchase After	Loss
Class Vab	122	€ 4.052.000	€ 33.213	€ 36.954.700	€ 41.006.700	11,0%
Class VIab	90	€ 7.399.000	€ 82.111	€ 56.646.800	€ 64.045.800	13,1%
Total	212	€ 11.451.000	€ 54.014	€ 93.601.500	€ 105.052.500	12,2%

Table 21: Result of Over Dimension (Cluster 1)

CEMT-Class	Number of Gates	Costs	Per Gate	Purchase Before	Purchase After	Loss
Class Vab	100	€ 2.704.000	€ 27.040	€ 38.061.200	€ 40.765.200	7,1%
Class VIab	82	€ 7.438.000	€ 90.707	€ 55.448.600	€ 62.886.600	13,4%
Total	182	€ 10.142.000	€ 50.230	€ 93.509.800	€ 103.651.800	10,8%

Table 22: Result of Over Dimension (Cluster 2)

8.3 Results and Discussion

Based on the categorization that is developed by the researcher, in consultation with experts from Lievense, the costs for over dimension are presented in the previous paragraph by the tables [21] and [22]. These can be seen as a result for the costs of gates when the standard is implemented for all river locks in the CEMT-classes Vab and VIab. These costs are derived from the assumption that the average depth is 5,5 meter, based on the CEMT-classification.[79] With the corresponding categories the total amount of steel can be calculated. From these tables it can be concluded that the classification of number 2 creates a lower loss on the effect of over dimensioning, namely 10,8% of the costs that are calculated if there is no standardization.

[79] *CEMT (1992); RESOLUTION No. 92/2 ON NEW CLASSIFICATION OF INLAND WATERWAYS*

The benefits of standardization, which are presented in chapter 7 shows that the purchasing of the gates is 11,1% lower when they are all standardized. As a result of this case study, where the financial costs are encapsulate from all other costs and market effects, it can be concluded that standardization of the gates for our country is a very small win of 0,3%.

This means that the very small profit of the effects of variety reduction, learning curve and over dimensioning is negligible. This conclusion is based on the uncertainty in the models, the assumptions that are made and the fact that the outcome is significantly small compared to the large scale of implementation. This does not mean that standardization isn't beneficial on the total life cycle costs. As could be seen in the analysis of the total life cycle not only benefits are accomplished by the construction phase but also on the maintenance. Because of the fact that the negative effect of over dimensioning will be offset by a positive effect of variety reduction and learning curve the real benefits of standardization lies in the maintenance.

Off course this conclusion can only be drawn by assumptions that are made in this chapter and the previous ones. For this chapter the assumption that all the river locks in the Netherlands can be categorized isn't proven yet. Off course the possibility is present, based on the functions and measurement but not all of them are equal. By RWS another categorization is made which is divided in 5 different locks, see table [23].

MWW-Class	Width	Length	Depth	Number
Small	12,5m	100m	3m	25
Medium	20,0m	175m	4m	73
Large	25,0m	250m	5m	14
XL	33,0m	305m		2
XXL	55,0m	427m		1

Table 23: MWW classification[80]

In my opinion this classification is not accurate enough. The differences in water levels are to large that over dimensioning will become a larger effect than the benefits. Even so is this classification based on a single river lock and not about different measurements inside a river lock. The dimensions can differ between the gates and mechanics. Hence, this classification is not accurate.

On the other side is it a good start to investigate the benefits of standardization. As stated in chapter 3, the effects are increasing when the size of a series is larger. When the total areal of river locks that fall under the supervision of RWS is divided in the more and more categories, it can be concluded that we are back at square one. Therefore in this report, one has decided to take other divisions in consideration as well to find the optimize balance point between competition and standardization.

[80] *MWW (2012); MultiWaterWerk ideeen*

9. Standardization on Regional Level

As described in the first chapter this second case study is added to the research to give another look at the implementation of standards in river locks. In the previous case study, the quantified effects are analysed to determine whether or not an element, in this case the gates, is beneficial when its standardized for the whole country. This abstract point of view does not take into consideration the implementation problems that might occur when elements of a river lock are standardized.

In this case study this line of reasoning is reversed. Here one has decided that the gates, lock heads and mechanics are chosen to be standardized. The main questions that will be answered in this case study are, what if these elements are standardized, based on the life cycle costs? What are the opportunities and threats you have to deal with? As a contradiction to the previous case study the abstract line is converted into a pragmatic study to the implementation of a standard on a regional level. This also means that some of the opportunities and threats are only qualitative because they occurred during this research.

The reason for this LCC aspect in the case study is mainly based on the available data and relevance to get support. As mentioned in the introduction, a major incentive for RWS is to optimize predictability and availability, but for the sake of this research these positive effects of standardization are not taken into account.

This regional level is chosen because of the fact that is it not manageable for this research to investigate the implementation on a national level. Even so, is it more likely to investigate the regional difficulties because on that level the implementation is more likely. A third reason for this regional level is that some problems and difficulties that might occur come to the surface when implement a standard on a small amount of river locks. When its implemented on a large scale this small hazards might be neglected.

The reason for the elements of gates, lock head and movement equipment is based on the interaction between these elements. As could be read in chapter 6, these three elements are connected and depending on each other. The more logical reasoning, which is partly the same, comes from the pragmatic view. If you standardize the gates, the suspension will be standardized, and so is a part of the lock head, and the mechanics, etc. The third reason is the fact that all river locks will be standardized, or some of them based on the scenarios explained in the next paragraph, and in that case the gates, lock heads and mechanics are more likely to be transformed than the other elements that are investigated in chapter 7.

To answer the main questions of this case study one has chosen to first elaborate the corridor that is used for this analysis. After this information and plans of the region that is pointed out for this research, the river locks are investigated by the parameters. This investigation gives a clear view on the different river lock complexes. By adding different scenarios to the replacement, in forms of finance, this case study will point out decisions and dilemma’s that has to be taken.

9.1 Corridor 3/Schelde Area

For this case study one has chosen to select corridor 3, also called the Schelde Area. The selection of this corridor is based on table [1] from the introduction. This table presents the functional and technical year of replacement of the river locks, of which can be concluded that 4 out of 4 river locks from corridor 3 should be replaced in the period till 2040. Another reason for these river locks is the fact that all of them have the same CEMT-class and therefore quite the same measures. In the light of maintenance and construction costs this could be of importance, based on the idea that economic of scale is only of influence when the elements are the same.

The last motivation for this corridor comes from an additional research, which is called LIVRA. This pilot concentrates on the division of ships in the locks, for these 4 river lock complexes. Based on the available date from BICS, IVS90, AIS and MIS-Cobiva, expectations are made on the capacity and availability of the lock complexes. The ultimate goal for this research is to optimize the planning process of lock division in which the skipper can schedule his journey to run efficiently. When this computer model works, the idea of standardized elements in the complexes could help to optimize the maintenance and predictability.

When we take a closer look at the Schelde area, see figure [29] on the next page, it can be noticed that this area contains more than the 4 river locks from table [1]. In fact there are 13 river locks. The most part of this 13 river locks that are of economic importance are situated on Belgium ground. As an answer to the main question of this case study it can be concluded that if it is decided to standardize the river locks of corridor 3, than the political borders will temper the positive effects of economic growth by an increased availability due to the limitations. With the assumption that the Belgium river locks are behind, in the field of capacity and availability, these locks can be seen as the weakest link. Were the river locks on Dutch soil are optimized for the availability it does not mean that the regional economy will benefit from this measurements. When this is zoomed out further, as noticed in chapter 4, the Schelde Area is part of a major TransEuropean corridor, with all positive and negative incidentals. Because of the scope of this research, and the fact that RWS is interested on the national implementation the focus is only on the Dutch river locks.

Figure 29: Map of the Schelde Area[81] ● = River Locks

9.2 River locks of Corridor 3

For the river locks of corridor 3 it can be determined when they need to be replaced, on the technical or functional reasoning. This is done as in chapter 1 is described by the Kooman spreadsheet and data from DISK, the technical database of RWS. In this model the following parameters are necessary to calculate the year of replacement:

- Year of build
- Condition
- Measures of the locks
- Number of locks
- Opening and operational data per week
- Operational time per usage
- Traffic offering at the lock: random of clustered
- CEMT-classes

[81] *ECORYS Nederland BV (2009); Capaciteitsanalyse binnenvaart Scheldegebied*

Volkeraksluizen

The Volkerak lock complex contains 3 locks for the commercial shipping, with fall height of 0,6 meters, see figure [30]. The average amount of passages is 111.819 per year. The locks of the Volkerak complex all contain miter gates and are operated on side by 168 hours a week. The average passage time that is used for the calculation is 52 minutes. This passage time is a combination of 37 min. waiting time, average levelling time of the locks and the amount of minutes that are needed to leave to lock.

In the tables [24] and [25] the specifications that are needed to calculate the I/C-ratio are listed. From these tables it can be seen that there will be an enormous waiting time, or in some cases a total congestion of the complex.[82]

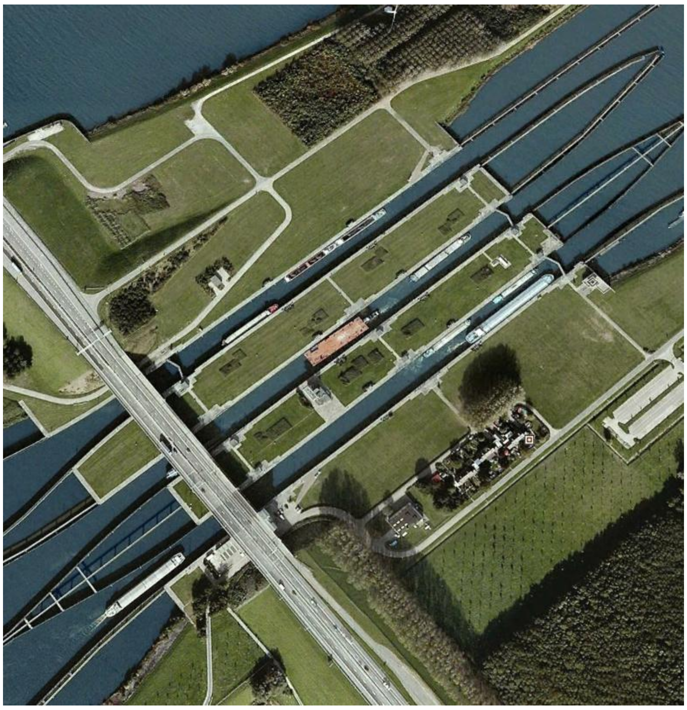


Figure 30: Volkerak lock complex[83]

	2007	GE 2020	TM 2020	SE 2020	RC 2020	GE 2040	TM 2040	SE 2040	RC 2040
I/C –ratio	0.62	0.73	0.68	0.63		1.04	0.79	0.65	0.47
Yearly Growth		1.9%	1.4%	0.8%		2.0%	1.0%	0.4%	-0.4%
Average Passage	52	75	62	52		n.b.	92	56	30
Average Waiting time	37	60	47	37		n.b.	77	41	15

Table 24: Scenarios for the Volkerak complex

	Year	Width	Length	Height	Technical	Functional
East	1967	24,1	329	7,05	2064	2020
Middle	1967	24,1	329	7,05	2064	2020
West	1977	24,1	331,5	7,05	2074	2020

Table 25: Specifications of the Volkerak complex

[82] *RWS (2012); MIRT-verkenning capaciteitsuitbreiding Volkeraksluizen*
[83] *Google Maps*

Kreekraksluizen

The Kreekrak lock complex contains 2 locks for the commercial shipping, with fall height of 2,0 meters, see figure [31]. The average amount of passages is 69.374 per year. The locks of the Kreekrak complex all contain lifting gates and are operated on side by 168 hours a week. The average passage time that is used for the calculation is 58 minutes. This passage time is a combination of 42 min. waiting time, average levelling time of the locks and the amount of minutes that are needed to leave to lock.

