Assessment of the Multi-layer Safety Approach in Dordrecht

Assessment of the Multilayered Safety Approach in Dordrecht using the ten building blocks assessment method.

T. Hamer (5608864), E.C. de Jong Posthumus (5589509) and M. Ilic (4044584)

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Introduction

Multi-Layer Approach in Dordrecht

Scientists across the world are becoming more confident that global climate change is altering the atmospheric dynamics and increasing the frequency and intensity of extreme weather. Some extreme weather includes flash flooding (extreme rainfall in a short period of time), storm surge flooding (from intense low pressure systems), and river flooding (extreme rainfall/rapid glacial melting). The increased frequency of extreme weather events is stimulating governments and organizations to create policies and laws to combat possible future natural disasters. The European Union (EU) created the revised EU flood directives in 2007 which are set of flood prevention laws EU member states need to execute. Article 4 states that each federal state has proceeded with a preliminary assessment of the flood risk. This means that each member state is required to make a preliminary flood risk assessment for each river basin on their territory and to determine those areas that present a potential significant flood risk. Article 5 states that catchments that have an area over 25.000 km^2 present a significant flood risk for the Netherlands (EC, 2007). This is shown in Figure 1.

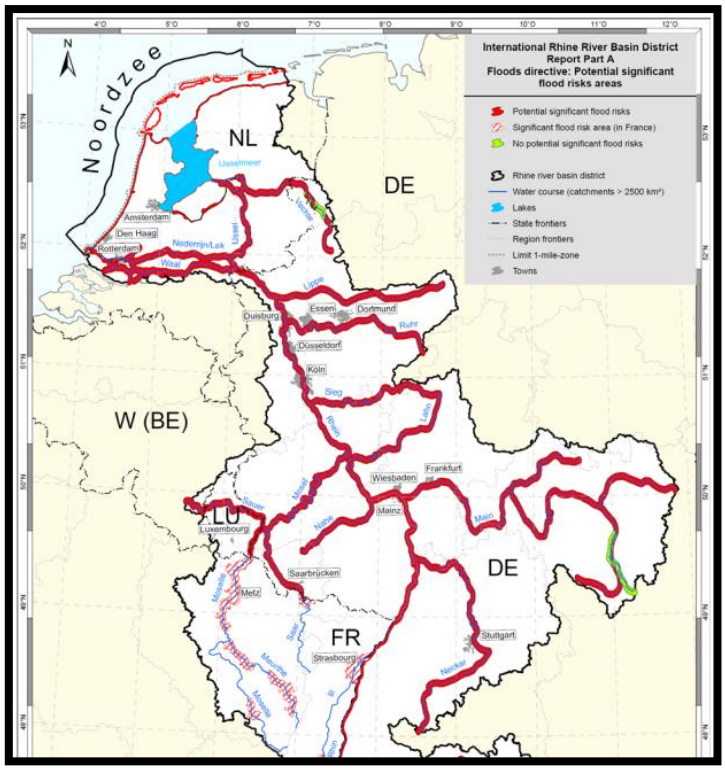

Figure 1: International Rhine River Basin District (EC, 2007).

The Netherlands is prone to significant flooding due to its downstream location. See figure 1 for an overview of receiving discharges from the rest of the Rhine Basin. The Meuse river Basin also poses a flood threat in the Netherlands.

To reduce a potential significant flood event in the future and comply with the EU directives, the Dutch government implemented policies and laws on a national, provincial and municipal level. Some examples of national regulation includes dike-ring areas, which were established to protect urban areas from a 1 in 10,000 year storm surge. The Defense Act of 1996 was put into effect to initiate any government to maintain flood defenses to pre-determined standards (Tulloch, 2010). The 12 provinces also have the responsibility of flood protection in the Netherlands. They are responsible for large projects such as the construction of dikes. At the lowest level there are 400 municipalities and 23 water boards who are responsible for local spatial planning and water system management (Rijkswaterstaat, 2012).

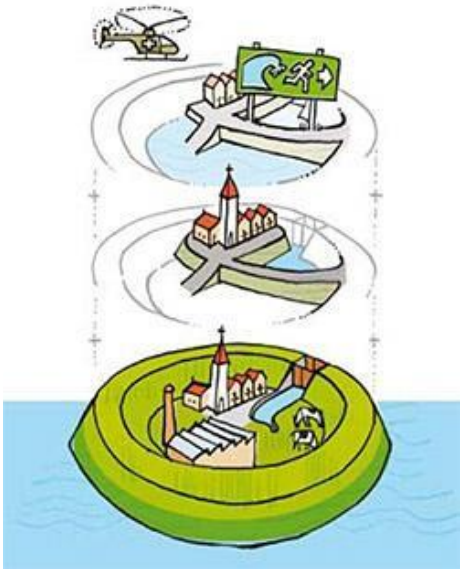

Figure 2: Multi-layer safety approach (GROENBLAU, 2009)

This report will focus on the Dutch city of Dordrecht which is situated on the Rhine-west and the Meuse river basins.

Article 5 of The EU directive places Dordrecht in the red zone where there is a potential for significant flooding (figure 1). Dordrecht flood defense has improved greatly since the 1953 flood, due to national, provincial, and municipal laws and policies. However, in 2011 and 2012 flooding hit the city again and streets were inundated. Global climate change and these recent flooding events prompted water management officials to rethink their existing policies and try to come up with a new possible framework that can minimize flooding in Dordrecht.

One possible approach is the multi-layer safety (MLS) approach. The MLS approach consists of three levels. This is represented in Figure 2. Prevention is the 1st layer of the MLS which includes technical measures such as dikes, water retention areas, permeable roads etc. The second layer focusses in sustainable water proof spatial planning through the implementation of secondary dike systems or other structures. (GROENBLAU, 2009). Lastly, you have disaster management. This involves realizing better co-ordination between the various emergency service providers, administrative decision-making, communication modes and evacuation plans.

