Flood Proof Myanmar

CIE4061-09 Multidisciplinary Project

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Boskalis

ARCADIS Design & Consultancy for natural and built assets

HKV LIJN IN WATER

DIMI Delft Infrastructures & Mobility Initiative

TUDelft Global Initiative
Science for the benefit of people. All people. Worldwide.

StuD Het betere werk

Preface

This report is the final work of the multidisciplinary project named 'Flood Proof Myanmar'. A multidisciplinary project is a master elective at the faculty of Civil Engineering. Flood Proof Myanmar consists of six students with different educational tracks, including Hydraulic Engineering and Transport, Infrastructure and Logistics. The project is realised under supervision of Dr. Ir. Martine Rutten, Dr. Ir. Adam Pel and Prof. dr. ir. Marcel Stive of Delft University of Technology. As the project name probably reveals this project is performed abroad in the rapidly changing and beautiful country of Myanmar. Due to these rapid changes Myanmar attracts great international interest of authorities and companies. Therefore the country of Myanmar is included in the International Water Ambition (IWA) of three Dutch ministries. This means that the Netherlands starts a long-term cooperation with a double goal: achieving sustainable water management in Myanmar and creating opportunities for the Dutch water sector. As a result Flood Proof Myanmar cooperated with three Dutch companies within this water sector: Boskalis, Arcadis and HKV Lijn in Water. Besides the cooperation with these Dutch water companies, there is also cooperated with Myanmar universities, namely Myanmar Maritime University and Yangon Technical University, a Myanmar department, namely the Irrigation Department and Myanmar organisation, namely Yangon City Development Committee. This is done to get national insights of Myanmar and to raise support for the project.

Acknowledgements

The realisation of this project would not have been possible without the help of many people, who have supported us throughout the entire process. Firstly we would like to express our sincere gratitude to Prof. dr. ir. Marcel Stive, who responded very enthusiastically when we showed him our interest in Myanmar and introduced us to Dr. ir. Martine Rutten. Besides he took the time to answer all of our questions about Myanmar, whether they regarded hydraulic problems, politics or the culture. Martine has been involved from the start and has guided us through the entire project. She has already been involved in many projects in Myanmar for years. Because of this she was a great help in defining the project and even more important, she introduced us to an entirely new world in Yangon for which we are very grateful. Her enthusiasm and critical questions really lifted our project to a higher level. Our third supervisor, Dr. ir. Adam Pel, we would like to thank for his motivation, enthusiasm and for his guidance concerning a multi-disciplinary project. He has had a widening view, showing us the importance of the aspects next to the technical content. Moreover, we are very grateful for his help concerning evacuation analyses.

Furthermore we would like to thank Ir. Alwin Commandeur, who familiarised us with the working culture in Myanmar and who introduced to valuable contacts. Also he was a great help in gathering data. We would also like to acknowledge Ir. Marjan Kreijns, who introduced us to Flood Proof Holland and gave us good advise. We thank Chit Yan Toe for welcoming us in Yangon when we arrived, showing us around, helping us to understand the cultural and political situation and especially for introducing us to the River & Coastal staff of the Myanmar Maritime University. Our gratitude goes out to Prof. dr. ir. Khin Kyu Kyu, head of the RiverCoastal Department at Myanmar Maritime University. She was a great help from the start on, welcoming us into their university, providing us with essential data and introducing us to other students.

Special thanks go to our partners, for collaborating with us on this project. Ir. Tanya Huizer from Arcadis helped us in the preparation phase in the Netherlands as well as in Yangon. Many thanks for this. Her sincere interest and enthusiasm really encouraged us to work hard. To Ir. Hermjan Barneveld from HKV, also many thanks for the help regarding the outline of the project and for the good advice right before we travelled to Myanmar. We would like to thank Dr. ir. Walter Jacobs from Boskalis for his honesty, his trust and the good advice. In addition we would like to express our gratitude to the people of DIMI and Ir. Friso Vos de Wael from Delft Global, for showing interest and trust and for opening up a platform for our videos.

Next, our gratitude goes out to Dr. Zaw Lwin Tun, who took the time to listen to us, gave us very useful advise and introduced us to key sources for this report. It was always a pleasure to speak with him, also because of his great sense of humor. We thank Ir. Kyaw Zayer Tint, Dr. Toe Aung and Ms. Nyein Aye as well for helping us gathering information about the research areas.

We thank Pan Ei Ei Phyoe, who has been an amazing help during our stay in Yangon. The survey in Nyaungdon could not have been conducted without her. We also thank her for making us feel at home in Myanmar, helping us fixing our accommodation, introducing us to other students and showing us around. Hopefully we will see each other again soon. Finally, we thank all of our friends, families and others who showed interest in our project and encouraged us from long distance. We tried our best to keep everybody informed and involved and we hope you enjoyed it.

Summary

The objective of this research is to make a general framework, that when run through one can find a suitable measure to make a particular area in Myanmar flood proof.

Myanmar suffers from yearly floods that have a huge impact on the population. Making an area flood proof is therefore one of the objectives of the civilian government. In this report 'flood proof' is defined as a status that shows that an area is prepared to control the effects of a flood. To achieve this goal a general framework has been created. This general framework guides the reader through multiple analyses, a development of alternatives, an assessment and an implementation. It has the objective to be transparent, reproducible, elementary, based on existing methods and based on data. To test this general framework on these criteria two cases with different research areas are chosen namely, case I: Nyaungdon and case II: Dala. The report is therefore developed as an incremental and iterative process.

In this report a range of alternatives has been taken into account, that includes more than only the hydraulic measures. To implement the Dutch method of treating a (potential) flood a multi-layer safety approach has been used. This approach consist of three layers namely, prevention, spatial solutions and crisis management. All the alternatives of this report can be classified into one of these layers.

The analysis phase of the general framework has been focussed on four specific analyses. The four specific analyses are a flood risk analysis, an actor analysis, an evacuation analysis, and a future scenario analysis. These analyses combined with the general analyses lead to the development of alternatives.

The method that has been used to determine the relatively best alternative is the multi-criteria analysis. Most of the time it is preferred to combine several alternatives in packages to generate the best possible solutions. After these solution packages have been created for every research area an implementation has been done including an adaptive strategy.

The data that has been used in this project is gathered by interviewing experts, conducting surveys and reading reports and researches. Due to a lack of data, a lot of assumptions have been made. An overview of the lacking data is given that is necessary to complete further research.

Case results

For both of the cases the framework could be implemented successfully. The results of the multi-criteria analyses are the following:

- Case I: the outcomes of the future scenarios did not show a lot of variety. Therefore it is recommended to implement one package. The package consists of optimising the dike, applying sandbags if necessary and a medium evacuation package.
- Case II: as the future scenarios differ in outcome, multiple packages are created. Each package

contains an alternative for each of the three layers. Each package consists of a flood wall, an improvement on a spatial solution and an evacuation package.

It can be concluded that the framework works. It gives a solution for a particular area that is threatened by a potential flood. However it is recommended to perform every analysis in a more detailed way. The framework should be optimized by applying it on more case studies and adjusted it if necessary.

Guide of report

This report needs some explanation regarding the structure. Three main parts can be recognized namely, the report on the framework itself, a case study about Nyaungdon and a case study about Dala. The case studies are located within the main report of the framework, as their function is to test the framework.

If desired, the three parts of the report can be read separately but references between the general framework and both case studies are present. It is recommended to read the entire report if one desires to know all the details about the case studies and the framework.

Additionally with the report some `Excel`-sheets have been provided. These have been used for the case studies and can be consulted to complete the corresponding analyses.