In the tables [26] and [27] the specifications that are needed to calculate the I/C-ratio are listed. From these tables it can be seen that there will be an enormous waiting time, or in some cases a total congestion of the complex.

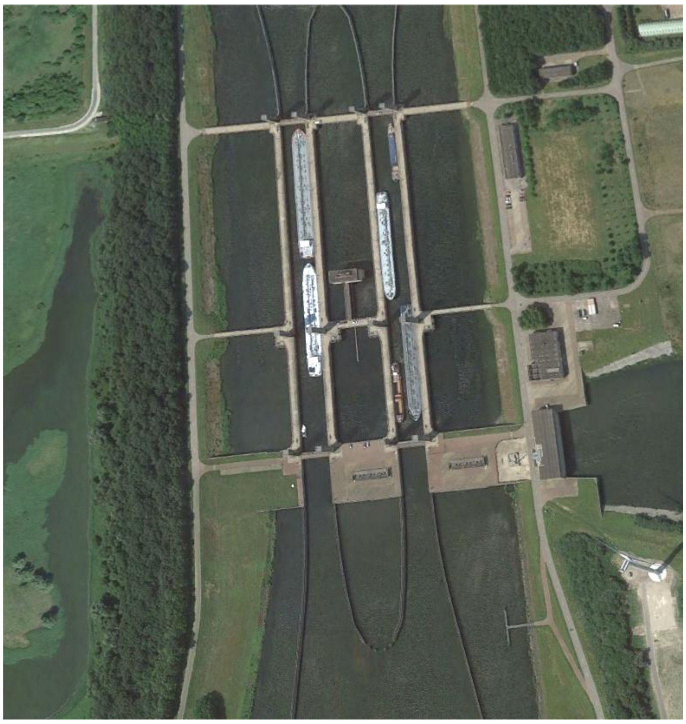


Figure 31: Kreekrak lock complex[84]

	2007	GE 2020	TM 2020	SE 2020	RC 2020	GE 2040	TM 2040	SE 2040	RC 2040
I/C –ratio	0.61	0.75	0.70	0.65		1.10	0.83	0.69	0.49
Yearly growth		2.2%	1.6%	1.0%		2.2%	1.1%	0.6%	-0.3%
Average Passage	58	89	73	63		n.b.	129	71	38
Average Waiting time	42	73	57	47		n.b.	113	55	22

Table 26: Scenarios for the Kreekrak complex

	Year	Width	Length	Height	Technical	Functional
East	1975	24,0	320	6,75	2069	2020
West	1975	24,0	320	6,75	2069	2020

Table 27: Specifications of the Kreekrak complex

[84] *Google Maps*

Sluis Hansweert

The Hansweert lock complex contains 2 locks for the commercial shipping, with fall height of 0,75 meters, see figure [32]. The average amount of passages is 51.862 per year. The locks of the Hansweert complex all contain roller gates and are operated on side by 168 hours a week. The average passage time that is used for the calculation is 36 minutes. This passage time is a combination of 17 min. waiting time, average levelling time of the locks and the amount of minutes that are needed to leave to lock.

In the tables [28] and [29] the specifications that are needed to calculate the I/C-ratio are listed. From these tables it can be seen that there will be an enormous waiting time, or in some cases a total congestion of the complex.

Figure 32: Hansweert lock complex[85]

	2007	GE 2020	TM 2020	SE 2020	RC 2020	GE 2040	TM 2040	SE 2040	RC 2040
I/C –ratio	0.38	0.42				0.54	0.43	0.34	0.26
Yearly Growth		1.5%				1.5%	0.7%	-0.1%	-0.6%
Average Passage	36	40				55	40	35	34
Average Waiting time	17	21				36	21	16	15

Table 28: Scenarios for the Hansweert complex

	Year	Width	Length	Height	Technical	Functional
East	1988	24,0	314	6,75	2088	2040
West	1988	24,0	314	6,75	2088	2040

Table 29: Specifications of the Hansweert complex

[85] *Google Maps*

Krammersluizen

The Krammer lock complex contains 2 locks for the commercial shipping, with fall height of -1,5 and +2,0 meters, see figure [33]. The average amount of passages is 97.296 per year. The locks of the Hansweert complex all contain roller gates and are operated on side by 168 hours a week. The average passage time that is used for the calculation is 79 minutes. This passage time is a combination of 45 min. waiting time, average levelling time of the locks and the amount of minutes that are needed to leave to lock.

In the tables [30] and [31] the specifications that are needed to calculate the I/C-ratio are listed. From these tables it can be seen that there will be an enormous waiting time, or in some cases a total congestion of the complex.

Figure 33: Krammer lock complex[86]

	2007	GE 2020	TM 2020	SE 2020	RC 2020	GE 2040	TM 2040	SE 2040	RC 2040
I/C –ratio	0.49	0.53	0.50	0.46	0.41	0.70	0.56	0.44	0.34
Yearly Growth		1.4%	0.9%	0.4%	-0.7%	1.5%	0.7%	-0.1%	-0.6%
Average Passage	79	84	79	75	67	112	87	72	65
Average Waiting time	45	50	45	41	33	78	53	38	31

Table 30: Scenarios for the Krammer complex

	Year	Width	Length	Height	Technical	Functional
North	1987	24,0	320,0	6,5	2087	2028
South	1987	24,0	320,0	6,5	2087	2028

Table 31: Specifications of the Krammer complex

[86] *Google Maps*

Summary of Data

The characteristics of the locks that are listed in the previous chapter are inserted in the model to determine the I/C-ratio of these river lock complexes. In figure [34] the outcome of the Kooman spreadsheet is shown, by a histogram with different I/C-ratios for the years 2008, 2020 and 2040. This figure only presents the Dutch river locks that are part of the Schelde Area.

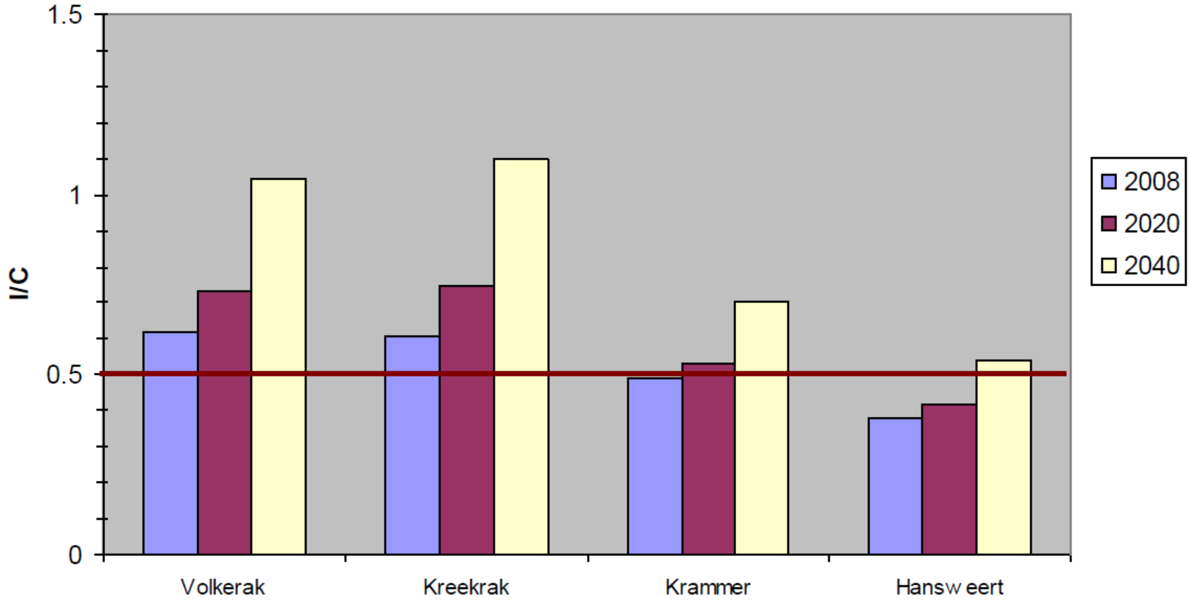


Figure 34: I/C-ratio river locks of Schelde Area[87]

As a summary of the previous data about the river lock complexes in corridor 3 the following table can be derived. Next to this data also the desired number[88] [89] of river locks to overcome all the congestion can be seen. The last two columns op this tables shows the costs for adding a new lock to the complex and the transformation of one river lock to the standard, which are both indicative. The total costs for a new lock is based on the MIRT exploration of the Volkerak lock complex. The transformation costs are the sum of demolishing and construction of these elements, with in mind the current situation. As noticed the numbers for the extension are all the same because of the missing data. This table is the starting point of the analysis.

	Technical	Functional	Present Number	Desired Number	Costs River Lock	Transformation costs (mitter)	Transformation costs (roller)
Volkerak	2064	2020	3	4	€ 154 mln	€ 25 mln	€ 80 mln
Kreekrak	2069	2020	2	3	€ 154 mln	€ 60 mln	€ 60 mln
Hansweert	2088	2040	2	3	€ 154 mln	€ 80 mln	€ 25 mln
Krammer	2087	2028	2	3	€ 154 mln	€ 80 mln	€ 25 mln

Table 32: Summary of the Schelde Area River Locks

[87] *RWS (2011); Deelrapportage Vaarwegen voor de NMCA*
[88] *ECORYS Nederland BV (2009); Capaciteitsanalyse binnenvaart Scheldegebied*
[89] *This desired number of locks in the complexes is also mentioned by Deltares*

9.3 Life Cycle Approach

As stated in the first paragraph one of the most urgent question, and the one that is quantified for this case study, is the moment a river lock complex should be transformed to a standardized object. Besides this question it is even more relevant if a river lock should be transformed and how many of the locks. Besides the LCC component of this replacement, it will also have influence on the predictability and availability. These last two effects of standardization are not taken into account for this case study because of the insufficient data.

Looking at the costs for a new river lock it can be concluded that it doesn't matter because for this case study these are all the same, this assumption is made in order to make no distinction between the lock complexes. Only when there isn't standardization in the river lock complex the costs for a new lock are higher. In all other cases the costs are multiplied by 0,92, based on the financial benefit that is calculated in chapter 7.