Research Goal

The research goal is to determine whether the multi-layer safety approach is a feasible option in Dordrecht. The feasibility of this approach will be evaluated by the 10 fundamental building blocks assessment method. Figure 3 gives a visual representation of these 10 building blocks:

Methodology

This literature study is based on information that is publicly available using scientific journals, published books, respectable and acclaimed news media and professional online material. The MLS approach will be evaluated on all three levels for each building block. If a building block is satisfactory on all three levels, the MLS approach would not be applicable since there are no improvements that are strictly necessary. All building blocks are assessed with the assumption that they are all of equal weight. If the MLS approach is not applicable in $\geq$ 20% of the building blocks, flood risk management in Dordrecht would not benefit from this approach. In case there are uncertainties in the future outcome of a building block, the MLS approach would not be feasible. The main research question is stated below with 10 sub questions that assess the MLS approach using the ten building blocks.

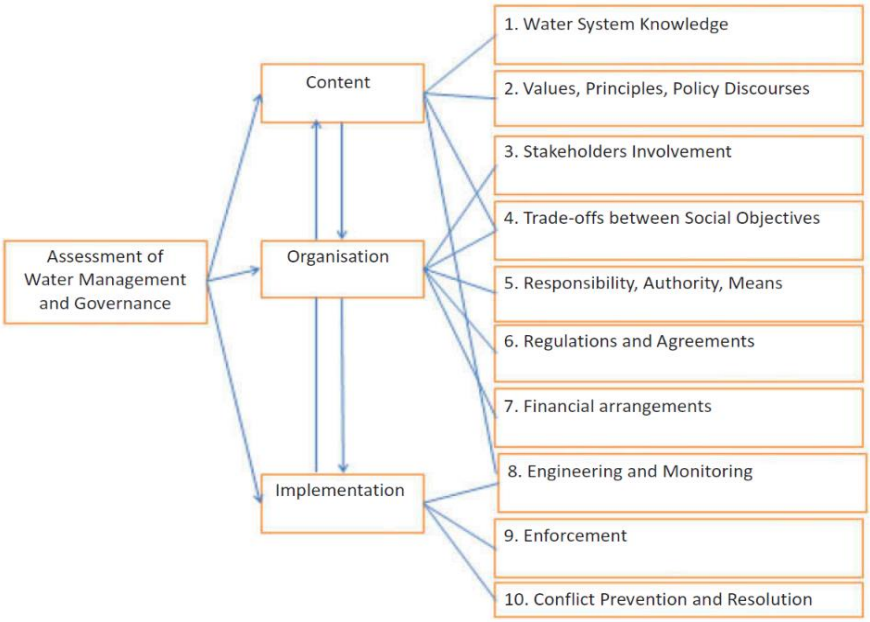

Figure 3 The ten building blocks assessment method (van Rijswick et al.).

Main research question:

Using the 10 building blocks assessment method, can the MLS approach reduce the flooding effects in Dordrecht?

Sub questions: 

1. What is the MLS approach and is there sufficient knowledge regarding this approach?
2. How do stakeholders play a role in the establishment of the MLS approach? Are there any conflicts between different stakeholders?
3. How will the MLS approach fit within the Dutch values, principles and policy discourses upon water management?
4. How can the MLS approach be applied in Dordrecht? Will this approach bring more benefits to Dordrecht or loses?
5. To what extend are authorities, responsibilities and means able to apply the MLS approach in an appropriate administrative scale?
6. Are regulations and agreements legitimate and adaptive, if not, what are the main issues regarding the above mentioned legitimacy aspects?
7. How will the MLS approach in Dordrecht be financed? Is it a robust and well-organized approach?
8. What are technical engineering solutions for Dordrecht and how can they be monitored for effectiveness?
9. Can the MLS approach be enforced efficiently in Dordrecht by private and public parties?
10. What are possible conflicts that may arise from using the MLS approach (ex: ecological, increased traffic etc.)? If problems occur, are there any resolutions available to solve these problems?

Keywords are: policy, governance, regulation, assessment, Dordrecht, Netherlands, Rhine, Meuse, Basin, Multilayers safety approach, EU law, European Commission, flood risk management, flood hazards, financial assessment. 

1. What is the MLS approach and is there sufficient knowledge regarding this approach?

The MLS approach was introduced in the National Water plan of 2008 to reduce both the probability and the consequences of floods. Within this concept there are three distinct layers:

1. Flood prevention by flood defense structures;
2. Sustainable, water proof, spatial planning;
3. Disaster management in case of flooding.

Traditionally all attention was given to the first layer by constructing flood defense structures in the forms of dikes and storm surge barriers. These measures were solely meant for protection against flooding. However with the introduction of the MLS approach, efforts are being made to also investigate the potential of flood and disaster management.

Due to the fact that Dordrecht is an island, only 15% of the residents can escape the island in times of flooding (Dieperink, Hegger, Driessen, 20[illegible] The municipality is aware of this problem and supports the idea of the island to be self-sufficient in case of flooding. Therefore Dordrecht is exploring the possibilities to implement the MLS approach.

The island of Dordrecht is enclosed by different rivers; the Old and the New Meuse, the Merwede, New Merwede and the Hollandse Diep. The city is situated in a transition zone between these rivers and the North Sea. Consequently the rivers are subject to tides. The tidal ranges are 30 cm in the natural area of the Bieschbosch and 80 cm near the historical town of Dordrecht (Herk, S. et all. 2011.). The city was built on a low-lying area. The average surface level is 0 meter above mean sea level and the average high water level of the rivers is approximately 1.0 meter above mean sea level (Herk, S. et all. 2011). To prevent the city from flooding the city is protected by a dike ring (nr 22). The dike ring has an exceedance probability of 1/2000 year according to the current norm (Herk, S Et. all. 2011). Every 5 years dike assessments are carried out to assess whether the dikes comply with the safety standards. A part of the city, including a part of the historical town, is not protected by primary flood defenses and has to deal with temporary flooding's due to high water levels in the river.

According to the European Floods Directive of 2007 each European member state (including the Netherlands) is obliged to indicate flood risks and making plans for national and trans boundary flood management (E.U. Directive: 2007/60/EG). Making flood risk maps is part of the duties. In the Netherlands this obligation was carried out under the project 'Veiligheid Nederland in Kaart' (Flood Risk and Safety in the Netherlands) in 2010. The results of this project for Dordrecht explained that the floods risks are high. In case of flooding high water depths (> 2 meter) can occur and in some areas this level can be reached within 9 hours' time (figure 1).