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1 | Introduction

1.1 Background

Problems with water have been present as long as people live near it and people have tried to protect themselves against its dangers. As the sea level rises, populations grow and densities of cities increase, the risks of floods increase. These risk became clear for the Netherlands about 60 years ago. The Netherlands have tried to deal with water ever since the middle ages, but a storm in 1953 permanently changed their way of thinking about their defences. Large parts of the Netherlands were flooded and the following decades structures were build and policy were adapted to prevent this from happening again.

As it is important for humanity that all countries are protected against the dangers of water, the Dutch government has worked together with many governments to prevent different water problems all over the world. A good example is the cooperation between Vietnam and the Netherlands, where a plan was made to deal with the problems of the main river of Vietnam; the Mekong Delta Plan. In 2013 a minister of the Dutch government and a consortium went to Myanmar to talk about the problems present in Myanmar and have signed a partnership agreement ("Minister Schultz: the Netherlands and Myanmar are making progress in water management", 2014).

In July 2016 a tender has been announced on the development of an integral strategic study of the Ayeyarwady Delta of Myanmar (Ministerie van Economische Zaken & Rijksdienst voor Ondernemend Nederland, 2016). At the time this report is produced, work is being tendered. This report has partly been written with the knowledge that its content might contribute to the production of this strategic study. Besides it is tried to grasp the big problem of flooding in Myanmar.

Figure 1.1: Breached dike during the flooding disaster in the Netherlands (Rijkswaterstaat, 1953)

1.2 History of Myanmar

To get insight in the current situation in Myanmar it is required to have some knowledge of the political, complex history of Myanmar. There is tried to give a brief summation of all the relevant political events that have happened in the past.

The Burmese population orginally comes from China where it was chased away to the south. In 1044 the first Burmese kingdom started, after this two more kingdoms have followed with periods of disunity in between. The third kingdom conquered a lot of new areas including the border area with India (Verrijp & Willems, 2016).

A period of Anglo-Burmese wars followed. On January 1886 Burma was completely under colonial policy by the British. This domination led to economic improvement. Roads, railways and ports were built. The Burmese economy was around 1900 one of the fastest growing and most developed of Asia. Though, the profits were mostly for the foreign investors and not the local Burmese population. This caused dissatisfaction and after the crisis in the agricultural sector revolts took place. As a result Burma became a bit more autonomous (Embassy of the Kingdom of the Netherlands in Yangon Myanmar, 2016).

In January 1942 the Japanese invaded Burma. The Burmese independent army helped the Japanese to drive off the British. At the end of World War II the Burmese sympathised with the Allied Powers and the Japanes surrendered in 1945 (Embassy of the Kingdom of the Netherlands in Yangon Myanmar, 2016). In 1946 the British conceded and this was the first step to independence, offically Burma became independent on 4 January 1948 (Verrijp & Willems, 2016).

The new government had a heavy task to fullfill, the economic situation was very poor due to the war and rebellious minorities were threatening the government. The situation became worse after elections and General Ne Win committed a coup d'etat in 1962. From then on the military was leading the country, the constitution disappeared and the economy stagnated due to the nationalisation measures. In 1988 the population was tired of this regime and massive protests took place. A lot of protesters died due to rough treat by the army (Verrijp & Willems, 2016). In this period the opposition started with the National League for Democracy and Aung San Suu Kyi was one of their foremen. She and her party became very popular and won the first election in 1990 with a great majority but the military wanted to prevent the National League for Democracy from governing the country so a lot of the leaders of this party were arested. The next elections in 2010, the first mostly 'democratic' elections in 50 years, were boycotted by this opposition parties because it did not agree with the new constitution and the independence of the election process (Embassy of the Kingdom of the Netherlands in Yangon Myanmar, 2016).

In 2011 the military gave the authority to a civilian government and the president promised a lot of improvement on democratisation, open market economy and fighting corruption. The dialogue with the opposition started as well. A year later, in 2012, the National League for Democracy won the elections with obvious numbers and it took place in the parliament. A few years later the National League for Democracy has a majority in the Parliament and Aung Suu Kyi fullfills some important tasks in the government. Nevertheless the military still has power, with reserved seats and ministries (Embassy of the Kingdom of the Netherlands in Yangon Myanmar, 2016).

1.3 History of flooding in Myanmar

Myanmar is a low lying country that suffers from regular flooding on annual basis, this is due to (relative) sea level rise, urbanisation, felling of mangroves, aquaculture, agriculture and infrastructural development (Kroon & Rip, 2015). These nationwide developments in combination with heavy rainfall during the rainy seasons and the cyclones that hit Myanmar every year cause major problems and lots of casualties all over the country.

According to figures from Myanmar's Relief and Resettlement Department, Ministry of Social Welfare, about 500.000 people have been affected by flooding in 11 states or regions across the country since June 2016. Many of the worst hit areas are along the overflowing Chindwin and Ayeyarwady rivers, as illustrated in figure 1.2, from the Myanmar Information Management Unit (Davies, 2016).

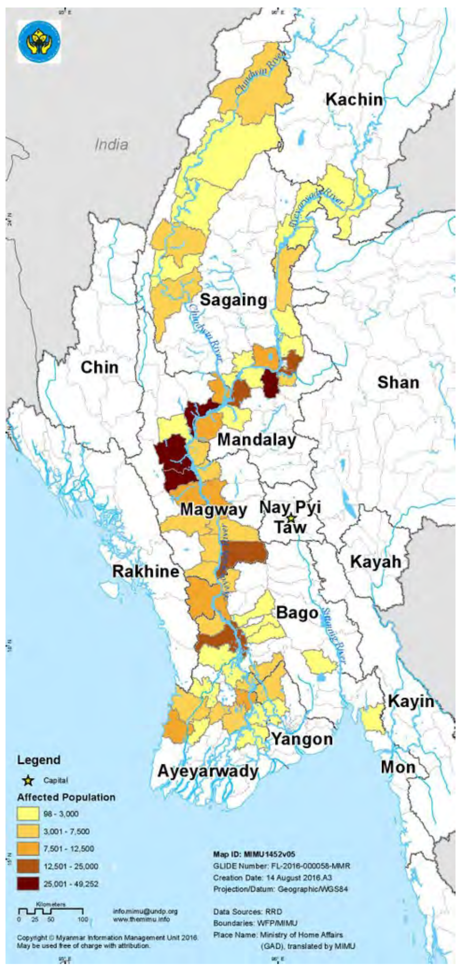


Figure 1.2: Flooded areas Myanmar in 2016

Flooding leads to loss of lives and properties, damage to critical infrastructure, economic loss and health related problems, such as: outbreak of water borne diseases when the lakes, ponds and reservoirs get contaminated. What is even ironic is that the main problem of floods is a lack of drinking water. The country receives practically all its rainfall between mid-May and October, the rainy season, during which flooding and landslides are common (Meteorology and Hydrology et al., 2009). In Myanmar, the threat of flooding usually occurs in three waves: June, August and late September to October. In these periods of flooding, four different types of floods occur:

- *Riverine floods* in the river delta. They are common among all rivers and they happen during the monsoon's heavy rainfall.
- *Flash floods* in the upper reaches of the river systems, normally the mountainous areas, caused by the heavy rainfall striking for a considerable period of 1-3 days.
- *Localized floods* in urban areas due to a combination of factors such as cloudburst, saturated soil, poor infiltration rates and inadequate or poorly built infrastructure. In rural areas due to the breakage of water resistance structures as dams and dikes.
- *Flooding due to cyclone and storm surge* in the coastal areas.

Over the years many floods have struck Myanmar, causing thousands of casualties. Most of these floods occur during the tropical monsoons, caused by heavy rainfall resulting in the rivers to overflow every year. The Ayeyarwady and Chindwin rivers, which are two of the largest rivers, cause floods when intense rain persists for at least 3 days over the northern part of Myanmar.