The transformation however is of importance because one has chosen to develop a standard with miter or roller gates. This means that all the locks that have different gates should be transformed. The cost for this transformation is different, based on the current construction, but is not distinctive. However the timing and amount of river locks that will be transformed into a standardized river lock can make a huge difference. To determine what will happen to the Life Cycle Costs of the 4 complexes one has distinguished 5 different scenarios:

1. No standardization

At first is there the zero scenario, where everything is the same in the future as it is nowadays. As the name already describes there is no standardization or what so ever in the complexes. The regular river locks are only subjected to annual maintenance and high maintenance, according to the year of built. The reason for this scenario is to see what the standardization is worth, compared with what we are used to do.

	Annual Maintenance	Construction river lock	Transformation	High Maintenance
Volkerak	€ 1,76 mln	2020: € 154 mln	X	2020 / 2045
Kreekrak	€ 1,31 mln	2020: € 154 mln	X	2025 / 2050
Hansweert	€ 0,85 mln / € 1,31 mln	2040: € 154 mln	X	2038 / 2063
Krammer	€ 0,85 mln / € 1,31 mln	2028: € 154 mln	X	2037 / 2062

2. Standardize when needed

In this second scenario the river lock complexes will be transformed to the standard if they are subjected to high maintenance. This includes the new and old river locks, based on the technical and functional end of life. As elaborated in the introduction this includes only the gates, lock head and mechanics. The annual maintenance of the complexes will differ when other complexes are also transformed with the standardized elements. This is based on the assumption that the amount of river locks will contribute to the benefits of the standard, in other words the costs for maintenance. In the table below it can be seen that the costs for maintenance will decrease from a certain amount. For example the

Kreekrak complex will be first € 1,24 per year but when they are transformed it is € 1,13 per year. When the other complexes are transformed it is € 1,07 per year.

	Annual Maintenance	Construction river lock	Transformation	High Maintenance
Volkerak	€ 1,56 mln	2020: € 141,68 mln	2025: € 75 mln	2020 / 2045
Kreekrak	€ 1,24 mln / € 1,13 mln ➔ € 1,07 mln	2020: € 141,68 mln	2025: € 120 mln	2025 / 2050
Hansweert	€ 0,85 mln / € 1,07 mln	2040: € 141,68 mln	2038: € 160 mln	2038 / 2063
Krammer	€ 0,85 mln / € 1,23 mln ➔ € 1,07 mln	2028: € 141,68 mln	2037: € 160 mln	2037 / 2062

3. Standardize everything at point 0

The third scenario is clear, from day 1 all the locks in the 4 complexes are extended and transformed into the standard. This is the scenario as it is analysed in the first case study. No exceptions based on dimensions or previous building methods, all the river locks will have the same gates, lock heads and mechanics.

	Annual Maintenance	Construction river lock	Transformation	High Maintenance
Volkerak	€ 1,42 mln	2020: € 141,68 mln	2020: € 75 mln	2020 / 2045
Kreekrak	€ 1,07 mln	2020: € 141,68 mln	2020: € 120 mln	2020 / 2045
Hansweert	€ 1,07 mln	2020: € 141,68 mln	2020: € 160 mln	2020 / 2045
Krammer	€ 1,07 mln	2020: € 141,68 mln	2020: € 160 mln	2020 / 2045

4. Standardize at point 0 and 10

A differentiation on the third scenario is the distribution of the execution. By taking 2 moments, at day 1 and after 10 years, the costs are spread out and the hinder during the construction is separated. Therefore this option is more likely to be realized. The reason for the 10 years is based on the year of built of the Hansweert en Krammer complexes.

	Annual Maintenance	Construction river lock	Transformation	High Maintenance
Volkerak	€ 1,51 mln / € 1,42 mln	2020: € 141,68 mln	2020: € 75 mln	2020 / 2045
Kreekrak	€ 1,13 mln / € 1,07 mln	2020: € 141,68 mln	2020: € 120 mln	2020 / 2045
Hansweert	€ 0,85 mln / € 1,07 mln	2030: € 141,68 mln	2030: € 160 mln	2030 / 2055
Krammer	€ 0,85 mln / € 1,07 mln	2030: € 141,68 mln	2020: € 160 mln	2030 / 2055

5. Only standardize new river locks

The last scenario will only standardize the new river locks. By this approach there will be no extra costs for the transformation and have benefits of the standard. The moment of construction is based on the functional end of life.

	Annual Maintenance	Construction river lock	Transformation	High Maintenance
Volkerak	€ 1,76 mln ➔ € 1,73 mln	2020: € 141,68 mln	X	2020 / 2045
Kreekrak	€ 1,30 mln ➔ € 1,27 mln	2020: € 141,68 mln	X	2025 / 2050
Hansweert	€ 0,85 mln / € 1,27 mln	2040: € 141,68 mln	X	2038 / 2063
Krammer	€ 0,85 mln / € 1,28 mln ➔ € 1,27 mln	2030: € 141,68 mln	X	2037 / 2062

9.4 Conclusion and discussion

As a result of the tables from previous chapter a figure can be presented which indicates the life cycle costs for the next 50 years. For the calculation of this LCC one has chosen to use a discount rate of 2,5%, which is the same for the calculation made in chapter 7. The reason for this number is the fact that for governmental projects the minister of Finance has set this discount rate. According to the literature there is no reason to doubt this measure, but to determine the sensitivity of this assumption also a discount rate of 2% and 5% is chosen. The outcome of this analysis pointed out that the mutual differences remain proportionate.

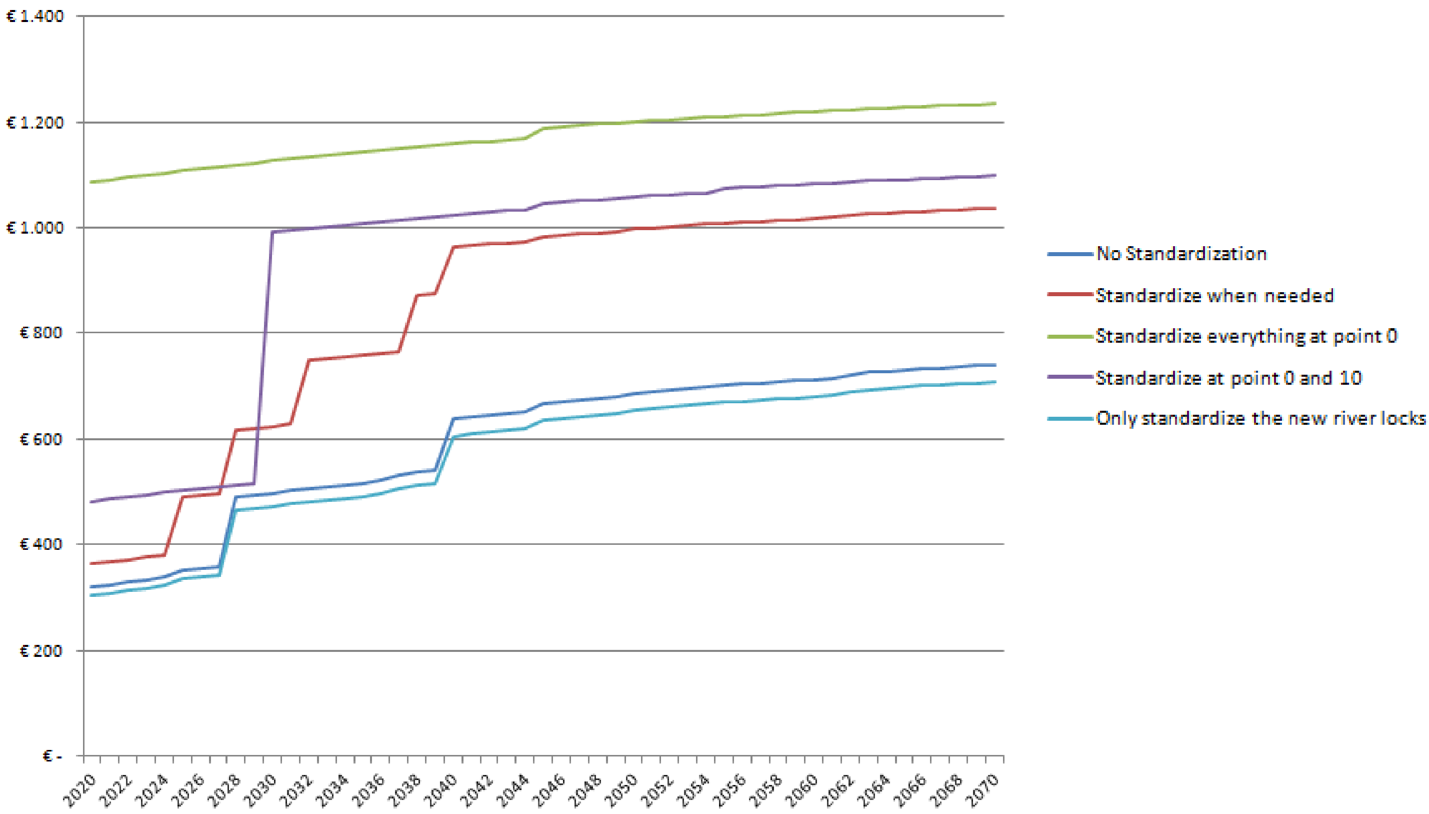


Figure 35: Life Cycle Costs for 5 scenarios with miter gates

As mentioned in the previous paragraph not only the LCC of miter gates are calculated. For the implementation of the roller gates as the standard, including the lock heads and mechanics, an analysis is made. In order to not copy past all the data and scenarios that are used to determine the LCC it can be said that the difference lies in the transformation costs. Hence as a conclusion for the standardization of roller gates instead of miter gates the following figure can be presented.