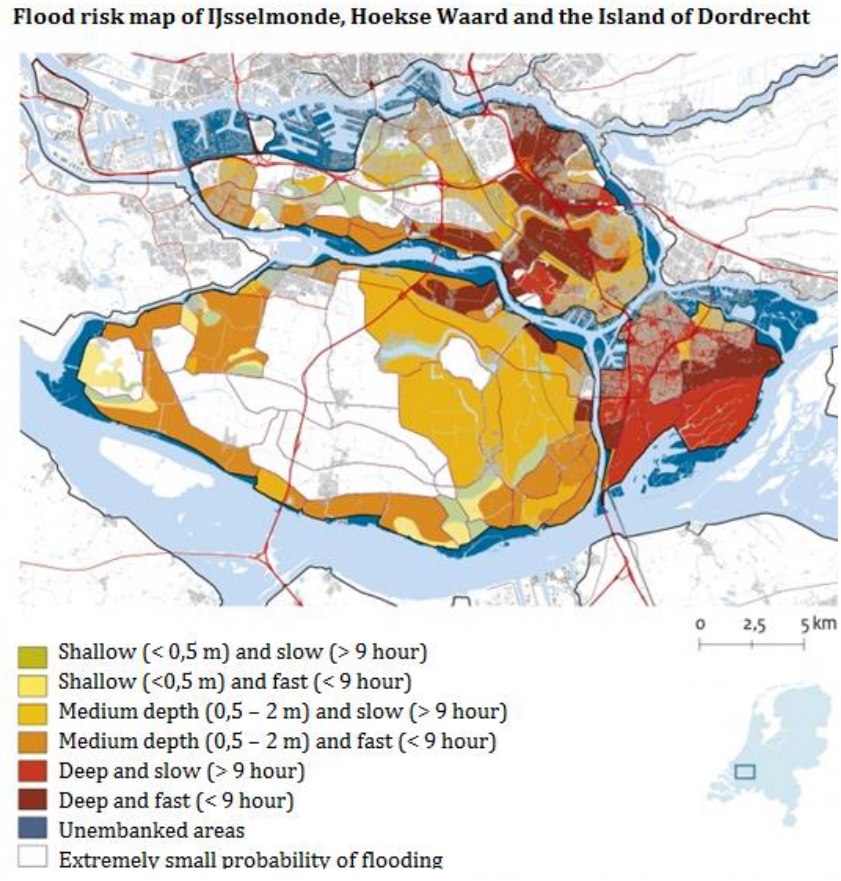

Figure 2: Dordrecht Flood risk map Source: PBL

Flooding from the rivers

Due to the closure of the Haringvliet Estuary in 1970, the risk of flooding in Dordrecht from the sea decreased significantly, however flooding caused by the rivers persisted. Over the past 40 years the rivers exceeded the 2 m + NAP level more than ten times causing the embankments to flood (Gemeente Dordrecht. 2013).

In November 2014, the Minister of Infrastructure and Environment has announced the implementation of the 'Kierbesluit', which means that the Haringvliet sluices will be partly opened again in 2018 (Rijkswaterstaat 2014). This decision was taken because the sluice was considered as a barrier for fish migration and therefore it was in conflict with the ecological objectives of the EU Water Framework Directive. By partly opening the sluice the tidal amplitude at Dordrecht will increase with approximately 10 cm.

Creating awareness of flood risks

In the city of Dordrecht people live outside of the dike rings. There are no legal security standards for these unembanked areas. The residents that live in these flood prone areas can count on the current policies for the management of flood risks (Overstromingsrisico en waterbeheer in Nederland. 2012). The Maeslantkering is a storm surge barrier in the Nieuwe Waterweg that provides security by high water levels in the Meuse River. The storm surge barrier closes when the water level rises to 2.9 m +NAP at Dordrecht or at a water level of 3 m +NAP at Rotterdam. Following the EU flood directive citizens that live in a flood prone areas are to be informed by the water authorities about the flood risks. In Dordrecht every year letters are sent to the 15.000 citizens that live outside of the dikes to remind them of the floods risks (Overstromingsrisico en waterbeheer in Nederland. 2012). This indicates that Dordrecht is implementing risk communication and hence following up the obligation of the EU Floods Directive, to inform citizens in flood prone areas about the flood risks. Actions of citizens such as making dikes of sandbags during small floods and making facades of houses waterproof demonstrates the sustainable water management. The municipality brings flood risk management into action by placing retaining walls in the flood prone areas of the town.

2. How do stakeholders play a role in the establishment of the MLS approach? Are there any conflicts between different stakeholders?

For the city of Dordrecht the possibilities to implement the MLS strategy are investigated in the 'Gebiedspilot meerlaagsveiligheid Eiland van Dordrecht' (Pilot multilayer safety Island of Dordrecht). In this exploratory study both public and private stakeholders are involved. Amongst the public parties are the Department Zuid-Holland of the Ministry of Infrastructure and The Environment (Rijkswaterstaat), the municipality of Dordrecht, the province of Zuid-Holland, the Water board Hollandse Delta and the Safety Region ZHZ. Private parties that are involved in the pilot project include Dura Vermeer, UNESCO-IHE, Deltares and the TU Delft. The mentioned stakeholders formed the project group Managing Adaptive REsponses to flood risk (MARE) (Herk, S. et All. 2011). See table 2 for the results of a stakeholder analysis for Dordrecht. Workshops are organized, as part of the pilot, in which interests, concerns and values of all actors including citizens and utility services were discussed. Also the municipality talked with the citizens of Dordrecht to share thoughts about the MLS approach. In Dordrecht citizens are in general more aware of flood hazards due to small scale flooding in recent years. Dordrecht citizens might welcome the MLS-approach positively since they are more aware of the negative effects from flooding. However there seems to be a lack of awareness of the potential risk of future flood disasters.

3. How will the MLS approach fit within the Dutch values, principles and policy discourses upon water management?

Changing approach to flood protection

Traditionally the Dutch approach to flood protection was focused on prevention. Dike rings and storm surge barriers became the core flood defense structures in the Netherlands. However since the river floods of the Rhine, Meuse and Waal in 1993 and 1995 the philosophy is changing towards a more flood risk management strategy. Multi-Layer Safety is an example of a new integral approach that was introduced in the 'National Water Plan of 2009-2015' by the Dutch Government (Ministerie van Infrastructuur en Milieu, & Ministerie van Economische Zaken. 2014).