Floods that occur less frequent are caused by severe cyclones that hit Myanmar only on average once in 40 years. Most tropical cyclones tend to head off to India and Bangladesh and not to Myanmar, but over the years a couple of strong cyclones have hit the country. Nevertheless, when they do strike the results can be devastating as was the case with cyclone Nargis in 2008, which killed over 120.000 people.

1.4 Problem analysis

Although the problems came forward in section 1.3 the history of flooding, this section tries to frame the problem for this particular report. In this section an overview of the problem definition, problem statement and scope is given. The objective of this section is to clarify the problem.

1.4.1 Problem owner

This report is written for the governance of Myanmar, which makes it the problem owner for this research. The (civilian) government is chosen since it has the ability, power and interest to have influence and reduce the damage of floods. The reason why a department of the governance is not selected, is because of the dependencies and shared responsibilities between departments concerning flood protection. For a more detailed information concerning the tasks of departments, see also appendix A.1.2

1.4.2 Problem definition

As is stated in the introduction is that floods can have a huge impact on the population in Myanmar. Reducing the damage of floods and having a good flood control are objectives of the Civilian governance of Myanmar. The current measures against floods are insufficient (van Meel et al., 2014). Consequently the research question that will be answered in this report is:

What is a good method to make several regions in Myanmar flood proof?

In this problem statement it is specifically chosen to phrase 'what is a good method'. Hereby meaning to find a method that has the ability to find the most suitable measures in a particular scenario in a particular area. In order to find this suitable measures multiple alternatives and multiple analyses are taken into account. In the second part 'several regions in Myanmar' are called. The goal of this report is not only to built a specific framework for a particular area, the framework must be applicable for every region in Myanmar. In the last part of the research question, there is spoken of the term 'flood proof'. Flood proof is a status that shows that an area is prepared and is ready to control the effects of a flood.

1.4.3 Research goal

The research goal is to make a general framework, that when run through, one can find a suitable measure to make a particular area flood proof. Since several parties are involved in decision-making and responsible when it comes to floods, the government would benefit from a structured approach to prevent and mitigate them. The framework has to be reproducible by all parties, in order to facilitate their cooperation. Another objective of this research is to identify which data is needed to generate an appropriate result and to identify which data is now missing and needs to be gathered in the future.

1.4.4 Limitations

For this project there are some limitations that have to be dealt with. The largest limitation is the lack of data, which affects the accuracy of the analyses. As a result, a lot of assumptions have been made. In this report there is tried to write the assumptions as clear and transparent as possible. Another limitation was the (mis)understanding of the Burmese language. Therefore some of the data is collected indirectly by using a guide who could translate the data. A final limitation was that it was not always even as simple to get in touch with the right person for the right questions. In Myanmar this takes more time than originally anticipated.

1.4.5 Geographical Scope

To test the framework two different research areas are chosen: a rural and an urban area. Both have the characteristic that they have struggled with floods in the past or they will struggle with floods in the near future. In consideration with the partners and supervisors of this project the two different specific regions are chosen, which are depicted below in figure 1.3.

1.4.5.1 Case 1: Rural: Nyaungdon

Nyaungdon is a rural area that has already been investigated by the Dutch Risk Reduction team (Steijn et al., 2015). One of the recommendations of the DRR team was to do a follow up investigation on the alternatives against flood protection.

1.4.5.2 Case 2: Urban, Dala (Yangon)

Dala is one of the townships of Yangon. It is separated by the Yangon river and therefore only accessible by ferry. However in 2020 a bridge that connects these two parts will be finished (Thander Tun, 2015). According to several sources Dala can be an upcoming area that might boost the economic welfare of Yangon. The only problem that is foreseen is that Dala is located near the unprotected waterfront. Due to the relative sea level rise, Dala will be affected by floods.

Figure 1.3: Location of the two research areas

From the general research question follows the research question for these two case studies.

What are suitable measures to make Nyaungdon/Dala flood proof?

2 | Framework Proposal

In this section the framework is introduced, together with its goal and the requirements it should satisfy. The approach and the general structure of the framework are also discussed, including its main phases and the relation between them.

2.1 Framework goal

As stated in the previous chapter it is crucial to find measures for the flooding related problems in Myanmar. This framework is a tool to find the best measure against floods for several areas in Myanmar. In order to design and optimize the framework, it has been applied to two different cases in Myanmar. Although it is only tested on two locations, the goal is to make it applicable for multiple locations in the country of Myanmar.

2.2 Framework criteria

To accomplish its goal, the framework should satisfy a list of criteria. These have been determined by using an objective tree, which has been elaborated in appendix A.1.1. The following criteria have been established:

- Elementary
- Transparency
- Objectivity
- Flexibility
- Use of existing methods
- Based on research

These criteria should not be confused with the criteria that the solution, given by the framework, should meet. These will be discussed and evaluated in the 'Assessment' phase, section 2.7. The framework criteria are hard to evaluate, since they cannot easily be expressed in quantities. Moreover, a profound and valuable evaluation could only be done after applying the framework to many different cases. Nevertheless, they will be evaluated as best as possible considering the two different cases of this report in chapter 18.

2.3 Approach

The framework approach is based on the Dutch method of treating a (potential) flood. Moreover the Dutch method is expanded in such way that it can be used in Myanmar. The multi-layer safety approach consists of three layers, which are described as follows (Hoss et al., 2013).

1. **Prevention**: this is defined as preventing river and sea water from inundating areas that are usually dry. This is done by building flood defences. These flood defences can be characterised with features such as: natural or artificial, static or dynamic and hard or soft. This is elaborated in section 2.3.1 with examples.

2. **Spatial solutions**: these contain spatial planning and adaptation of buildings to decrease the negative effects of a flood when it occurs. This framework mainly focusses on the methods: elevation and (re)location. Besides, attention is given to other measures such as drainage systems.

3. **Crisis Management**: this focuses on the organisational preparation for floods such as disaster plans, risk maps, early-warning systems, evacuations and temporary physical measures (e.g. sandbags, see section 2.3.1) and medical help.

Layers 1 and 2 are more physical measures, whereas the third layer focuses on organisational measures. Figure 2.1 gives a graphical representation of the multi-layer safety approach.

Figure 2.1: Multi-layer safety approach (Kolen et al., 2010)

Two important definitions are frequently used in the framework to describe the reaction to floods of the research location. To prevent confusion about their interpretation the definitions are described as followed:

- **Resilience**
  Over the years several definitions of resilience have been presented. In this report the following definition will be used: "Resilience is the ability of systems to withstand or adapt to changes without being harmed in their functionality" (Restemeyer et al., 2015). This definition shows the two main aspects of resilience: withstanding and adaptation. The objective of implementing resilience into the framework is the continuation of a system's functioning by minimizing the consequences of a disturbance (Barroca & Serre, 2013), which in this case could be a high water level for instance.

- **Resistance**
  Resistance can be defined as the ability of a system to withstand disturbances without reacting at all (de Bruijn, 2015).

Combining both concepts one can conclude that a system's reaction to a disturbance depends on its resistance and resilience.

2.3.1 Existing measures

As flooding is a problem that has existed for many centuries, numerous flood defences and measures have been developed and improved. Still new ways to prevent flooding are being developed, especially in the area of temporary flood defences.

As described above, the layers of the multi-layer safety approach are characterised with different flood defences and other measures. In this section the many features of defences and measures to adapt to or defend from flooding have been described.

2.3.1.1 Layer 1: Prevention

As mentioned, layer 1 is characterised with the following features:

Natural defences

- **Dunes**
  These sand structures are found along the coast, protecting the hinterland from the sea. Dunes are naturally formed at sandy shores and can be adapted to function as a defence.