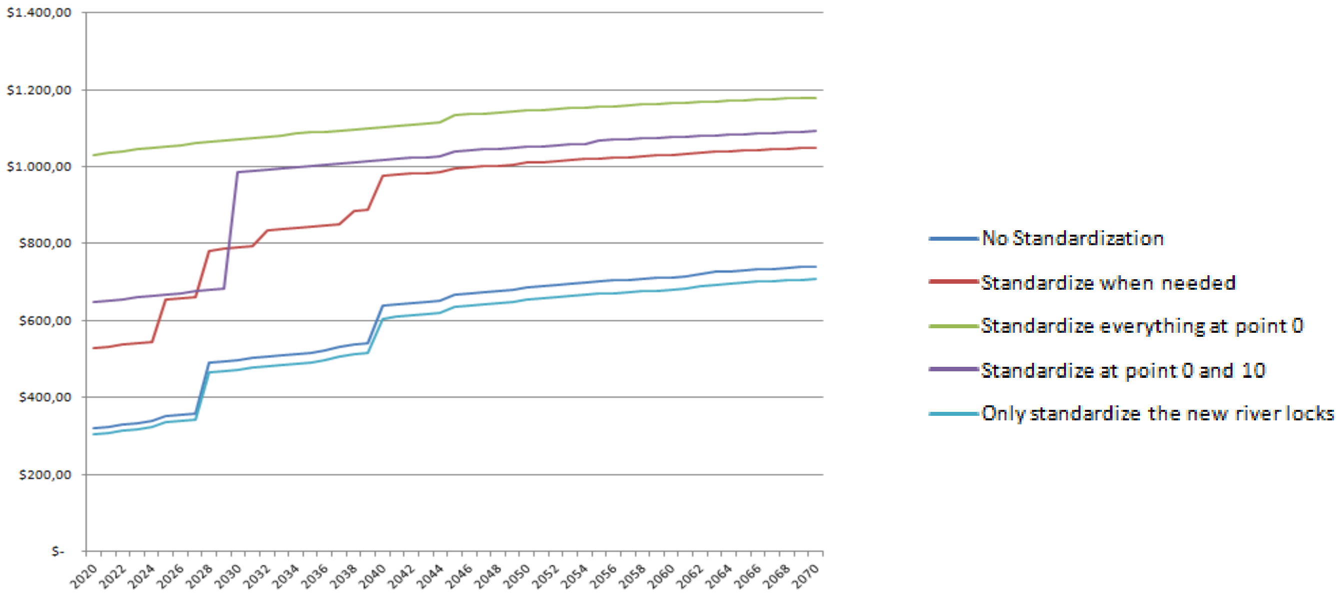


Figure 36: Life Cycle Costs for 5 scenarios with roller gates

Based on what we know it can be concluded that there is a huge difference between the different scenarios of timing. As a result of this, the possibility to standardize everything from today, even the locks that are not at the end of life is not preferable. In fact all the scenarios that are involved the transformation to a standardized river lock does not score very well, compared to the other options. It can be concluded from this point of view that reduction of maintenance costs does not outweigh the costs of transformation, even over the time span of 50 years.

This means that only the standardization of new river locks is financially attractive. However, the amount of new river locks is heavily depending on the need for expansion. In the summary of the river lock complexes from corridor 3 it is stated that the desired number of locks are all plus 1. According to this data only 4 river locks in the whole corridor will have the same gates, lock heads and mechanics. It can be seen in the following table that the difference between no standardization and the standardization of new locks does not differ very much.

	Life Cycle Costs over 50 years (miter)	Life Cycle Costs over 50 years (roller)
No standardization	€ 740.070.000	€ 740.070.000
Standardize when needed	€ 1.037.080.000	€ 1.049.760.000
Standardize everything at point 0	€ 1.235.000.000	€ 1.180.000.000
Standardize at point 0 and 10	€ 1.098.750.000	€ 1.091.890.000
Only standardize the new river locks	€ 707.560.000	€ 707.560.000

The positive effects from chapter 3 says that the predictability and availability will increase by this standardization, but what is the effect when only 4 of them will be standard. Based on the available literature, the effect of increasing availability is negligible because all the complexes does still have other designs that are not standardized. This does not mean that the predictability of the maintenance costs and availability will also be negligible. This effect might outweigh the long process of engineering the perfect standard, and the relative low financial benefits.

As a result of this outcome and multiple conversations with experts in the field of river locks the problem still lies in the approach. The design of the standard has to fulfil all the needs of multiple locks. This sounds logical but when this will be implemented for all the river locks, the costs that comes within are way larger than the maintenance. By adding the quality in the form of predictability and availability it is just a feeling that it is worth to standardize, but the business case shows different.

To encounter the low financial benefits from standardization in this corridor there are some possible options, which are calculated on the same basis as the LCC. One of the options is to enlarge the amount of river locks for maintenance. As a result on the I/C-ratio calculations of the nearby river locks in Belgium there are 2 complexes that should also be extended to cover the growing demand, namely the Zennegat and Wijnegem complexes. When these river locks are engineered in the same way by the standard that is developed for the 4 river locks of this case study the following LCC can be presented. These costs are only for the 4 complexes on the Dutch soil.

	Life Cycle Costs over 50 years (Dutch)	Life Cycle Costs over 50 years (With Belgium)
No standardization	€ 740.070.000	€ 740.070.000
Standardize when needed	€ 1.049.760.000	€ 1.045.050.000
Standardize everything at point 0	€ 1.180.000.000	€ 1.175.100.000
Standardize at point 0 and 10	€ 1.091.890.000	€ 1.087.110.000
Only standardize the new river locks	€ 707.560.000	€ 705.990.000

In this idea of combining the Dutch and Belgian does not turn out to be very beneficial. Even with the possibility to benefit from the maintenance and not have the costs for implementation the differences are very small. Based on this it can be concluded that indeed the financial benefits of standardized maintenance are relatively small against the construction costs.

Based on this conclusion it is an option to search for other methods to reduce the total life cycle costs of the river lock complexes. One of the first things that sounds logic is the ability to transform only some of the locks, and not extend all of them. When looking at the Schelde Area 2 of the 4 complexes have the potential to be only transformed, with in mind that this will cause financial benefits, and on their term does not have a negative economic effect. By these 2 it is meant the Krammer en Hansweert complex. This is because of the main Schelde – Rijn route from Rotterdam to Antwerp, which goes through the Volkerak and Kreekrak complexes. The second reason is the fact that Hansweert does not necessarily be a problem and at last that the Krammer complex can deal with the congestion if the fresh-salt separation stops.

	Life Cycle Costs over 50 years (Extension of 4)	Life Cycle Costs over 50 years (Extension of 2)
No standardization	€ 740.070.000	€ 519.690.000
Standardize when needed	€ 1.049.760.000	€ 847.020.000
Standardize everything at point 0	€ 1.180.000.000	€ 896.640.000
Standardize at point 0 and 10	€ 1.091.890.000	€ 870.530.000
Only standardize the new river locks	€ 707.560.000	€ 504.820.000

Another method to reduce the construction costs a (for now) not existing idea is researched. In this case the construction costs of the river locks are 50% of the original costs. This for now futuristic idea came forth out of the contact with experts from Lievense, RWS, Arcadis and co students. By this thought is possible that due to the invention of 3D-printers the costs of constructions will rapidly fall. By the development of usage it is thinkable that the gates will be replaced by this light and strong material. In that case the construction costs will be lower, for the extension and transformation. In the table below the 5 scenarios are listed with in mind this idea.

	Life Cycle Costs over 50 years (Normal)	Life Cycle Costs over 50 years (With 3D-printer)
No standardization	€ 740.070.000	€ 475.880.000
Standardize when needed	€ 1.049.760.000	€ 599.060.000
Standardize everything at point 0	€ 1.180.000.000	€ 666.640.000
Standardize at point 0 and 10	€ 1.091.890.000	€ 620.470.000
Only standardize the new river locks	€ 707.560.000	€ 464.510.000

As the answer to the main question of this case study: "What if?" it can be said that the implementation has to encounter a lot of difficulties. Not only the method and timing of the implementation is of importance to optimize the process. Besides these financial considerations the broader picture can also play a huge part. By this one has to think of European, national and regional development. Also the research to new possibilities in the light of materials, central control system and numerical models that can calculate and regulate the lock divisions can change the way in which the standard should be implemented.

All together will standardization of the gates, lock heads and mechanics be financial advantageous in corridor 3 if, and only if the standards will be used in new river locks, based on the assumptions and models used in this case study. The usage of new technologies and changing demands from the market will adjust the situation and hence the approach that has to be used in order to create the most positive effects.

10. Conclusion and Recommendations

The conclusion of this study is presented by the structure that is used in this report. One has chosen to do so because of the fact that the determination of the most desirable element cannot be concluded by a single answer. The main question as stated in the introduction is:

"Which elements of a river lock are most suitable for standardization by the replacements of river locks in the Netherlands, based on the balance between financial/economic benefits and competition benefits?"

The conclusion that is made on the basis of the introduction, is that RWS as the main supervisor of all main inland waterways is searching for more reliability and predictability of the availability and costs. By this research to the most suitable element of a river lock it can be concluded that the predictability of the availability and costs will improve when an element or multiple elements are standardized. This comes forth when one studies the effects on all the levels of standardization.

As a conclusion to the literature study on this topic, the variation of standards is enormous, and the corresponding effects even more. In all sort of daily life habits we are confronted with standards, all with their own purpose en needs. This is also the case when one looks at the river locks. Not only the technical and functional aspects can be standardized, the procedures and strategy could also be part of it. And this is not all, the level of implementation has to be set and the effects can be disadvantageous for certain parties. Hence, the implementation of a standard can be war by combining all these outcomes and interests of the involved parties.

Therefore for this research, one has decided to set a framework of standardization types, possible effects on the life cycle phases and the level of implementation. As a conclusion for this approach it is a good start for providing insight in the outcome of a standard. Not only this selection of framework is of importance by answering the main question. Also the selection of elements out of the total database is necessary to create a clear investigation. By this filter is does not only answered some questions whether or a not an element is most desirable, it can be concluded from this massive database that the differences between the river locks are huge, and not only on the dimensions.

The results of this research show a comparison between the selected elements of a river lock. Based on this scale it can be concluded that the mechanical part of a river lock is most desirable for standardization, compared to the other selected elements on the conservational level. The movement equipment showed a major benefit on the decrease of the maintenance costs, which comes forth out of the learning curve that comes with the execution of fixed, and variable maintenance.

Based on this outcome of the analysis and the above-mentioned results one can state that the hypothesis: "Elements with a high ratio of maintenance vs. construction costs are more desirable for standardization" can be assumed. This conclusion is in line with the expected positive and negative effects of standardization for the elements in a river lock, were the construction costs do not make a difference but the maintenance does.

As a conclusion of the case study it can be presented that for the gates that the positive effects of variety reduction and learning curve offset the negative effect of over dimension. The results shows a slightly positive decrease of the total cost, by 0,3%. This means that the costs for purchase of this particular element is not rising nor falling by the standard. By this it must be noticed that all the benefits of variety reduction and learning curve might therefore be beneficial in the next phases of the life cycle.

However the second case study shows that the approach of implementing the standard on all river lock complexes is not financial beneficial, because of the transformation costs that are involved when the total areaal of RWS has to implement the standard. Based on this case study it can be concluded that it is only financial advantageous to engineer and construct new river locks by the standard.

All together, based on the literature and case study, is that standardization as a means to reduce the costs will not be very effective. Taking in consideration that the construction costs are a much larger part of the total life cycle costs than the maintenance, the expected financial benefits will be small or maybe negligible.

However when standardization is used as a means to improve the predictability and availability of the main waterways it is a useful tool. Based on the fact that it does not have a negative effect on the financial cost-benefit analysis, it can be assumed that the positive effects of development and implementation of a standard for the replacement of river locks can be advantageous for the economy. At last but not least it is advantageous for the ease of asset management by the operation and maintenance, which is the instigator for this research.