Developments in risk assessment

The First Delta Commission was established after the flood disaster in 1953. The Commission advocated for stricter requirements on flood protection. The first safety standards were set on basis of high water levels that occurred in that time. Later a new safety philosophy was introduced; security risks were from this moment based on exceedance probabilities. The flood protection norms for different dike rings were imbedded in the 'Wet op de waterkering' (Act on the flood defense), nowadays embedded in the Water Wet (Water Act). The norms for the different dike rings were dependent on the kind of the threat (river, sea, and lake), the size of the area and the economic value represented by that area (VNK. 2015).

The exceedance probability approach was used until, in January 2015, the Rijkswaterstaat Projectbureau VNK introduced a new risk assessment method. This method calculated the flood risks in a more comprehensive way including multiple failure factors of flood defenses and dunes and the potential effects in terms of economic damage and casualties. According to this method the VNK has indicated the flood risks for all the 87 dike ring areas.

For Dordrecht it turned out, that the annual probability of flooding is 1/710 and the effect in terms of economic damage and casualties will be 80 million euros and 12 casualties respectively (table 1).

(VNK, 2015). These statistics can add strength to the argument of the municipality of Dordrecht to mitigate the risk and the effects of flooding.

Legal framework

The norms for flood protection, the continuous process of testing, management, improvement and the responsibilities of the water authorities are established in the Water Act. Following this act the local authority, responsible for managing the dike system, is obliged to perform a dike assessment. The norms for each assessment session are established in the Wettelijke Toets Instrumentatie (Legal Assessment Toolbox) by the minister of Infrastructure and Environment. Consequently the results of the assessment sessions are submitted to the House of Representatives.

Table 1: Flood risks in Dordrecht (VNK, 2015)

Annual flooding probability	1/710
Annual economic risk	€ 100.000
Average damage per flooding	€ 80.000.000
Annual casualty risk	0,02
Average number of casualties per flooding	12

4. How can the MLS approach be applied in Dordrecht? Will this approach bring more benefits to Dordrecht or loses?

The MLS approach is helpful in slowing down the cycle of dike reinforcements, a lesser need for stronger flood defenses (in case flood proof building has been done) and safety improvements by flood anticipation. The overall goal of the MLS approach is that it opens the way to more costs-efficient flood risk management.

These above advantages however are only beneficial in a cost efficient way if heavy investments in Dordrecht would be lacking. Since the city of Dordrecht is heavily embanked in high dikes and flood defenses, the MLS approach is not cost efficient (Hoss, Jonkman & Maaskant, 2011). However when looking at some specific areas within Dordrecht, which have been mentioned in the previous chapters, tailor made MLS approaches could be beneficial over 'traditional' flood prevention methods.

The big disadvantage of the MLS approach for Dordrecht is that only 15% of the residents of this island could evacuate in case of flooding (Dieperink, Hegger, Driessen, 2014). Therefore, the emphasis on evacuation in the third layer becomes one of self-sustainability in means of available emergency goods and active citizenship. The fact that evacuation is not possible for the remainder 85% of the residents poses a substantial problem for its implementation. What is the tradeoff in having 85 percent of the population ineligible to evacuate? Shelters and evacuation shelters would be recommendable to be incorporated into the MLS approach. Another major disadvantage for the implementation of the MLS approach in Dordrecht is its vulnerable location. In Dordrecht there are dikes through the old city Centre, a number of inhabitants live in unprotected areas, existing dikes are currently under maintenance and the island is near to rivers (Dieperink, Hegger, Driessen, 2014)., The 15.000 people of Dordrecht that live in unembanked areas are at a much greater flood risk (Overstromingsrisico en waterbeheer in Nederland. 2012). An advantage that comes with the awareness that is that the city is very proactive in flood risk management.

Available barriers for the MLS approach in Dordrecht are its existing safety norms, the division of responsibilities and financing structures. Drivers for this approach include financial resources, scientific expertise and the local support of the municipality and participating residents (Dieperink,

Hegger, Driessen, 2014). These should be taken in regard when implementing the MLS approach. Application of this approach is done by implementing policies and to add awareness to it for the inhabitants.

Further uncertainties would be the question of whether the benefits are greater than the financial investments. Also, should the smaller population be displaced due to the engineering improvements for the safety of the greater population? Besides this, the lack of knowledge in the second and third layer may provoke protests and anger the public, because people are knowingly being put at risk for mitigation. These matters have not been addressed in this building block. It would be recommended to assess the possibility of financial compensations for the affected people, educating the public on the first and second layer.

Dutch flood risks are generally speaking not insurable, demarcating between inner dike and outer dike areas. Inner dike areas are exposed to a limited chance of flooding with substantial damages, due to these low chance, citizens would not be eager to pay for these risks (Lengkeek, 2010). Usually, insuring outer diked areas is not done in the Netherlands due to its assumed high risks as opposed to its low population, which would make premiums to be too high. Insuring outer dike areas is currently under reassessment by the MARE pilot project since research has pointed out that risks of flooding in the outer dike areas are low for Dordrecht (van Herk et al., 2011).

5. To what extend are authorities, responsibilities and means able to apply the MLS approach in an appropriate administrative scale?

The administrative context with regard to flood protection in Dordrecht is straightforward; there is one municipality, one water board, one safety region, within one province and one regional department of the federal agency Rijkswaterstaat (Herk, S. et All. 2011). Responsibilities amongst the different stakeholders with regard to flood management is investigated and presented in table 2.

Table 2: Stakeholders and responsibilities (after: Dieperink C. et All. 2013.)