- **Salt marshes and mangroves**
  Salt marshes and mangroves are naturally formed ecosystems that contribute to coastal protection. The coasts of Myanmar contain mangroves, as Myanmar is close to the equator where mangrove forests are very common.

Artificial defences

Artificial defences are characterised by the fact that they are non-natural and thus created by humans. There are many different types of defences:

- **Dikes**
  Dikes are typical measures to prevent floods. These soil bodies can be constructed to retain water. The height of these dikes can be adapted. High dikes can withstand extreme circumstances, but one can also design a system with multiple dike rings with lower heights.

- **Dams**
  Dams are structures with water on both sides. Types of dams can range from examples like the Afsluitdijk in the Netherlands, which is type of a dike with water on both sides, to the Hooverdam, which is a blockage in the river ('stuwdam' in Dutch).

- **Flood walls**
  Floods walls are vertical, most often concrete, structures that have a water retaining purpose. As water performs a horizontal force on these walls, the foundations of the flood walls have to be very strong.

- **Moving structures**
  Moving structures might also be a solution for flooding problems. These structures are often case specifically designed, in order to fulfil their purpose. A good example is the Maeslantkering (Measlant Barrier) near the Hoek van Holland, The Netherlands. This barrier is used as a storm surge barrier, see figure 2.2.

Figure 2.2: Maeslantkering while closed (van Eyck & Rijkswaterstaat, 1997)

Hard and soft measures

Beach and bank erosion can be a reason for the increase of flood vulnerability. In order to prevent severe erosion, hard and/or soft measures could be undertaken. Examples of hard measures are groynes or breakwaters. Soft measures are for example nourishments.

2.3.1.2 Layer 2: Spatial solutions

Layer 2 is distinguished by the following methods:

Elevation

Elevation of current houses and or facilities is a measure to prevent damage from flooding. Since people do not like to move their houses elsewhere they have to move their houses upwards. In Myanmar this often means that houses are constructed on stilts, see figure 2.3.

Figure 2.3: A house built on stilts near the waterfront, Dala (image by Joke Blom)

(Re)location

Location and relocation are two different definitions. Locating functions and facilities requires thinking ahead and trying to foresee a problem before it occurs. Relocation of functions and facilities stands for moving from their current location to a different location. An example of (re)location is found near Nijmegen, the Netherlands. It is a project called 'Room for the River', see figure 2.4. Space is preserved for the river such that the river has more room to flow. This reduces the flood risk, therefore some facilities had to be relocated. Although this measure might sound like a prevention measure, for this project it is defined as a spatial solution measure since the solution for the flooding problem is located outside the case area. Therefore it is defined as a spatial solution.

Figure 2.4: Room for the River (Ruimte voor de Rivieren, n.d.)

When implementing such solutions to a country like Myanmar, one has to think of the willingness to move facilities and functions. Families might not want to move in order to make room for a river and could prefer to heighten their houses or to construct a dike.

2.3.1.3 Layer 3: Crisis management

The following measures are characteristic for layer 3:

Temporary defences

Most often sandbags are used to protect areas from flooding, but many different types of temporary defences have been developed in recent years. The temporary defences have been subdivided into four categories namely inflatable, membrane, modular barriers and regular sandbags.

- **Water inflatable barriers**
  These temporary defences are installed by inflation with water. This means that the barriers have to be filled before the water starts to rise. Examples are the SlamDam and Mobiele Dijken (Mobile Dikes).

- **Membrane barriers**
  Membrane barriers make use of the rising water to stabilize the barrier on the ground. Examples are the Tubebarrier and the Water-Gate.

- **Modular barriers**
  Modular barriers are barriers that are constructed of many different separate parts, together functioning as one barrier. An example is the BoxBarrier.

- **Sandbags**
  In order to prevent floods, bags filled with sand, are stacked. The sandbags are preferably stacked before high water. Often the bags are used when dike failure occurs. An alternative for regular sandbags is the Green Soil Bag, which is a sandbag with fertile soil inside. This allows a transformation of sandbags into a new part of the dike.

Evacuation

When defences or any other preventive measure against flooding fails, the most effective option to reduce the number of casualties and fatalities is by evacuating the population. It is a fall-back solution. Evacuation is in principle the movement of people, animals and property to a relative safer location (Kolen, 2016). But in this report the term evacuation can be seen as the entire process of alerting, warning, preparing, moving and temporary housing. Although, evacuations can have disadvantages; it is costly, can cause a crisis in the society and can cause a risk of fatalities. Still according to Kolen (2016) investing in evacuations pays off in supplementing prevention measures such as dike reinforcements. This makes it one of the reasons that evacuation is taken along into the process of the framework to find a solution for a flood proof area.

The existing evacuation plan in Myanmar is usually written by the National Disaster Committee and is a section of the local disaster plan. This will be eleborated in more detail in section 2.5.7.

2.4 General structure framework

As earlier stated, the main product of this project is a general framework. The position and integration of the framework in the entire project can be observed in figure 2.5. A more detailed structure of the framework and its elements is shown in figure 2.6.