Recommendations

- In this research one has decided to investigate certain standards, which are set by RWS as the main supervisor of the river locks. When a institution like RWS will implement a standard they're the leader in this process, and are therefore subject to all sort of different interests and powers of stakeholders. By giving this process to the market, an engineering company, in combination with construction companies can set the standard, whether or not this is a nationwide standard. This can create a *de* facto standard that is supported by the market and not set by the government. Hence, the market benefits from the standard without comprising between different parties.

- The assumption of the amount of river locks that has to be replaced in the near future is based on a model that includes the functional and technical approach. These two parameters are useful as a starting point but does not cover the whole initial question: "Why do these river locks had to be replaced?". The usefulness and necessity of the replacement is partly described by these two approaches, respectively the technical end of life and the functional scenarios. What is missing is the reasoning for each individual river lock, with the extension of which part has to be replaced, regional usefulness and necessity of the river lock itself.

- In addition to the previous recommendation the master plan of the replacement cannot be written as a static process towards the future. It is recommended that this plan is adaptively for all possible scenarios, like the new Delta program[90], which includes possibilities to adapt, based on future predictions and current events. These scenarios can be domestic but in my opinion the international developments are more of importance due to the inter dependency between countries. Hence, the question why the river locks has to be replaced forms the foundation for this plan.

- The categorization of the river locks in the Netherlands has to be different than it is used nowadays. The tipping point between standardization and competition depends on this division, and should therefore be optimized. Therefore it is recommended that the database of RWS should be supplemented with all the necessary information that is needed to make a proper categorization that fits the needs of a well-based division.

- Not only is it of importance to have a complete and accurate database of all constructions that are falls under the supervision of RWS for the estimation of categories, also the predictability and on their term the availability of a river lock. At this point not all the construction are investigated by the same method. Hence, it is recommended to have a clear view on the existing constructions before standardization of it can be started.

- Not only an element is suitable for standardization, also the lay-out could be beneficial. In this research the focus was set on a particular element, but an investigation to the lay-out of a river lock there might be other elements suitable, or even more suitable than the movement equipment. As shown in chapter 6, the differences between the river locks are enormous, based on the used elements. On this basis it's recommended that besides the investigation to the standardization of elements it, the use of elements could be investigated.

- The last recommendation might seem far-fetched but as we follow the trends of the last couple years, it can be noticed that the European Union is becoming closer. The borders are vanished and the monetary founds are placed under one commission. By this statement it is meant that a developed standard today could be of no importance by tomorrow. Therefore my last recommendation is that RWS cooperates with the surrounding countries in developing an international standard. In Germany they are also developing standards for river locks, by combining the best of both worlds a standard can be set that fits for both countries and has higher real benefit.

[90] *MinIenM (2011); Deltawet waterveiligheid en zoetwatervoorziening*

Reflection

At the end of this thesis a reflection about the most crucial points are elaborated. In nearly all chapters of this research a discussion paragraph was already inserted to show different opinions and statements regarding the choices and models that are made or used. In this last part of my research to the most suitable element and the financial trade-offs, these discussion parts are summarized. Next to that a reflection stated about the total research, which describes what should be different on what we know now. This last part will help future researchers on this topic.

The first topic is about the research question of this master thesis. From day one till the end the question changed only on words but not in content. Even though new insights were found and comments from my committee were valid on this point, it stayed the same. The reason for this was my drive and enthusiasm to find the so-called core of a river lock, that forms the heart of all new locks that will be build today and in the future. When looking back at this process multiple adjustment could or should be made.

One of these options is to reverse the question by asking which element is not suitable for standardization, based on different effects. Another is to investigate the need, whether or not this goal can be reached by standardization of elements. All these questions will clearly be interesting for further research but without my initial question those insights were not come to surface.

As a follow-up to this discussion is the filter that is used to excludes a lot of elements out of this research. Based on the initial research question, to find the most suitable element, and the time that is available for this thesis, a global distinction has to be made. If this filter was not part of the analysis, too many elements had to be investigated on their costs, materials and maintenance. It is true that some of the elements that didn’t made the cut for further investigation, can be beneficial, but some of them had to be selected in order to compare them. Otherwise the question should be, which element is suitable for standardization.

Next point of reflection is the discussion about the level of implementation during the whole process of my research. Based on the quest of Rijkswaterstaat, and in their following VONK and MWW, the need is to find a solution for the increasing variety of elements with a similar function. Their task is to do this on a national level and so is this research. This assumption is formed by multiple conversations with RWS, operational staff and users. The counterpart of this assumption is that the differences between the locks is huge and it cannot be applied by a single measure. However, to determine the most suitable element it is wise to take an abstract view on the situation, with a large amount of constructions, rather investigate on CEMT-level or corridor. Because when the argument is put through, you might end up by a single lock in a complex. By then the fact that implementation of a standard comes forth out of the quest to find the heart of a lock, which implies of all locks in the Netherlands, is no longer in the picture.

This discussion of implementation has a strong connection with the level of decomposition that is used. In this research the so-called conservation level of RWS is investigated, which indicates sections of a lock. Some say it is better to go deeper because the benefits might be there and the differences between the locks are too strong. While for this research it is chosen to take the abstract level, whether or not these elements or sections could fit into all different locks. The reason for this is again to find the most suitable part and not if this would work.

The last subject for this reflection are the models and data that is used. To determine the most suitable element for this research, they had to be compared on the advantages and disadvantages of standardization, both the financial and economic values. Unfortunately not all of the effects could be quantified, because of the origin of the effect, lack of data and/or the importance of the effect. All these arguments played a part by selecting the effects that were taken into account. Hence, more investigation could lead to a more scientifically based conclusion, but this research was not set up to calculate the effects perfectly but to give a significant outcome, in order to compare the elements.

All together, as a reflection on this research other choices could have been made based on what we know now. These choices would have changed this research and probably the outcome, but not the discussions. This circle below represents the line of reasoning for every step. Wherever you begin, the previous block gives answer to the question why. Standardization is based on the differences in specific river locks, which comes forth out of CEMT/Corridor implementation, who has on their term a basis on the Generic level, at last this idea and strategy is from the need to standardize. Therefore to investigate the elements of a lock and start somewhere, the circle had to be broken. However, based on the meetings with experts and my thesis committee, the location of this crack in this circle is doubtful.

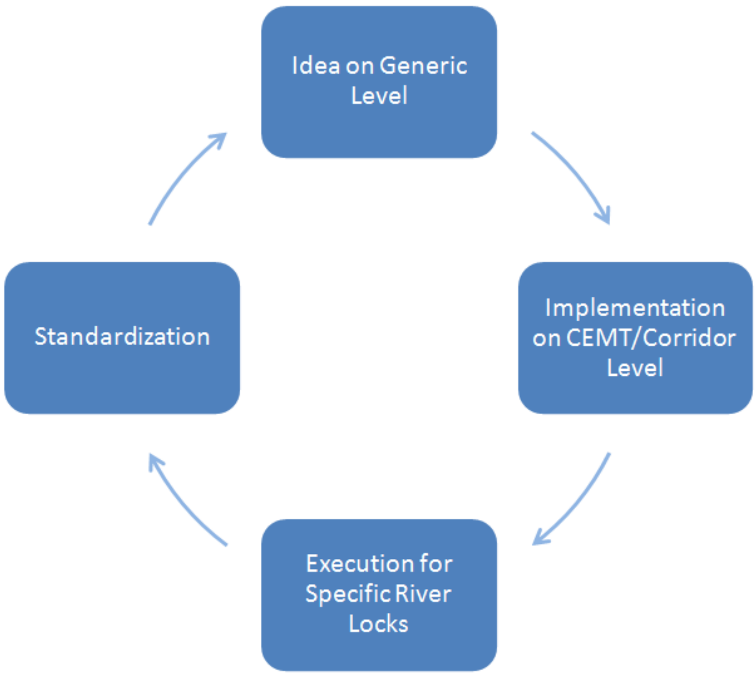


Figure 37: Circle of Standardization in River Locks

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Appendices

Appendix A: Background Information WLO Scenario's[91]

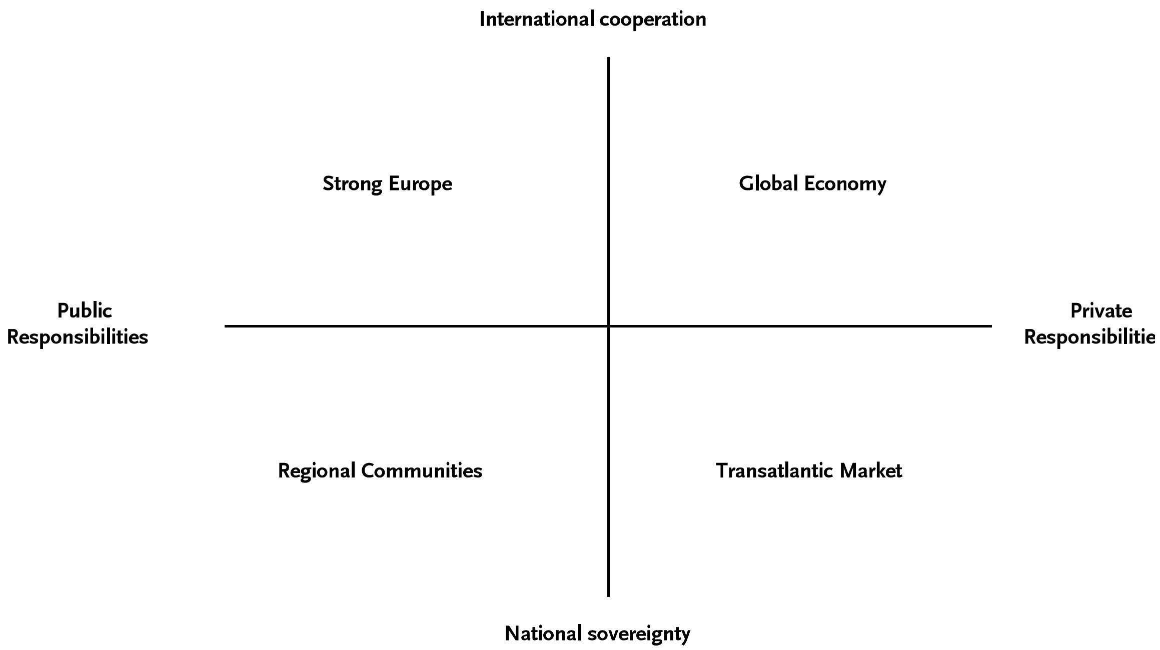

Figure 38: Four Futures of Europe

Strong Europe

European countries maintain social cohesion through public institutions. As a result, society accepts that the more equitable distribution of welfare limits the possibilities to improve economic efficiency. Yet, governments respond to the growing pressure on the public sector by undertaking selective reforms in the labor market, in social security, and in public production. Combined with early measures to accommodate the effects of ageing, these policies help to maintain a stable and growing economy. In the European Union, member states learn from each other's experience, which creates a process of convergence of institutions within Europe.

Reform of the process of EU decision-making lays the foundation for a successful, strong European Union. The enlargement is a success, and integration advances—geographically, economically and politically. European leadership is important for achieving broad international cooperation, not only in the area of trade but also in other areas like climate change.