Stakeholders	Responsibilities
Municipality of Dordrecht	- Responsible for the spatial planning in Dordrecht (permits, land use planning) and local disaster management. - Spatial developments are based on the land use plan. - Informing citizens that are living in unembanked areas.
Water board Hollandse Delta	- Responsible for the construction and maintenance of the dikes - Performing a dike assessment every 5 years.
Province of Zuid-Holland	- Responsible for coordinating spatial planning and water management at provincial level - Influencing water safety policies via spatial planning in unembanked areas - Involvement in compartmentalization in embanked areas
Ministry of Infrastructure and The Environment, Department Zuid-Holland (Rijkswaterstaat)	- Setting standards for and financing primary flood defenses - Responsible for policy and governance with regard to national water management - Establishing the National Water Plan, Nationaal Bestuursakkoord Water, Delta program

Safety region ZHZ	- Partnership between authorities and public services with regard to tasks related to firefighting, disaster management, crisis management and medical aid. - Has a coordinating role in disaster management and collaborates with municipality, regional water authority, and, if needed, province and national government. - Responsible for the establishment of disaster plans and for educating people about disaster scenario's and practicing evacuation
Emergency services	Dealing with calamities
Citizens	Citizens living outside dike-protected areas are responsible for flood mitigation, preparation and recovery
Private companies	No direct responsibility

Since the MLS approach is different to the traditional preventive approach it requires a mental shift from the stakeholders towards a new way of dealing with floods. Stakeholders who were formerly not used to cooperate will now have to. Particularly in the second and third layer, in which flood control and disaster management is discussed, involvement of private parties and citizens will play an important role. The following aspects are important for these (Terpstra, T. & Gutteling, J. (2006) layers:

1) Reducing the risk of a disaster and its possible consequences
2) Preparation of a possible disaster
3) Acting at the time of the disaster
4) Recovery after the disaster

The first component focuses on taking preventive measures. There's abundant knowledge in Dordrecht on the prevention of flooding. It is well known to what extend the defense system provides safety in the embanked areas in Dordrecht. However there's a lack of knowledge what to do when this first layer fails. In this stage 'risk communication' comes into play. This includes information on the possible flooding scenarios, the scale of the possible consequences and the measures that should be taken by the water authorities so that casualties and economic damage are limited. Two extreme scenarios were calculated in the pilot project for Dordrecht. In the extreme scenario Dordrecht will flood in less than 9 hours and water depths of 2 meters will be reached. The citizens of Dordrecht have experienced several floods (2011, 2012) making them more aware of the flood risks. During these flood-events citizens have showed initiatives by placing sandbags to protect areas from flooding. However this concerned floods on small scale and are not in proportion to the extreme scenarios mentioned in the pilot project.

In Dordrecht 15,000 people live in unembanked areas. The municipality informs the citizens of the flood risks by sending them every year a letter (Overstromingsrisico en waterbeheer in Nederland. 2012). This indicates that Dordrecht is already implementing risk communication and hence following up the obligation of the EU Floods Directive, to inform citizens in flood prone areas about the flood risks.

The third component focuses on; minimalizing the damage and the casualties, an early warning system, evacuation and the residence time of evacuated citizens. A comprehensive evacuation plan on flooding should include an evacuation plan for people and livestock, a communication plan and plans for emergency services. Such a plan, which focuses on current scenarios, can mitigate the negative effects of flooding in Dordrecht.

Finally, in the last component it is important to clarify if there are delayed effects such as risks of collapsing buildings, damaged electricity networks, breached dikes and storage of hazardous materials and how to deal with this risks.

6. Are regulations and agreements legitimate and adaptive, if not, what are the main issues regarding the above mentioned legitimacy aspects?

High water discharges of the Rivers Rhine and Meuse in the past triggered a change in governmental policy, public awareness and international co-operation in terms of flood management in the form of a rapid dike reinforcement program, protection of existing water discharge capacity by legislation and the development of programs such as the project Room for the river. This also led to International co-operations on measures, public awareness and early warning systems and the anchoring of flood protection measures between and outside the dikes in planning and policy (Baosheng Wu., Zhao-Yin Wang. & Guangqian Wang., 2002);(van Stokkom, Smits & Leuven, 2005).

Figure 3: Safety Region Zuid Holland Zuid of which Dordrecht is a part of (Imergis.nl, 2015).

Water management regarding flood risk management in the Netherlands starts with the measuring of the water quantity of the water system by the National Water Monitoring Network (Landelijk Meetnet Water). These data end up at the Water Management Centre (Rijkwaterstaat) where the data are interpreted together with weather forecasts from the KNMI and models from Deltares. From these data, and regional water reports, a national picture is derived. The Water Management Centre provides information to water authorities on which intervention can be done through pumping stations, locks and weirs. After this intervention, measurements start over, as so does the process. In case of a disaster, activities are also coordinated with the Departmental Coordination Centre for Crisis Control (DCC) of the Ministry of Infrastructure and the Environment and the Shipping Centre (SVC) and Traffic Management (VCNL). Advice is provided to the safety regions via the regional water authorities (Rijkswaterstaat, 2011). See figure 6 for a schematization of this process, see figure 5 for the safety region of which Dordrecht is a part of. The latter would be the third layer of the MLS approach and the first would be the first layer of the MLS approach.

The first layer of the MLS approach focusses on prevention of flooding and the second layer focusses on the mitigation of flooding (Rijkswaterstaat, 2012), which is done according to the following policies and regulation that encompasses the Water wet (Water Act), Wet Milieubeheer (environment Protection Act), the EU Water Framework Directive (2000/60/EC) and the EU Floods Directive (2007/60/EC) and underlying delegated laws (Ec.europa.eu, 2015); (Ec.europa.eu, 2015); (Wetten.overheid.nl, 2015);

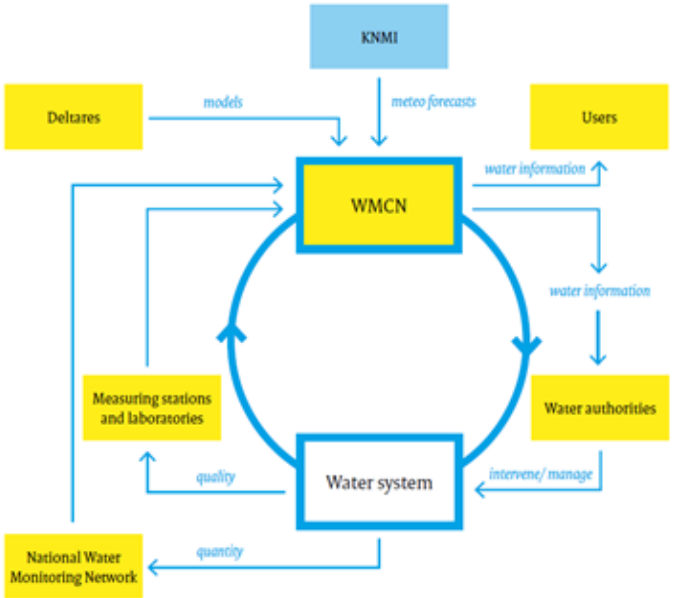

Figure 4: Water management in the Netherlands (Rijkswaterstaat, 2011).