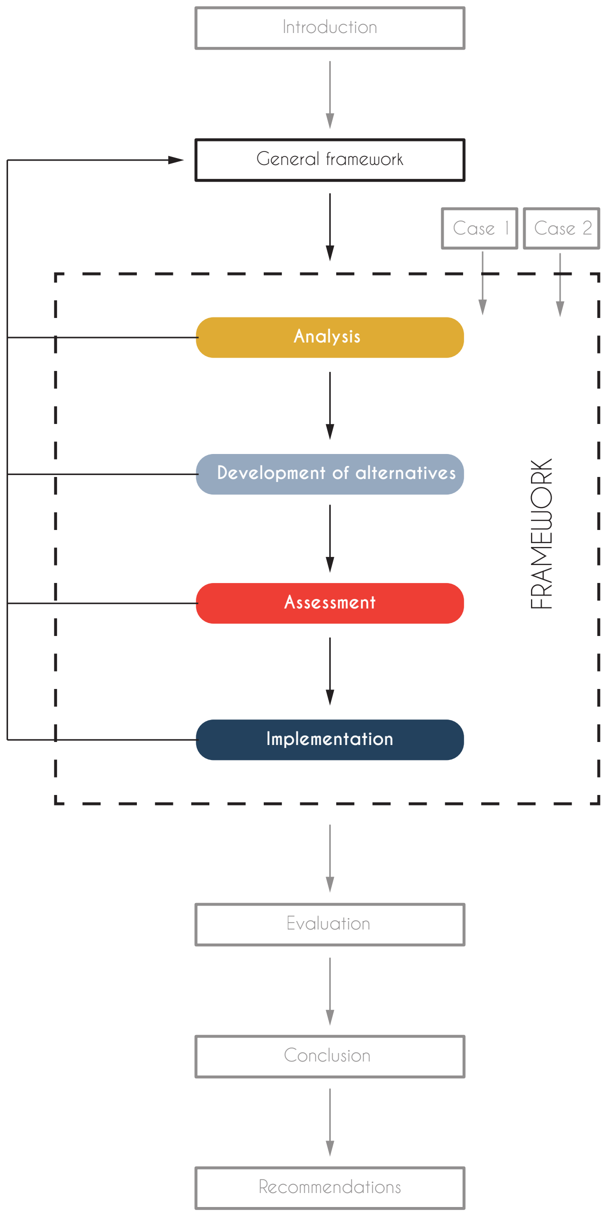


Figure 2.5: Structure report

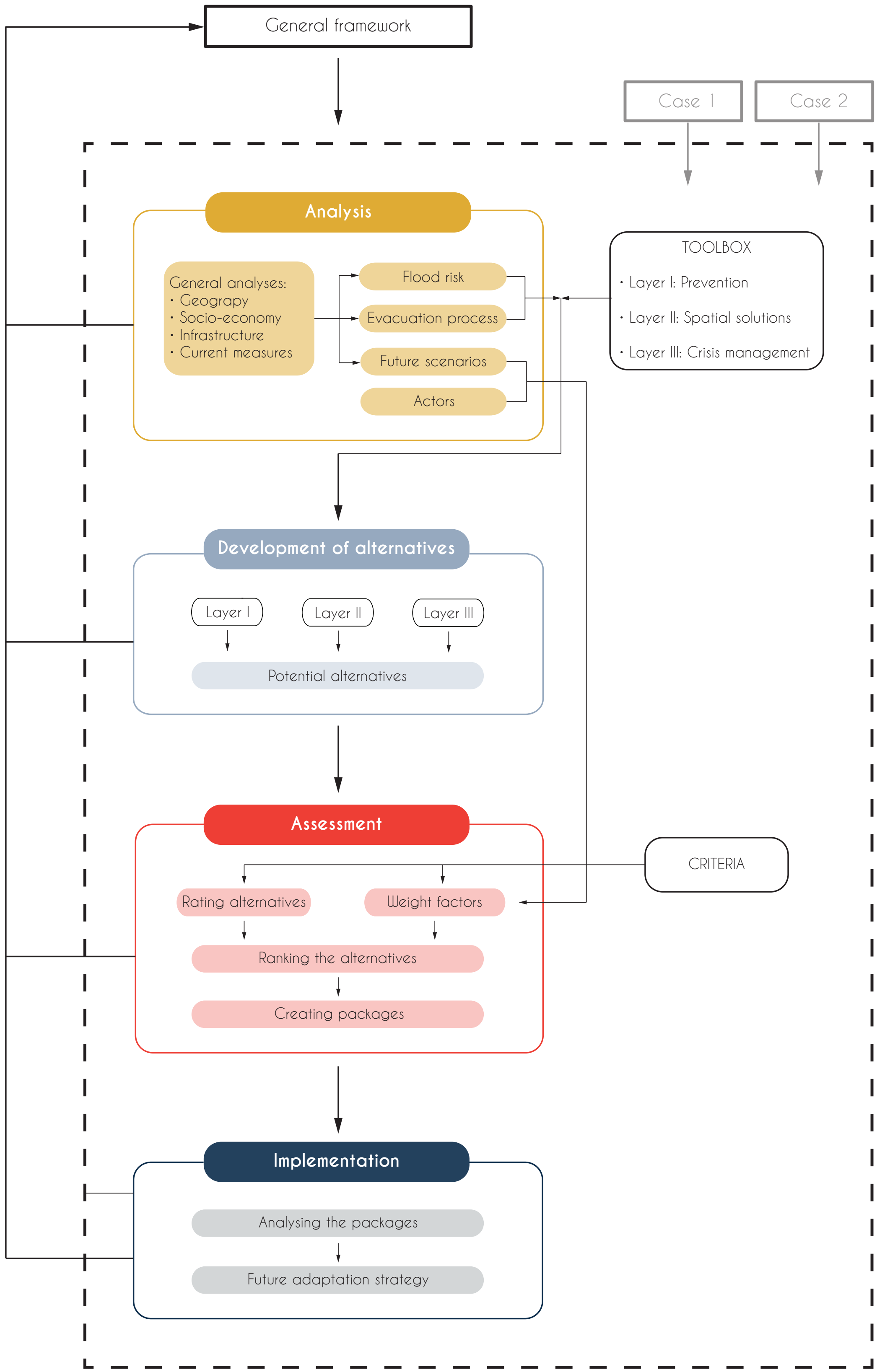


Figure 2.6: Structure framework

As the figure shows, the framework can be divided into four different phases. Feedback loops from the phases coupling back to the general framework can be noticed. This framework is developed both incremental and iterative. When developing a framework incrementally one writes down all the steps of the framework. The steps have been laid out and they only have to be followed. Building a framework incrementally can lead to faults in the framework. No time is taken to improve the faults in the framework, because there is no feedback. The correcting strategy is an iterative development of the framework (Cockburn, 2008). Adding an iterative strategy ensures that faults in the framework can be prevented.

The phases of the framework have been elaborated in the following sections below.

2.4.1 Analysis

Goal

Collecting and interpreting data about the current situation by using different analysing methods in such a way that the current situation can be mapped objectively and that insight could be gained concerning the possible future with a certain accuracy.

Approach

The location has to be analysed on different aspects. The analyses shown in the schematic drawing 2.6 only shows the three most important analyses that have been used. Besides these three analyses this framework treats all the analyses that are listed below.

- Physical geography
- Socio-economy
- Infrastructure
- Current measures against floods
- Actor analysis
- Flood risk analysis
- Evacuation process analysis
- Future scenario analysis

2.4.2 Development of alternatives

Goal

Developing and gathering possible solution methods for the flood related problems at the location, considering all future scenarios defined in the analysis phase. This demands a consideration between the current situation and the future state.

Approach

The current state and the expected future state of the location have to be combined in order to investigate potential solutions. These states have already been investigated in the analyse phase. All appropriate measures for the future scenarios should be considered in the potential solutions.

2.4.3 Assessment

Goal

Finding the best solution out of the potential solutions for the flooding problem within the set criteria for all scenarios.

Approach

In order to determine what the best alternative is, the following evaluation analyses should be done:

- Multi-criteria analysis
- Cost-benefit analysis

2.4.4 Implementation

Goal

To design the chosen solution in more detail, so that it can be integrated in the current situation, still fitting the future scenarios. Furthermore this phase functions as a check to determine whether the solution that is chosen based on the framework, is feasible or not. Thus it can be considered a check for the framework combined with the particular situation.

2.5 Phase 1: Analysis

In this first phase of the framework all the different analyses will be elaborated in more detail, showing all the steps that has to be taken in order to perform a good analysis.

2.5.1 Physical geography

2.5.1.1 Topography

This section should describe the relief, the three dimensional quality of the surface and the identification of specific landforms as hills and mountains. This holds for the case location as well as for its surroundings. This is importan to know because this way one can find out where higher areas are located which is usefull to know in later stages of the framework.

The use of free `SRTM` maps is recommended to obtain a general idea since they are openly accessible and give clear results. The downside is the relatively poor accuracy. In horizontal direction the accuracy is within a range of 30 metres, and for the elevation the range is within 16 metres of accuracy. Another option is the use of DEM data, which cost €1,75/ km^2 for an accuracy range of 5 metres and €43,80/km^2 for results with an accuracy range of 0.5-2 metres (Tighe & Chamberlain, 2009). In case a detailed plan has to be made for the location, the use of accurate DEM data is highly recommended.

2.5.1.2 Geomorphology

The soil type of the research area has to be investigated. The map below shows the general distribution of the soil types in Myanmar. Unfortunately, it does not provide information on the amount of clay and sand. This variable is very important for the selection of measures later on, since hard prevention measures cannot be implemented in soft clay en silty soils. In case no information is available about the soil composition, a soil survey is required to determine the most suitable measure.

Figure 2.7: Soil types Myanmar

2.5.1.3 Bathymetry

The bathymetry is the description of depths of oceans, estuaries or rivers. Bathymetry maps often show a lot of details, like the varying depth of a river near a river bend or the location of sand bars. The bathymetry is of importance for river discharges, localizing erosion or accretion and for the navigability.