Regional Communities

European countries rely on collective arrangements to maintain an equal distribution of welfare. At the same time, governments are unsuccessful at modernizing welfare-state arrangements. A strong lobby of vested interests blocks reforms in various areas. Together with an expanding public sector, this situation puts a severe strain on European economies.

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[91] *Lejour, A. (2003); Quantifying four scenarios for Europe*

The European Union cannot adequately cope with the Eastern enlargement and fails to reform its institutions. As an alternative, a core of rich European countries emerges. Cooperation in this sub-group of relatively homogeneous member states gains a more permanent character. The world is fragmented into a number of trade blocks, and multilateral cooperation is modest.

Global Economy

European countries find a new balance between private and public responsibilities. Increasing preferences of people for flexibility and diversity, and growing pressure on public sectors, give rise to reforms. New institutions are based on private initiatives and market-based solutions. European governments concentrate on their core tasks, such as the provision of pure public goods and the protection of property rights. They engage less in income redistribution and public insurance, so that income inequality grows.

International developments also reflect increasing preferences for diversity and efficiency. Political integration is not feasible, as governments assign a high value to their national sovereignty in many areas. Moreover, policy competition becomes standard in many policy areas. Economic integration, however, becomes broader (not always deeper), as countries find it in their mutual interest to remove barriers to trade, investment and migration. With a limited amount of competences and a focus on the functioning of the internal market, the European Union finds it relatively easy to enlarge further eastwards. Similarly, negotiations in the WTO are successfully completed. Regional and global integration puts poor countries on a path of catching-up and high growth. As international cooperation in non-trade issues fails, the problem of climate change intensifies, while European taxes on capital income gradually decline under tax competition.

Transatlantic Market

European countries limit the role of the state and rely more on market exchange. This boosts technology-driven growth and increases inequality. The inheritance of a large public sector in EU countries is not easily dissolved. New markets—e.g. for education and social insurances— lack transparency and competition, which brings about new social and economic problems. The interests of the elderly dominate policy decisions, which makes it difficult to dismantle the pay- as-you-go pension systems in continental Europe. Government failures thus compound to market failures.

EU member states focus primarily on national interests. EU decision-making is not reformed, which complicates further integration in the European Union. The EU redirects its attention to the United States, and agrees upon transatlantic economic integration. This intensifies trade in services, which yields welfare gains on both sides of the Atlantic. The prosperity of the club of rich countries is in sharp contrast with the poverty in Eastern Europe and in developing countries.

Strong Europe

Mondiale handel met voortgaand Europees milieubeleid
Voortgaande infrastructuuruitbreidingen

Inwoners 2040	18,9 miljoen
BBP/hoofd (2001 = 100)	156
Huishoudens	8,6 miljoen
Personenautobezit	9,7 miljoen

Ontwikkeling 2002-2040	
Reizigerskilometers	+30%
Goederenvervoer ton km	+40%
Congestie-uren	0%
NO_x-emissie	-70%
CO_2-emissie	+20%

Global Economy

Mondiale vrijhandel
Huidige EU milieunormen continueren
Voortgaande infrastructuuruitbreidingen

Inwoners 2040	19,7 miljoen
BBP/hoofd (2001 = 100)	221
Huishoudens	10,1 miljoen
Personenautobezit	11,8 miljoen

Ontwikkeling 2002-2040	
Reizigerskilometers	+40%
Goederenvervoer ton km	+120%
Congestie-uren	+70%
NO_x-emissie	-40%
CO_2-emissie	+70%

Regional Communities

Handelsblokken en heffingen ter bescherming van milieu
Accent op nationaal milieubeleid
Voortgaande infrastructuuruitbreidingen

Inwoners 2040	15,8 miljoen
BBP/hoofd (2001 = 100)	133
Huishoudens	7,0 miljoen
Personenautobezit	7,7 miljoen

Ontwikkeling 2002-2040	
Reizigerskilometers	+5%
Goederenvervoer ton km	-5%
Congestie-uren	-70%
NO_x-emissie	-75%
CO_2-emissie	-5%

Transatlantic Market

Handelsblokken en importheffingen ter bescherming nationale productie
Geen sterk milieubeleid
Voortgaande infrastructuuruitbreidingen

Inwoners 2040	17,1 miljoen
BBP/hoofd (2001 = 100)	195
Huishoudens	8,5 miljoen
Personenautobezit	9,5 miljoen

Ontwikkeling 2002-2040	
Reizigerskilometers	+20%
Goederenvervoer ton km	+65%
Congestie-uren	-10%
NO_x-emissie	-55%
CO_2-emissie	+35%

Figure 39: Results of the Mobility scenario[92]

[92] *CPB, MNP & RPB (2006),* Welvaart en Leefomgeving: Een scenariostudie voor Nederland in 2040, *Den Haag/ Bilthoven: Centraal Planbureau, Milieu- en Natuurplanbureau en Ruimtelijk Planbureau.*

Appendix B: List of potential bottlenecks by river locks

Groslijst sluizen voor capaciteitsanalyse		
Corridor: Route	**sluis**	**Motivatie wel of geen potentiëel knelpunt sluis**
Rotterdam-Duitsland	Rozenburg	Nee, in beheer van GHR, combinatie van binnen- en zeevaart
	Hartel	Nee, alleen operationeel in comb met stormvloedkering
Amsterdam-Rijn	Zeesluis IJmuiden	Ja, MIRT-planstudie loopt
	Beatrixsluis	Ja, MIRT-planstudie loopt
	Irenesluis	**Mogelijk knelpunt: verder analyseren**
	Marijke	Alleen operationeel bij extreme waterstanden Lek
	Bernhard	**Mogelijk knelpunt: verder analyseren**
	Amerongen (Lek)	**Mogelijk knelpunt: verder analyseren**
		3,5% v/d tijd staat stuw open en gaat scheepvaart door stuw
	Driel (Lek)	Afhankelijk van I/C bij Amerongen wel of niet I/C bepalen
		11% v/d tijd staat stuw open en gaat scheepvaart door stuw
	Hagestein (Lek)_	Afhankelijk van I/C bij Amerongen wel of niet I/C bepalen
		3,5% v/d tijd staat stuw open en gaat scheepvaart door stuw
Westerschelde-Rijn	**Volkerak**	**Mogelijk knelpunt: verder analyseren**
	Kreekrak	**Mogelijk knelpunt: verder analyseren**
	Krammer	**Mogelijk knelpunt: verder analyseren**
	Hansweert	**Mogelijk knelpunt: verder analyseren**
Westerschelde	Terneuzen	MIRT-verkenning loopt
Amsterdam - Noord-Nederland	**Oranje**	**Mogelijk knelpunt: verder analyseren**
	Houtrib	**Mogelijk knelpunt: verder analyseren**
	Prinses Margriet	**Mogelijk knelpunt: verder analyseren**
	Gaarkeuken	**Mogelijk knelpunt: verder analyseren**
	Oostersluis	**Mogelijk knelpunt: verder analyseren**
	Delfzijl	Nee, o.b.v. eerder advies DVS 2005 en recente studie provincie
	Meppelerdiep	Ja, gaat naar verwachting in 2011 in realisatie
	Krabbersgat, IJsselm	Eerder knelpunt is opgelost door bouw naviduct
	Lorentz, IJsselm	Volgens Richtlijnen Vaarwegen voldoet 1 kolk tot ongeveer
		10.000 passages beroepsvaart/jaar
	Stevin, IJsselm	Volgens Richtlijnen Vaarwegen voldoet 1 kolk tot ongeveer
		10.000 passages beroepsvaart/jaar
Rijn - Oost-Nederland	Eefde	Ja, MIRT-planstudie loopt
	Delden	**Mogelijk knelpunt: verder analyseren**
	Hengelo	Volgens Richtlijnen Vaarwegen voldoet 1 kolk tot ongeveer
		10.000 passages beroepsvaart/jaar
Maasroute	St. Andries	Nee, o.b.v. eerdere MIRT-verkenning 2007 'Oost Westtak Maasroute'
	Prinses Maxima	Nee, in 2000 uitgebreid met nieuwe tweebakskolk
	Grave, gek. M	Nee, o.b.v. eerdere MIRT-verkenning 2007 'Oost Westtak Maasroute'
	Weurt, M-W kan	**Mogelijk knelpunt: verder analyseren**
	Heumen, M-W kan	Extra 2e kolk gebouwd via Maaswerken, staat meestal open
	Sambeek, gek. M	Al geschikt voor tweebakkers, lange kolk
	Belfeld, gek. M	Al geschikt voor tweebakkers, lange kolk
	Heel, lateraal kan	via MoMaro: verlenging kolk voor tweebakkers, extra capaciteit
	Maasbracht, Jul K	via MoMaro: verlenging kolk voor tweebakkers, extra capaciteit
	Born, Jul. kan	via MoMaro: verlenging kolk voor tweebakkers, extra capaciteit
	Limmel	staat meestal open.
Kustcorridor	geen	
Overig	Algerasluis bij Krimp	Nee, stormvloedkering staat meestal open; ook volgens Richtlijnen
		Vaarwegen geen capaciteitsprobleem
	Wilhelmina (Zaan)	Ja, (voorbereiding) uitvoering nieuwe sluiskolk loopt
	Julianasluis Gouda	Uitvoering nieuwe sluiskolk wordt door provincie voorbereid
	Sluis Harderwijk	Nee, sluis is vervangen door aquaduct en hoge brug.
	WHK: Sluis 1	Volgens Richtlijn VW bij Oosterhout geen capaciteitsprobleem
	WHK: Sluis 2 en 3	Realisatie: vervangen door nieuwe sluis bij Tilburg
	Marksluis	Volgens Richtlijn VW geen capaciteitsprobleem op het Markkanaal
	Henriëttesluis	Nee, na omleiding Zuid-Willemsvaart Den Bosch geen probleem
	ZWV: sluis 0	Nee, na omleiding Zuid-Willemsvaart Den Bosch geen probleem
	ZWV: sluis 4, 5 en 6	Nee, sluis 4, 5 en 6 zijn recent verruimd tot klasse IV
	ZWV: Sluis 10 t/m 13	Nee, sluis 10 t/m 13 zijn gerenoveerd en verruimd tot klasse III
	Spoolder (Zwolle)	Nee, vooral omleidingsroute bij stremming balgstuw
		Volgens Richtlijn VW geen capaciteitsprobleem
	Sluis Panheel	**Mogelijk knelpunt: verder analyseren**
Legenda:		= I/C Factor nader bepalen met spread-sheet van Kooman