(Wetten.overheid.nl, 2015); (Rijksoverheid.nl, 2015). The third layer of the MLS approach is the crisis management and disaster control aspect (Rijkswaterstaat, 2012), which is covered in the Besluit informatie inzake rampen en crises (Decision information on Disasters and Crises), the well-being of health and safety workers during disasters is covered in the OSH Framework directive (89/391/EEC) and the protection of critical infrastructure is covered in the Green Paper on a European Program for Critical Infrastructure Protection. (Eur-lex.europa.eu, 2015);(Eur-lex.europa.eu, 2015), (Wetten.overheid.nl, 2015).

7. How will the MLS approach in Dordrecht be financed? Is it a robust and well-organized approach?

Historically, majority of the financial investments in the Netherlands were and still are focused on the prevention layer. The prevention layer can become very costly where millions of euros are necessary to build the dikes and keep them well maintained. Flood resistant Engineering solutions and new policies that are applied to the second and third layer can be a more cost effective approach. The application of sandbags is one solution that can be applied in the second layer that has the ability to minimize flooding. However, the application of sandbags and other technologies in both of these layers may not be enough to keep Dordrecht safe from flooding. However, is it worth investing less and relying more on the second and third layer, or is it better investing more money on the dike system which has proven to significantly reduce flooding? Another key issue, is the fact that many new parties would become involved. For example, if Dordrecht were to install permeable pavement, the city would get involved. Insolation on houses would cause private owners and companies to become involved. This can all lead to conflicts between parties which can prohibit financial investment in the second and third layers.

Of the MLS approach, most measures seem to be cost-inefficient, while strengthening the primary and secondary dikes turns out to be a more efficient plan. The city is better off with dikes, because the city is bounded by the Northern half of the dike ring, the compartmentalization dike. One part of the MLS approach that is very cost efficient however are the sandbags, which is due to its low price. The effect of sandbags is limited and depended on quality of operation and the condition of the flood defense (Hoss, Jonkman & Maaskant, 2011). For Dordrecht however, spatial and financial objectives have prevailed for master planning, when using flood risk was as a defined design variable (van Herk, Zevenbergen, Gersonius, Waals & Kelder, 2014). See figure 7 for a financial overview of the MLS approach in Dordrecht (Hoss, Jonkman & Maaskant, 2011).

Table 2: Results of cost-effectiveness-analysis for MLS measures. Results for whole dike ring in standard letters, results for new neighborhood in Italic letters. NPV: interest rate 4%, unlimited time horizon.

Measure	Effect	NPV of EAD Reduc [million €*]	EANC Reduc. [lives per year*]	NPV of investment [million €]	CBA factor [-]***	CSX [million € /lives per year]***	
1-3: Redistribution of water load over river arms	Decrease probability of water overload to 1/4,000 yr^{-1}	44.5 (50%)	0.431 (50%)	200	4.5	500	Dike ring
		1.7 (50%)	*0.008 (50%)*		*118*	*25,000*	*Neighbor.*
1-6: Strengthen primary dikes	Decrease probability of water overload to 1/20,000 yr^{-1}	79.5 (89%)	0.771 (89%)	200	2.5	300	Dike ring
		3.1 (89%)	*0.015 (89%)*		*65*	*13,300*	*Neighbor.*
2-6: Strengthen compartmentalization dike (Wieldrechtse Zeedijk)	Model compart. dike as unbreachable	72.5 (81%)	0.837 (97%)	100	1.4	100	Dike ring
		3.0 (87%)	*0.016 (96%)*		*33*	*6,300*	*Neighbor.*
2-7: Build new neighborhood on 1m pillars (alleviation)	Inundation depth decreases by 1m	1.2 (1%)	0.009 (1%)	120	92	13,300	Dike ring
		1.2 (36%)	*0.009 (52%)*		*92*	13,300	*Neighbor.*
3-5a: Evacuate 15% of new neighborhood**	Decrease number of exposed by 15%	0	0.003 (0.3%)	3	NA	1,000	Dike ring
		0	0.003 (15%)			1,000	*Neighbor.*
3-5b: Evacuate 15% of dike ring**	Decrease number of exposed by 15%	0	0.129 (15%)	25	NA	200	Dike ring
		0	0.003 (15%)			*8,300*	*Neighbor..*
3-6: Strengthen primary dike with sand bags	Decrease probability of water overload to 1/2,500 yr^{-1}	18.0 (20%)	0.172 (20%)	0.5	0.03	3	Dike ring
		0.7 (20%)	*0.003 (20%)*		*0.7*	*200*	*Neighbor.*
3-8: Improve warning and preparation	Damage reduces by 10%	8.9 (10%)	0.086 (10%)	12.5	1.4	150	Dike ring
		0.3 (10%)	*0.002 (10%)*		42	*6,300*	*Neighbor.*

* Percentage of total risk in reference situation; ** It was assumed that the percentage of people evacuating is 0 in the reference situation; ***rounded

Figure 5: Financial overview of the MLS approach in Dordrecht (Hoss, Jonkman & Maaskant, 2011).

8. What are technical engineering solutions for Dordrecht and how can they be monitored for effectiveness?

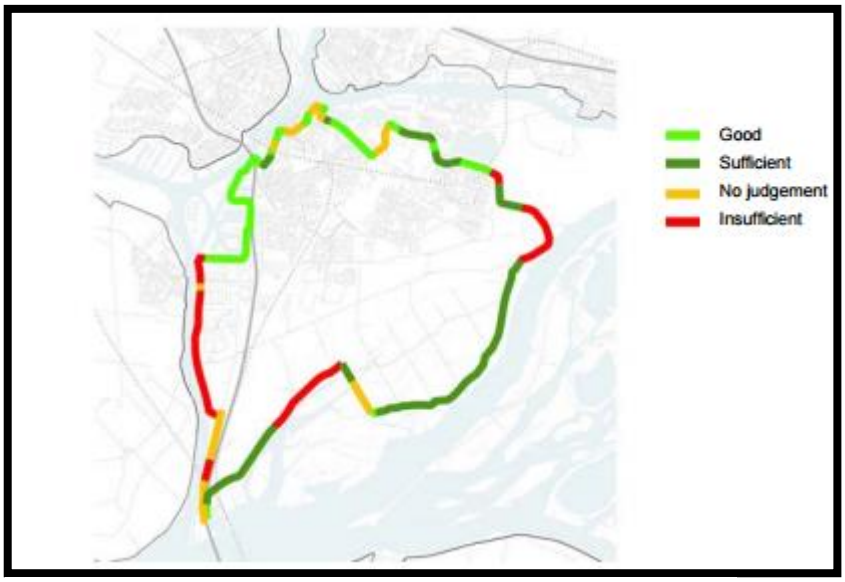

Figure 6: Dike efficiency map (RIVM, 2006).