2.5.1.4 Climate

The climate of Myanmar varies depending on the region: about two-third of the country is located between the tropic of Cancer and the Equator resulting in a tropical climate, mostly determined by the monsoon periods. The central part of Myanmar, situated in the shadow of the Arakan Mountains, is the driest region with an average rainfall of 760 mm per year. The higher elevations are regularly subject to heavy snowfall and bad weather (van der Velden, 2015).
Since the climate can vary depending on the region, it is of great importance to study the climate

of the case location in detail. The amount and period of rainfall should be considered, since this is often the primary cause of floods.

2.5.1.5 Hydrology

Describing the hydraulic conditions is essential as they conceal information that might give insight on the problem and its solution. These hydraulic conditions are furthermore needed for the flood risk analysis. Depending on the location in Myanamar the hydraulic conditions can consist of:

- Current velocities for river systems.
- Water levels, both for mean water levels as high water levels due to high river discharges.
- Tidal ranges for coastal regions. Near the delta the rivers are also affected by tides.
- Storm surge levels due to storms and cyclones, especially for coastal regions, but possibly also for inland rivers.
- Wave heights and wave periods in case of coastal regions.
- Tsunami waves due to earthquakes.

Preferably in an analysis of an area the hydraulic conditions have been measured for many years on specific locations. More data enables accurate defining of hydraulic conditions and one could do probabilistic calculations. Currently the amount of data of hydraulic conditions in Myanmar is limited. Data is available, but only for some specific locations. Besides, the measurements have not always been done for long periods. It might be needed to use data from different surrounding locations in order to say something about the research area, but this should be based on well founded assumptions.

2.5.2 Socio-economy

This sections shows social aspects and processes of the research area and the way they affect the economic activity. These data is necessary to fulfil the flood damage assessment. Moreover, the economic situation partly determines the kind of flood protection that is feasible.

2.5.2.1 Population

Population information such as number of inhabitants, families and housings should be gathered to create a general idea of the social situation in the area. Also the occupation of the population is very useful to know.

2.5.2.2 Economy

The economic situation of the location should be described, preferably showing the industrial structure and the main import and export products. Considering the future scenarios that will be considered in the following phase, it is very important to investigate economic trends and make an assumption on the amount of money there is to spend on water protection measures.

2.5.3 Infrastructure

For the infrastructure it is important to look at different kinds of infrastructure to tell which infrastructural networks are present. One should check the roads, waterways and railways and elaborate on them if present. Maps can help to give a good idea about the infrastructure. For the roads it is important to identify what kind of roads are present, which material they are made off (asphalt, concrete, gravel or soil) and what the width of the roads is (especially the number of lanes). This can be necessary for an evacuation plan. Next to this, it is important to check if there are concrete plans for future infrastructure. If plans are made and it is likely that the infrastructure will change, it is important to take this into account because it will influence the measures.

2.5.4 Current measures against floods

When analysing an area one should always look for current measures that have been taken against flooding at the location of interest. By doing so an idea is formed about the current level of protection. One should look for the measures as described in section 2.3.1 which gives a good overview of the solutions that could be present.

2.5.5 Actor analysis

In this section an overview is given of all the important actors and key players concerning flooding in Myanmar. For the largest part the actor analysis is already done at a national level and can be found in appendix A.1.2. It is recommended to read this appendix first. The objective of this chapter is to complement the analysis at regional and local level. Therefore the steps to complement the analysis are written down below.

An actor is a social entity, person or organisation able to act on or exert influence on a decision (Enserink et al., 2010). In other words: actors are those who have a certain interest in the system or have the ability to influence the system both directly and indirectly (Enserink et al., 2010). This analysis is useful to understand which actors are critical for the problem owner and should always be involved in every decision step.

This actor analysis is split up in 3 different parts. In section 2.5.5.1 an example of an overview is provided covering the actors, their interest and objectives. In section 2.5.5.2 a formal chart is exhibited including the formal tasks, authorities and relations of actors in-between. In section 2.5.5.3 all the actors are classified based on the level of support/interest and power.

2.5.5.1 Overview of all the actors involved

One of the first steps in an actor analysis is making an inventory of the actors involved including their interest/objectives and solutions. One structured way to do so is to fill in table 2.1. The table supports a systematic comparison of the problem formulation and helps to identify similarities and differences between actors (Enserink et al., 2010). For each actor their interest, desired situation, expected situation, the causes and possible solutions are written down.

Actors	Interest	Desired situation/objectives	Expected or existing situation	Causes	Possible solutions / sources

Table 2.1: Example structure of a table

In appendix A.1.2 the above table is already filled in at a national level. The overview should be complemented by defining which regional and local authorities have interest and power to influence flooding. Besides, special notes should be made about which humanitarian organisations and which multinationals have interest in this specific region. At last determine the population group of the research area and investigate their relations with the government.

A recommendation is to search for actors of humanitarian organisations by using the website of Myanmar Information Management Unit (Myanmar Informartion Manegement Unit, 2016). All of the organisation present in the township during flooding are classified by sector.

2.5.5.2 Formal chart

In figure A.2 below the most important relations between actors are provided. It is chosen to describe the formal relations as well as the informal ones. A dashed rectangle means the actors belong to the same shared group. A single-headed arrow indicates a hierarchical relation, a two sided arrow indicates a representation of a relation (Enserink et al., 2010). Appendix A.1.2 shows the explanation of the formal chart at a national level.

Since the political climate is constantly changing it is important that all the relations in the national formal chart are checked. For instance: are the departments still at the same ministry? Arrows and actors can be removed or added for the particular research area. Although the formal chart can look complex it can be an useful tool to give insight in how all the actors are related.