Appendix C: River locks by the different scenarios

maatgevende maand	2008	2020			2028			2040		
Sluis I/C Factor -->		RC	SE	GE	RC	SE	GE	RC	SE	GE
Corridor 2: Amsterdam - Rijn										
Prinses Irene	0.40	0.30	0.35	0.45	0.30	0.35	0.45	0.30	0.35	**0.50**
Prins Bernhard	0.40	0.30	0.40	0.45	0.30	0.40	0.45	0.30	0.35	**0.50**
Amerongen	0.30	0.30	0.30	0.35	0.30	0.30	0.40	0.25	0.30	0.40
Corridor 3: Westerschelde - Rijn										
Volkerak	**0.60**	**0.55**	**0.65**	**0.75**	**0.50**	**0.65**	**0.85**	**0.50**	**0.65**	**1.05**
Kreekrak	**0.60**	**0.55**	**0.65**	**0.75**	**0.55**	**0.65**	**0.90**	**0.50**	**0.70**	**1.10**
Krammer	**0.50**	0.45	0.45	**0.55**	0.45	0.45	**0.60**	0.45	0.45	**0.70**
Hansweert	0.40	0.35	0.35	0.40	0.35	0.35	0.45	0.35	0.35	**0.55**
Corridor 5: Amsterdam - Noord-Nederland										
Oranje	0.40	0.35	0.40	0.45	0.35	0.40	0.45	0.30	0.40	**0.50**
Houtrib	0.35	0.30	0.30	0.35	0.25	0.30	0.40	0.25	0.30	0.40
Prinses Margriet (Lemmer)	**0.55**	**0.50**	**0.60**	**0.65**	0.45	**0.60**	**0.65**	0.40	**0.60**	**0.70**
Gaarkeuken	0.45	0.40	0.45	**0.50**	0.35	0.45	**0.55**	0.35	0.45	**0.55**
Oostersluis	**0.50**	0.45	**0.55**	**0.60**	0.45	**0.55**	**0.65**	0.40	**0.55**	**0.65**
Corridor 6: Rijn - Oost-Nederland										
Delden	0.45	0.45	**0.50**	**0.60**	0.45	**0.55**	**0.65**	0.40	**0.60**	**0.75**
Corridor 7: Maasroute										
Sluis Weurt	0.45	**0.50**	**0.55**	**0.65**	0.45	**0.55**	**0.65**	0.40	**0.55**	**0.70**
Sluis Panheel	0.30	0.20	0.30	0.30	0.20	0.30	0.30	0.20	0.30	0.30

Appendix D: Elements x River Locks Matrix

Appendix E: Number of Appearances

This table indicated the number of appearances with the following colours:

Red: under the 50%

Orange: between 50% and 80%

Green: over 80%

Nr.	Name:	Appearances:
1.	Aandrijving en bewegingswerk, elektrohydraulisch	21
2.	Aandrijving en bewegingswerk, elektromechanisch	31
3.	Aandrijving en bewegingswerk; mechanisch	2
4.	Aarding- en bliksembeveiligingsinstallatie	34
5.	Afmeervoorziening	20
6.	Afsluitboominstallatie	8
7.	Airconditioning	2
8.	Audiologgingsysteem	1
9.	Bebording/bewegwijzering (statisch)	11
10.	Bedienings- en besturingssysteem	33
11.	Binnenverlichting	17
12.	Bodembescherming	34
13.	Brandblussysteem	18
14.	Brandmeld- en ontruimingsinstallatie (BMI)	5
15.	Closed Circuit TeleVision installatie (CCTV installatie)	25
16.	Communicatieinstallatie	9
17.	Compressorinstallatie	7
18.	Debietmeetinstallatie	8
19.	Doorlaatkoker	1
20.	Fundering	9
21.	Gebouw	23
22.	Gebouwen en terreinen	7
23.	Gebouwinstallatie	16
24.	Grendelinrichting	3
25.	Heftoren	14
26.	Hek	0
27.	Hemelwaterafvoer (HWA)	24
28.	Hijs- en transportinstallatie	16
29.	Hoofddraagconstructie	5
30.	Hoogspanningsinstallatie	5
31.	Hoogtelicht	0
32.	Hydro-/meteomeetinstallatie	7
33.	Inbraakbeveiligingsinstallatie	3
34.	Informatie en Volgsysteem Scheepvaart 1990 (IVS90)	9
35.	Intercominstallatie	12
36.	Kabeldraagconstructie	21
37.	Kelder	2
38	Kerende constructie	33
39.	klimaatinstallatie	3

40.	Laagspanningsinstallatie	35
41.	Leuning	23
42.	Loopbrug	3
43.	Luchtbellenscherminstallatie	8
44.	Marifooninstallatie	17
45.	Nautofooninstallatie	1
46.	Niveaumeetinstallatie	14
47.	Nivelleermiddel	10
48.	Noodstroominstallatie	9
49.	Noodstroominstallatie, roterend	8
50.	Noodstroominstallatie, statisch	14
51.	Objectverlichting	32
52.	Oeverbescherming	10
53.	Omroepinstallatie	14
54.	Onderhoudsvoorziening	27
55.	Openbare verlichting (OV)	1
56.	Opstal	17
57.	Personenzoekinstallatie (PZI)	1
58.	Pompinstallatie	4
59.	Radarinstallatie	11
60.	Remming- en/of geleidewerk	29
61.	Scheepvaartdetectie-installatie	5
62.	Scheepverkeersbeseining	35
63.	Schuifconstructie	6
64.	Slijtlaag	3
65.	Sluisdeur (hef, punt, rol)	38
66.	Sluishoofd	38
67.	Sluiskolk	38
68.	Steiger	1
69.	Talud	3
70.	Telefooninstallatie	10
71.	Terrein	18
72.	Toegangshek (elektro-mechanisch rolhek of draaihek)	11
73.	Vangconstructie t.b.v. scheepvaart	8
74.	Verkeersregelinstallatie (VRI)	7
75.	Verwarmingsinstallatie	1
76.	Vleugelwand	1
77.	Vluchtweginstallatie	9
78.	Waterkerende constructie	4

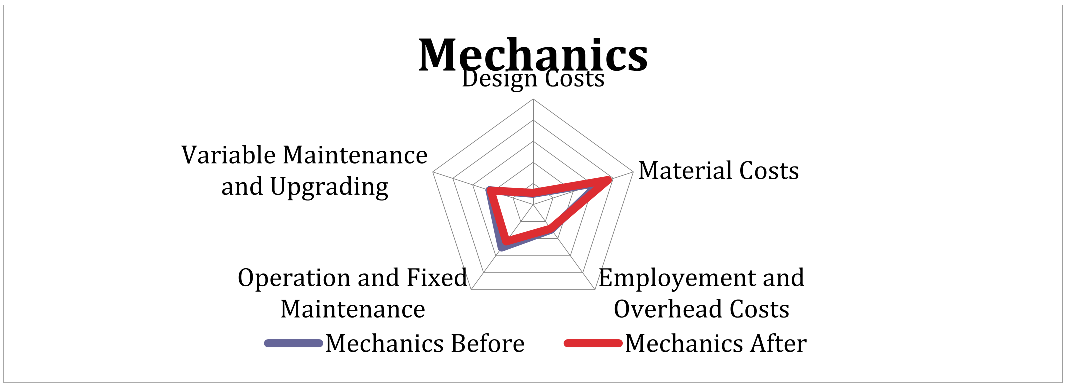
Appendix F: Effects of standardization

	Product Development	[%]	Material Costs	[%]	Employment and Overhead Costs	[%]	Transaction Costs	[%]	Operation and Fixed Maintenance	[%]	Variable Maintenance and Upgrading	[%]	Total Maintanance	[%]	Totaal Costs
Mechanics															
Before	€ 4.800.000,00	5,0%	€ 32.000.000,00	33,1%	€ 14.789.120,00	15,3%	€ 51.589.120,00	53,4%	€ 24.189.171,17	25,0%	€ 20.868.556,44	21,6%	€ 45.057.727,62	46,6%	€ 96.646.847,62
After	€ 4.482.035,62	5,3%	€ 29.060.000,00	34,2%	€ 14.182.898,21	16,7%	€ 47.724.933,83	56,1%	€ 18.388.963,56	21,6%	€ 18.951.257,82	22,3%	€ 37.340.221,38	43,9%	€ 85.065.155,22
Percentage	7%	-0,3%	9%	-1,1%	4%	-1,4%	7%	-2,7%	24%	3,4%	9%	-0,7%	17%	2,7%	12%
Command and Control System															
Before	€ 1.125.000,00	3,6%	€ 7.500.000,00	24,0%	€ 4.165.920,00	13,4%	€ 12.790.920,00	41,0%	€ 3.791.828,92	12,2%	€ 14.617.520,41	46,9%	€ 18.409.349,33	59,0%	€ 31.200.269,33
After	€ 1.012.135,07	3,7%	€ 6.705.000,00	24,3%	€ 3.925.781,02	14,2%	€ 11.642.916,09	42,2%	€ 2.882.604,10	10,4%	€ 13.068.063,25	47,4%	€ 15.950.667,34	57,8%	€ 27.593.583,43
Percentage	10%	-0,1%	11%	-0,3%	6%	-0,9%	9%	-1,2%	24%	1,7%	11%	-0,5%	13%	1,2%	12%
Bed Protection															
Before	€ 1.299.120,00	7,0%	€ 8.660.800,00	46,7%	€ 3.583.147,52	19,3%	€ 13.543.067,52	73,0%	€ 176.267,38	1,0%	€ 4.826.972,10	26,0%	€ 5.003.239,49	27,0%	€ 18.546.307,01
After	€ 1.077.394,48	6,1%	€ 8.419.103,26	47,6%	€ 3.348.404,68	18,9%	€ 12.844.902,41	72,6%	€ 146.680,95	0,8%	€ 4.692.265,91	26,5%	€ 4.838.946,86	27,4%	€ 17.683.849,27
Percentage	17%	0,9%	3%	-0,9%	7%	0,4%	5%	0,4%	17%	0,1%	3%	-0,5%	3%	-0,4%	5%
Gates															
Before	€ 2.223.000,00	4,8%	€ 14.820.000,00	32,2%	€ 5.651.808,00	12,3%	€ 22.694.808,00	49,2%	€ 15.017.171,96	32,6%	€ 8.381.011,54	18,2%	€ 23.398.183,50	50,8%	€ 46.092.991,50
After	€ 1.999.978,91	5,0%	€ 13.167.770,27	32,9%	€ 5.253.265,12	13,1%	€ 20.421.014,30	51,0%	€ 12.136.454,32	30,3%	€ 7.446.642,01	18,6%	€ 19.583.096,33	49,0%	€ 40.004.110,63
Percentage	10%	-0,2%	11%	-0,8%	7%	-0,9%	10%	-1,8%	19%	2,2%	11%	-0,4%	16%	1,8%	13%
Lock Head															
Before	€ 13.418.250,00	9,7%	€ 89.455.000,00	64,5%	€ 26.520.552,00	19,1%	€ 129.393.802,00	93,3%	€ 2.998.760,04	2,2%	€ 6.366.164,45	4,6%	€ 9.364.924,49	6,7%	€ 138.758.726,49
After	€ 11.605.248,98	8,9%	€ 85.706.885,47	65,5%	€ 24.983.584,37	19,1%	€ 122.295.718,82	93,4%	€ 2.495.419,04	1,9%	€ 6.099.425,71	4,7%	€ 8.594.844,75	6,6%	€ 130.890.563,57
Percentage	14%	0,8%	4%	-1,0%	6%	0,0%	5%	-0,2%	17%	0,3%	4%	-0,1%	8%	0,2%	6%
Lock Chamber															
Before	€ 8.025.543,75	8,6%	€ 53.503.625,00	57,3%	€ 24.022.842,20	25,7%	€ 85.552.010,95	91,7%	€ 1.306.851,93	1,4%	€ 6.479.685,96	6,9%	€ 7.786.537,89	8,3%	€ 93.338.548,84
After	€ 6.655.795,11	7,9%	€ 48.853.309,93	58,4%	€ 21.177.879,52	25,3%	€ 76.686.984,57	91,6%	€ 1.118.833,60	1,3%	€ 5.916.498,31	7,1%	€ 7.035.331,91	8,4%	€ 83.722.316,47
Percentage	17%	0,6%	9%	-1,0%	12%	0,4%	10%	0,1%	14%	0,1%	9%	-0,1%	10%	-0,1%	10%
Total															
Before	€ 30.890.913,75	7,3%	€ 205.939.425,00	48,5%	€ 78.733.389,72	18,5%	€ 315.563.728,47	74,3%	€ 47.480.051,40	11,2%	€ 61.539.910,91	14,5%	€ 109.019.962,31	25,7%	€ 424.583.690,78
After	€ 26.832.588,17	7,0%	€ 191.912.068,93	49,9%	€ 72.871.812,92	18,9%	€ 291.616.470,02	75,8%	€ 37.168.955,58	9,7%	€ 56.174.153,00	14,6%	€ 93.343.108,58	24,2%	€ 384.959.578,60
Percentage	13%		7%		7%		8%		22%		9%		14%		9%