The major flood event of 1953 became a new benchmark for Dutch water management. The majority of Dutch polices and engineering solutions that are visible today were constructed in an effort to prevent flooding events of that magnitude from happening again. These efforts have been generally successful, however, recently issues have been appearing in Dordrecht's flood management on all three MLS layers. The traditional Dutch approach focusses on the 1st layer of the MLS approach where physical defense such as dikes are important. Even though the prevention layer is fairly strong in the Netherlands, the dike system is beginning to age. About 15% percent of the current dikes in the Netherlands do not meet Dutch standards and 35% are of unknown status due to insufficient dike monitoring. Part of Dordrecht's dike system happens to be in the insufficient category of 15%. (RIVM, 2006). Figure 8 shows where dike strengthening is needed. The Water board (Waterschap Hollandse Delta), is responsible for maintaining Dordrecht's dike system and needs to work together with the residents and private companies to find an engineering solution to fortify its dikes. Engineering solutions can include hybrid dikes which are more durable and cut costs to around 30 percent. Monitoring is also an issue in Dordrecht's flood management. A re-evaluation of the current monitoring policy and an establishment of a new more reliable one is needed. One solution could be an integrated sensor technology policy. This would give periodic LiDAR measurements (FLI-MAP and / or DRIVE-MAP) for dikes into the design of the dike reinforcement (Arcadis, 2015). This technology measures distance by illuminating a target with a laser and analyzing the reflected light.

Compared to the first layer, the second and third layers of the MLS approach (spatial planning / emergency management) are not effectively addressed in Dutch policies. This is mainly due to the heavy reliance on the first layer. Also, Dordrecht lacks a reliable flood vulnerability map which prevents certain engineering solutions (ICFM6, 2014). A proper flood vulnerability map would give a better idea to which structures are most vulnerable to flooding and can use engineering upgrades. Some engineering solutions that can strengthen the second layer are structural enhancements such as proper insolation, permeable driveways, and raised structures. To implement these solutions, the city could provide compensation for the companies/people who have properties in flood prone areas. This could be in the form of tax reduction, subsidies, or a discount in flood insurance. Lastly, an effective evacuation plan is necessary in Dordrecht. An engineering solution in the third layer can involve a central safe gathering place during a flood. With the help of local authorities, people would be guided to a fortified building which is engineered to withstand any amount of water. This building could be funded by the city of Dordrecht (ICFM6, 2014).

9. Can the MLS approach be enforced efficiently in Dordrecht by private and public parties?

The 1st level of the MLS approach is currently enforced by the Rijkswaterstaat and the Water boards. Rijkwaterstaat requires dikes to maintain a certain height and the water board is responsible for the assessment of the dikes every 5 years for insufficiencies. However as discussed earlier, many dikes are insufficient or not accurately monitored. Stricter enforcement is needed for the dike system to prevent dike inefficiencies and penalties should be given to the appropriate parties who do not follow the rules.

The second and third layer of the MLS approach lack enforcement (Arcadis, 2015). Many structures are vulnerable to flooding in case of a dike collapse where the economic damage can be immense. Enforcing permeable pavement would be difficult due to the traffic congestion, and soil composition (Arcadis, 2015). Permeable pavement in Dordrecht would only be applicable if the soil underneath allows it. However, enforcing laws that require buildings in flood prone areas to meet a certain flooding code is possible. Unfortunately, this would need to be approved on a national level which may lead to conflict between different governmental bodies. Also, residents that live in buildings that are vulnerable may revolt due to investments needed to meet flooding codes. In the third level, evacuation routes should be enforced since it would prevent casualties. Many cities across the world give mandatory evacuations to areas that will experience flooding (RIVM, 2006).

10. What are possible conflicts that may arise from using the MLS approach (ex: ecological, increased traffic etc.)? If problems occur, are there any resolutions available to solve these problems?

The MLS approach can enhance flood safety and increases evacuation awareness. It avoids casualties and reduces costs of damages. However its conflicts and disadvantages should not be overlooked. A mentality chance is needed, the old and known way of hard engineering flood prevention is challenged by the MLS approach. The (government) experts and the inhabitants, might disagree with what the approach suggests. One of the biggest challenges in governance is the lack of legal obligations to account for the MLS approach, which is a problem because standards for flood safety at this regard and crisis management might be lacking (Watercap.eu, 2015). Environmental regulation is not addressed properly in the MLS approach, regulation conflicts with flood safety measures and with the regulations own purpose. An environmental conflict comes with nature conservation areas that can hinder the discharge of the river. In the MLS approach opportunities for nature development in those areas is missed (S. Van Herk., 2014). These problems can be solved by communication, improving awareness and by promoting legal standards that account for multi-layer safety.

11. Conclusion

After assessing the MLS approach for Dordrecht using the ten building blocks, the building blocks conclude the following:

Building Block	Applicable
1 Water System Knowledge	yes
2 Values, Principles, Policy Discourses	yes
3 Stakeholder Involvement	no
4 Trade-off between Social Objectives	no
5 Responsibility, Authority, Means	yes
6 Regulations and Agreements	no
7 Financial arrangements	no
8 Engineering and Monitoring	yes
9 Enforcement	no
10 Conflict Prevention and Resolution	no

Figure 7: Evaluation Tabl

Based on the literature review it can be concluded that there is sufficient knowledge available on the water system among the water authorities and citizens in Dordrecht. Potential flood risks are indicated at small scale and dike assessments are carried out every 5 years to check whether the dikes comply with the safety standards. Citizens outside dike areas are informed about the flood risks and are aware that high river discharges can cause flooding in streets. Certain practices have shown examples of citizens that take measures themselves to protect their properties in case of flooding. For example, using sandbags to protect buildings from flooding and making facades of houses waterproof. The municipality brings flood risk management into action by placing retaining walls in the flood prone areas of the town. There is sufficient knowledge in the first and second layers of the MLS approach. However, in the third layer there is a knowledge gap in flood disaster management on a small scale. A sound evacuation plan tailored to the future flood risks is missing. Input of emergency services, citizens and the safety region is required for successful evacuation planning. The MLS approach can substantially reduce this knowledge gap reassessment of the third layer, which is a challenge that can be overcome for this approach. This makes that the MLS approach is applicable according to the first building block.