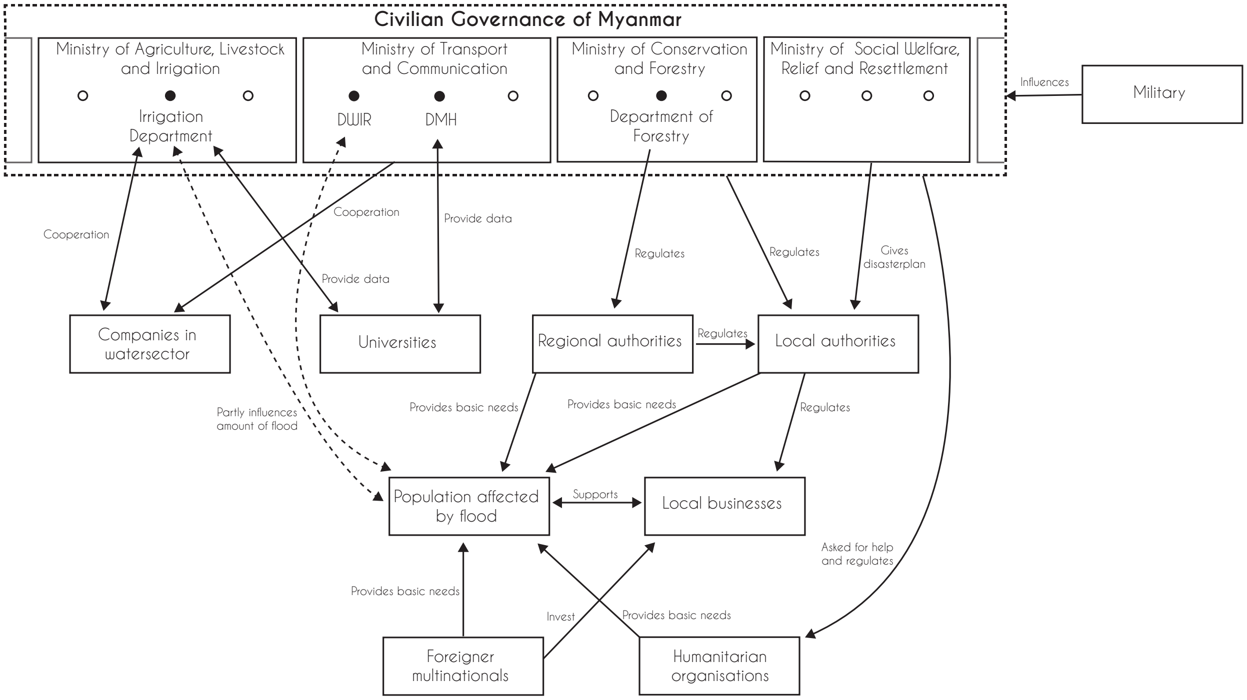


Figure 2.8: Formal Chart

2.5.5.3 Power and interest of actors

A tool to visualize interdependencies is a power/interest matrix (Bryson, 2004). Such a matrix provides a quick overview of the total actor environment and how actors should be treated. Every actor is categorized in one of the four possible groups based on power and interest. Whereas the plusses and minuses are used to indicate if an actor supports or opposes the main interest and objects of the governmemt of Myanmar concerning floods (Enserink et al., 2010). The objective of the civilian government is to have a good flood protection. For now the pluses and minuses are given without taking into account specific alternatives. The alternatives may change the amount of support/opposes on the interest and objects. The amount of power is based on the amount of important resources an actor has and whether they are replaceable or not. The amount of interest is determined by whether a decision concerning flooding influences the behaviour of the actor. The matrix in figure 2.9 should be complemented with the added actors.

The four groups in the power/interest matrix are classified as crowd, subjects, context setters and key players (Enserink et al., 2010). The actors have to be classified as well and a strategy on how to threat them should be considered.

- **Crowd**: has low interest and low power. Has minimal effect but can provide information that is valuable to make decisions.
- **Subjects**: has high level of interest but lack of power. The way of handling this actor group is to keep them informed.

- **Context setters**: are important because they have high power but low interest. The context setters should be kept satisfied.
- **Key players**: are the critical players and should always be taken along.

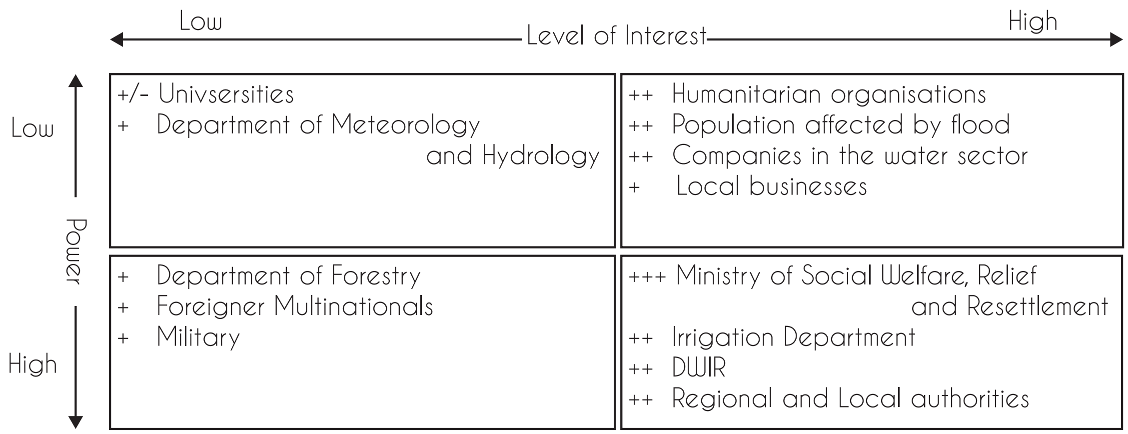


Figure 2.9: Power Interest matrix

2.5.6 Flood risk analysis

A flood risk analysis aims to find the most risky zones concerning floods in the area of research. These risky zones can be found by multiplying the probability of a flood event with the consequences. A flood risk analysis involves the following parts (Jonkman & Schweckendiek, 2015):

1. **Flood hazard analysis**
   Finding the hydraulic boundary conditions, which are partly elaborated for the framework in section 2.5.1.5. This normally includes probabilities of discharges or high water levels for rivers. For coastal areas it can also include storm surge levels and waves and tides. These probabilities could for example be computed by using the extreme value theory.
2. **Flood scenarios**
   The flood scenarios can be established by defining different hydraulic boundary conditions due to different causes or due to a combination of these causes. Including the probabilities of occurrences found in the flood hazard analysis is preferable. This is elaborated in more detail further in section 2.5.6.1.
3. **Flood damage assessment**
   A flood damage assessment is a method to evaluate the potential consequences in monetary damages as well as in loss of life for all the different flood scenarios that have been discrebed. These monetary consequences can be derived from the flood characteriscs, flood simulations, flood scenarios, the number and the type of land use functions affected and their values(Jonkman & Schweckendiek, 2015). This is elaborated in section 2.5.6.2.

4. **Risk analysis**
   The risk analysis combines the flood scenarios by multiplying their probability against their consequences of the previous parts. After this analysis all the risky zones are identified and classified. More details are provided in section 2.5.6.3.

5. **Applying multi-layer measures**
   This part is specially added for combining the risk with measures from the multi-layer approach. All these measures reduce the risk on multifarious time-scale and quantities of risk in damages per year. Although preventive measures reduce the risk, they are costly and complex to implement in the current circumstances. Spatial solutions do not necessarily reduce probability of a flood, however they do reduce the consequences. Therefore they should be taken into account for the feasibility of a project since they are less expensive. so for example, it can be more profitable for low risk areas to spend more money on an evacuation than on constructing a very expensive dike.

   To give an overview, prevention will reduce the probability, spatial planning will reduce the monetary damage and crisis management will mainly reduces the fatalitities (Jonkman & Schweckendiek, 2015). Table 2.2 shows a general overview of the mentioned features regarding the multi-layers. The measures are valued with plus and minus sings by comparing them with each other. In this table the time-scale is defined as: the time in which a measure can be implemented.

	Timescale	**Quantity of risk in damage(€)**
Prevention	-	++
Spatial planning	0	+
Crisis management	++	-

Table 2.2: General overview of reducing risk for different layers in the multi-layer approach

Since this framework is used for Myanmar there is a lack of long and accurate measurements. This flood analysis is focussed primarily on the flood scenarios, the flood damage assessment and the flood risk analysis. These parts have been discussed in more detail in the following sections to give more insight in the method to be used.

2.5.6.1 Flood scenarios

An possible scenario of a flood is if the water level rises due to spring tide. Another possible scenario is for instance if the water level rises due to the occurrence of a storm in combination with high water. These two phenomena can also occur simultaneously, which results in a higher water level rise. For these examples there are three scenarios with different water level rise with respect to mean sea level which results in different probabilities of occurrence. Table 2.3 shows an example of how these scenarios could be ordered. The values that are especially difficult to determine in developing countries are marked gray such as the probabilities. Note that the probability of occurrence is given in 1/day and in 1/year.

	Water level rise due to			Probability	
	spring tide	**storm & high water**	**h(m)**	**1/day**	**1/year**
Scenario 1	X		4	$7,1 \cdot 10^{-2}$	1
Scenario 2		X	5	$1,4 \cdot 10^{-4}$	$5,0 \cdot 10^{-2}$
Scenario 3	X	X	6	$9,7 \cdot 10^{-6}$	$3,6 \cdot 10^{-3}$

Table 2.3: Example of scenarios

2.5.6.2 Flood damage assessment

In this section the flood damage assessment is described in more detail. A flood can have an effect on humans, public infrastructure, buildings, cultural heritage etc. An overview of all these classifications are given in table 2.4. These classifications are divided into four levels. Firstly, into direct damage and indirect damage depending on whether or not it is a physical aspect. Secondly, into tangible and intangible damage depending on whether or not a loss can be assessed in monetary value (Jonkman & Schweckendiek, 2015).