Appendix G: Benefits of standardization

In this appendix the different elements are shown with the corresponding benefits.

Mechanics



Real benefits

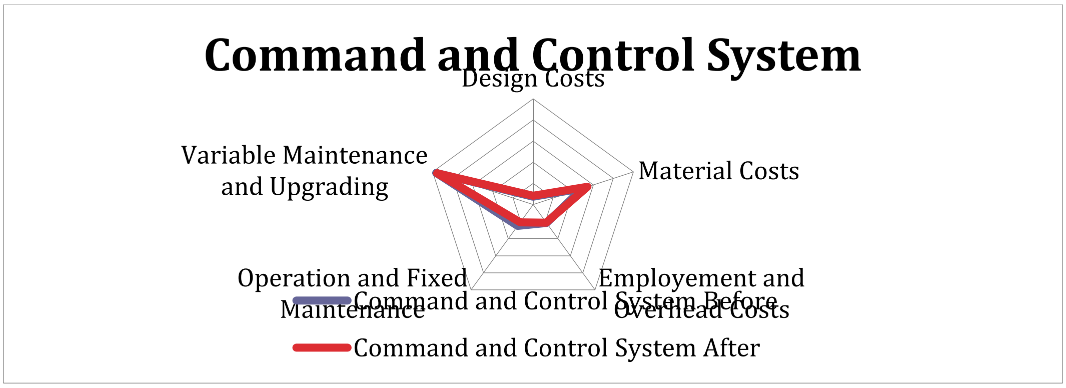
Transaction costs: -1%

Maintenance costs: 13%

Total costs: 6%

Availability: Increase

Command and Control System



Real benefits

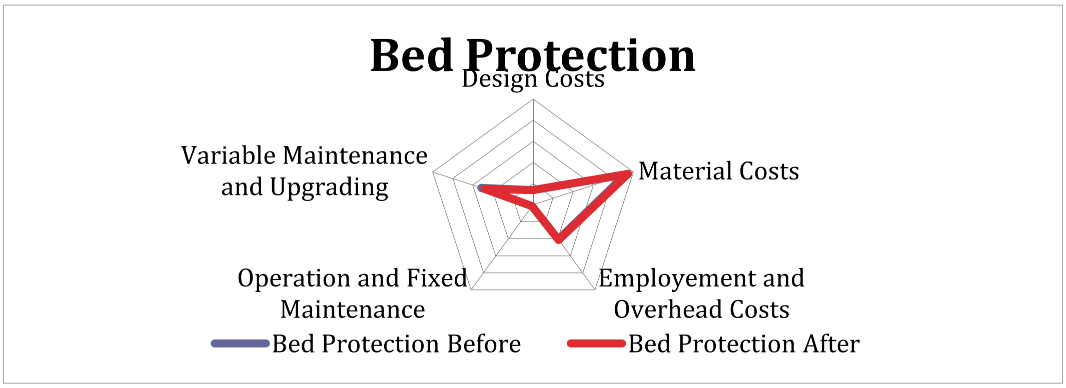
Transaction costs: -1%

Maintenance costs: 7%

Total costs: 4%

Availability: Increase

Bed Protection



Real benefits

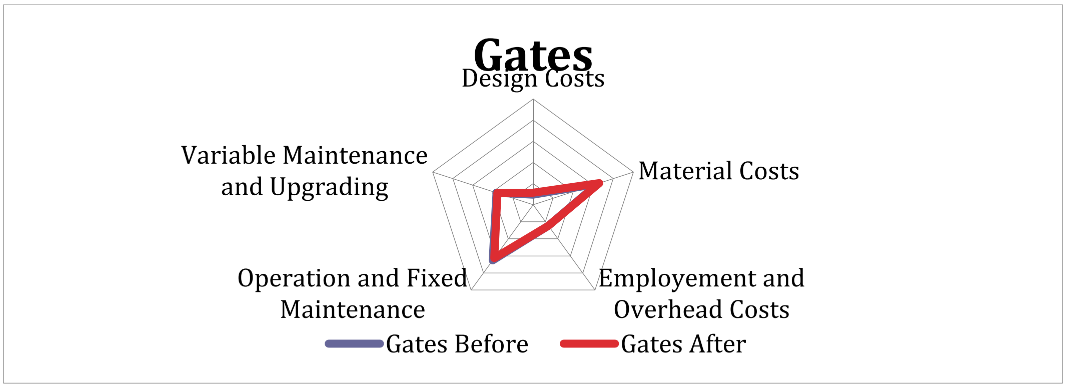
Transaction costs: 8%

Maintenance costs: 6%

Total costs: 7%

Availability: No effect

Gates



Real benefits

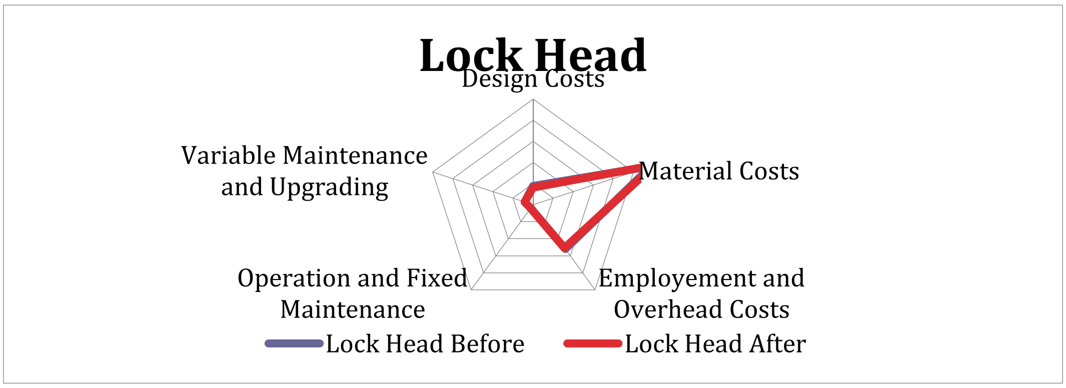
Transaction costs: 5%

Maintenance costs: 12%

Total costs: 8%

Availability: Little Increase

Lock Head



Total benefits:

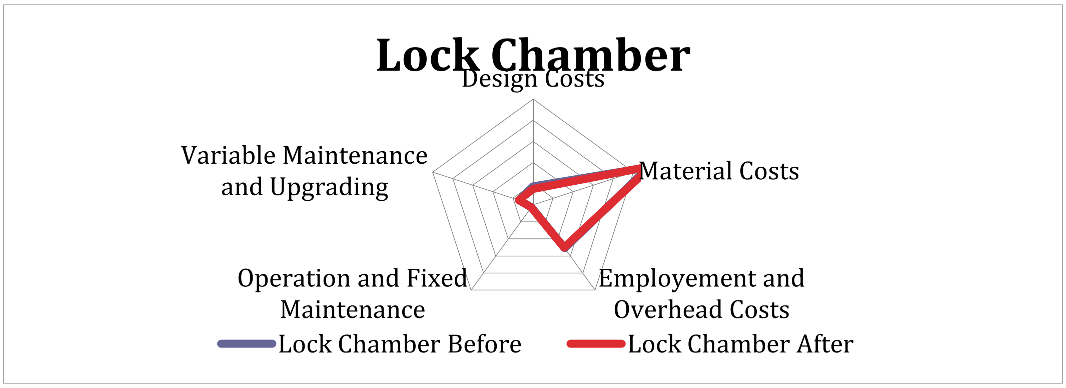
Transaction costs: 6%

Maintenance costs: 4%

Total costs: 6%

Availability: No effect

Lock Chamber



Total benefits:

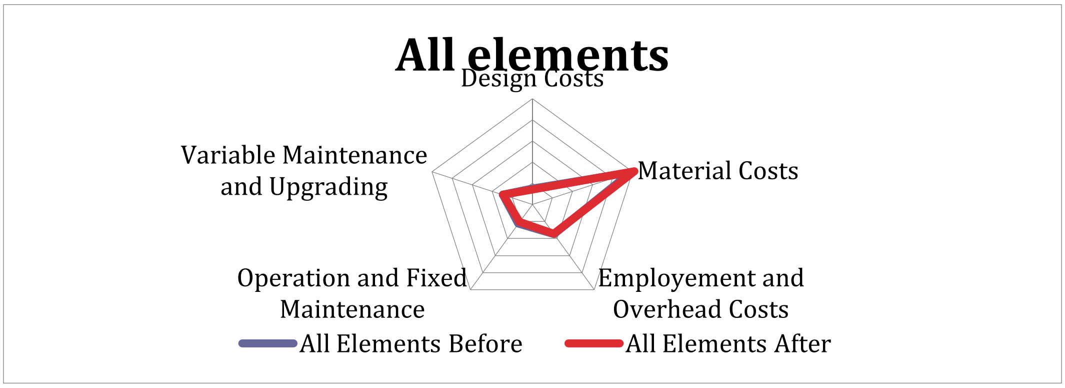
Transaction costs: 7%

Maintenance costs: 4%

Total costs: 6%

Availability: No effect

Combination of elements



Total benefits:

Transaction costs: 5%

Maintenance costs: 10%

Total costs: 6%

Availability: Increase

Appendix H: Input for the Case Study