The administrative context with regard to flood protection in Dordrecht is straightforward. There is one municipality, one water board, one safety region and one regional department of the federal agency Rijkswaterstaat (Herk, S. et All. 2011). Knowledge is shared among the different stakeholders including private parties. From the stakeholders' perspective, the Island of Dordrecht is an ideal location to explore the support amongst the different stakeholders for the application of the MLS approach. The MLS approach is an addition to the existing preventive policy. There seems to be consensus amongst the different stakeholders in the solution search process for the application of

the MLS approach in Dordrecht. The second building block is applicable since overall consensus is available, but the MLS approach can have an influence on awareness.
The Dutch values and principles upon water management are traditionally focused on a preventive approach to flood risks. It is the belief among the citizens that the water authorities will protect the land from flooding. In Dordrecht citizens are generally more aware of flood hazards due to small scale flooding in recent years. The citizens of Dordrecht might welcome the MLS approach positively since they are more aware of the negative effects from flooding. Dordrecht scores high on stakeholder involvement. Private parties are also involved. The third building block is not applicable to the MLS approach, since there are no issues on the three levels of this approach regarding stakeholder involvement.

Further uncertainties would be the question of whether the benefits are greater than the financial investments. Also, should the smaller population be displaced due to the engineering improvements for the safety of the greater population? Besides this, the lack of knowledge in the second and third layer may provoke protests and anger the public, because people are knowingly being put at risk for mitigation. These matters have not been addressed in this building block. It would be recommended to assess the possibility of financial compensations for the affected people, educating the public on the first and second layer. As research for insurability of flood risks in Dordrecht is currently ongoing (van Herk et al., 2011), this aspect is to be ignored awaiting its outcome. The fourth building block assesses the MLS approach as not feasible for Dordrecht.

The administrative context for Dordrecht is straightforward, the responsibilities in flood related areas are shared among the different authorities, which are the municipality, the water board, the province and Rijkswaterstaat. However the MLS requires a higher level of coordination by the different stakeholders with regard to sustainable spatial planning and disaster management. Based on this notion it can be concluded that the MLS is applicable regarding the fifth building block.

Regulations and agreements would need to be altered at regard of the MLS approach. At regard to regulations and existing directives the MLS approach would not conflict, however at regard to the third layer, the evacuation policy is already there in the form of the Safety Region. The MLS approach would only confuse people during the evacuation process, however this approach can build upon existing evacuation plans on a more detailed level for Dordrecht. Further assessment on the existing policy regarding the third layer would be recommendable before it can be concluded that the MLS approach is of added value in Dordrecht. Since further assessment is needed, uncertainty arises. Given this uncertainty, the MLS approach is not applicable in the sixth building block.

Overall there are uncertainties associated with technological flood performance in the second and third layer, while the dike system (first layer) is well known to be effective. In general, the MLS approach is, depending on the local situation, cheaper than implementing massive hard engineering solutions. However the island of Dordrecht already has an extensive dike system. Financial analysis has shown that the MLS approach is not cost-efficient for this specific area. The sandbags of the third layer, however, are cost efficient (Hoss, Jonkman & Maaskant, 2011). While spatial and financial objectives have prevailed for master planning (van Herk, Zevenbergen, Gersonius, Waals & Kelder, 2014). Due to these uncertainties and financial conflicts amongst parties, the financial arrangements are not robust which is why the MLS approach would not be applicable to the seventh block.

Engineering and monitoring solutions can be applied to all levels of the MLS approach and help deal with Dordrecht's flooding issues. It is important to implement engineering solutions on all levels for

enhanced flood safety. If the first layer fails, the second and third layers need to be strong to minimize casualties and economic damage. The MLS approach would also help stimulate engineering innovation. This can be achieved through smart engineering and the cooperation of the regional government, local government, private companies, and local people. Thus, the MLS approach is applicable to the eighth building block.

It will be difficult to enforce the MLS approach since enforcement is not applicable to all three levels. The first layer is enforced by top Dutch government officials and stricter enforcements are needed to maintain all dikes. The second layer can be established more on a policy level than an enforcement level since many solutions in spatial planning can lead to conflicts between different stakeholders (ICFM6, 2014). The third layer can be enforced by the city and safety region such as mandatory evacuations. Since the second layer cannot be adequately enforced, the MLS approach cannot be applied in the enforcement building block.

Communication, legal standards and awareness are needed since these cause conflicts for the feasibility of the MLS approach. The absence of legal standards for this approach is a conflict for the MLS approach. This is a problem because flood safety standards and crisis management might be lacking (Watercap.eu, 2015). Another conflict is that the MLS approach does not account for environmental gains which could mean that nature development opportunities are missed (S. Van Herk., 2014). Furthermore, a mentality change would be needed since the Dutch are more accustomed to not focusing on only prevention. Next to that there might be conflicts regarding real estate since some places would need to be redeveloped to take in account flood resilience in the second layer of the MLS approach. Old private buildings that are fragile would conflict with flood safety standards from the MLS approach. These problems can be solved by communication, improving awareness and by promoting legal standards that account for multi-layer safety. Our further recommendation is to approach enforcement with the following thought in mind, that enforcement is much easier with compensation and carrot measures. Adjusting the Safety zones (veiligheidsregio) can contribute to better evacuation in the third layer. With so many uncertainties and conflicts, the MLS approach would not be feasible according to the tenth building block.

Overall the MLS approach cannot be applied to 60 percent of the building blocks. Due to this, the MLS approach is not a robust solution for Dordrecht.

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