	Tangible and priced	**Intangible and unpriced**
Direct	Residences Structure inventory Vehicles Agriculture Infrastructure and other public facilities Business interruption Evacuation and rescue operations Reconstruction of flood defences Clean up costs	Fatalities Injuries Animals Utilities and communication Historical and cultural losses Environmental losses
Indirect	Damage for companies outside the exposed area Substitution of production outside the area Temporary housing of evacuees	Societal disruption Damage to government

Table 2.4: Classification of flood damages, based on Jonkman et al. (2007)

Moreover, classifications can be distributed into an economic flood damage assessment and the loss of life evaluation. Losses of life are challenging to evaluate in developing countries. Therefore a loss of life evaluation will be neglected for this framework. This framework aims for an extensive economic flood damage assessment which is elaborated below.

Economic flood damage assessment

The economic flood damage assessment aims to visualize the total tangible/priced and predominantly direct damages. This can be realized by following three steps (Jonkman et al., 2007):

1. **Determination of flood characteristics**
   The primary goal of this step is to sample the inundation depth of the research area, however also the duration time and time of occurance could have a significant influence (Jonkman et al., 2007). Nevertheless it is not currently possible to determine all mentioned characteristics

for Myanmar. Consequently, setting-up a fully hydrodynamic model could be time-consuming or even impractical. However if this data is available, hydraulic models like `Sobek` or `Mike` can be used to simulate the flooding areas. This gives an insight in flood velocity and flooding surface of the low laying areas. For this framework Myanmar is simulated in a geographic information system (GIS) model such as `Qgis` which makes use of digital elevation maps. These digital elevation maps, Shuttle Radar Topography Mission (`SRTM`), are public and published by NASA, see section 4.1.1. The simulation of the different flood scenarios in the GIS model gives an insight of the inundated areas with different water depths. As result a map is constructed which consists of the flooded areas for the different flood scenarios, which will be referred to as the flood map.

2. **Assembling information on land use data and maximum damage amounts**
   The direct physical damages are divided into 3 different categories: general land use (for instance vegetation or fishery), infrastructure and households. The determination of the economic values in these categories is done by using different data or reference projects. Because data is not accurate enough some assumptions should be made in such a way that the values are realistic. Table 2.5 shows the direct damage per category and their values in Myanmar. It is assumed that these values are the same for the whole country. If more data is available the values could be adapted. Lastly, the areas of land use are mapped in the GIS model by using `landsat` images, which are open-source satellite images also publicised by NASA, these maps will be referred to as land use maps.

Damage categories	**Damage sub-category**	**Measurement unit**	**Maximum direct damage [€]**	**Data source**
Land use	Vegetation	m^2	0,1	Appendix A.1.3
	Fishery		0,5	Appendix A.1.3
Infrastructure	Railway	m	2000	(Railway Technical Web, 2016)
	Soil road		60	(Collier et al., 2013)
	Gravel road		70	(Collier et al., 2013)
	Concrete road		90	(Collier et al., 2013)
	Asphalt road		160	(Collier et al., 2013)
Building	Bamboo house	Object	1.150	Engineer at ID
	Wooden house		3.850	Engineer at ID
	Concrete house		11.600	Engineer at ID

Table 2.5: Direct costs per category

3. **Application of stage-damage functions**
   According to Smith (1994): "a stage-damage curve normally relates to a specific class of building or crop and presents information on the relationship of flood damage to depth of flooding(stages)". In this assessment the stage-damage function relates the percentage of damage to the inundating depth. Thereby for simplification it is assumed that the stage-

damage function is the same in every class/category. This stage-function is illustrated in figure 2.10. The figure is based on the Dutch standards as described by Jonkman et al. (2007). This graph differs from the original, which can be found in appendix A.1.3, in two aspects. First, 100% damage will occur in a earlier state. Second, there would be more damage in terms of percentage relative to lower inundating depths, because buildings and infrastructure have less resistance due to weaker construction materials. Normally, 100% damage will occur at 4,5 m inundating depth and less percentage damage will occur in the leading stages.

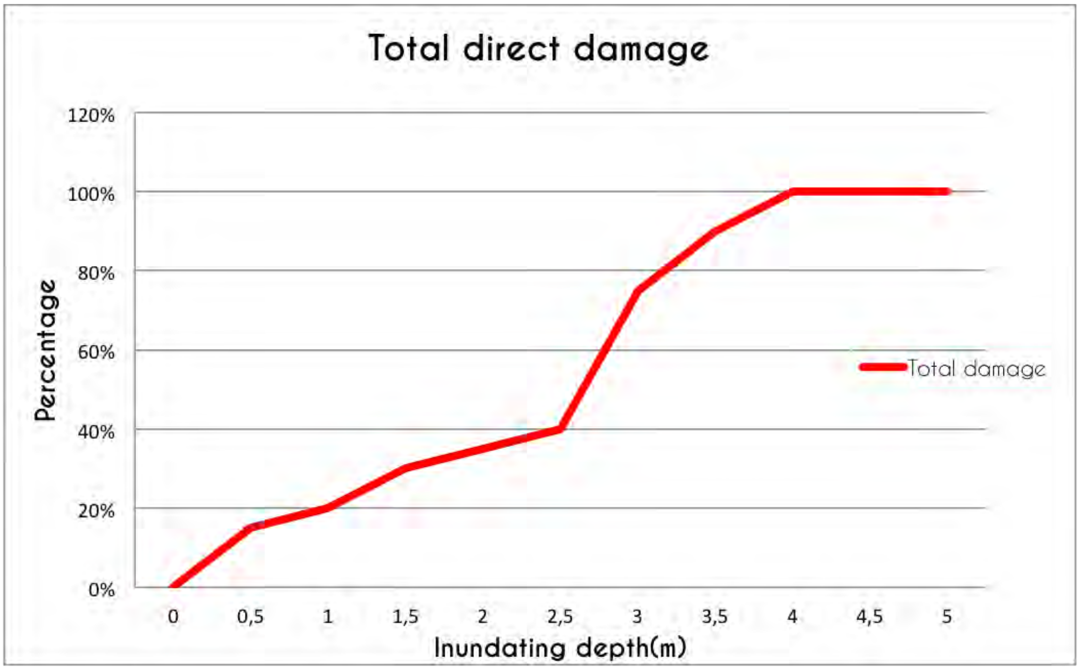


Figure 2.10: Relation between the percentage direct damage and the inundating depth

For a flood damage assessment the flood map and the land use map are integrated and combined with the stage-damage curve (Jonkman et al., 2007). Normally, this will be simulated in a extensive and complex GIS system. Such a extensive and complex GIS system would be difficult to implement in Myanmar. Therefore it is chosen to create an `Excel`-sheet which is elementary and transparent. Despite the outcome is more inaccurate, it will give a good insight of the damage and risk of the study regions. The `Excel`-sheet divides the study area into three areas in order to see how different areas have different risks and damages. These three areas are constructed by integrating the flood map and land use map and dividing the whole research area into three logical areas. Furthermore the areal damage is calculated by visually grading the land use and inundating depth and combining this with the stage-damage function. Further explanation and guidance is described in the `Excel`-sheet itself. The `Excel`-sheet is included with this report.

2.5.6.3 Risk analysis

In the risk analysis the damages and probabilities come together. As stated before, risk is defined as a probability multiplied with the consequences. In the `Excel`-sheet the consequences, which are monetary damages in this framework, of several flood scenarios are found for the study area. The probabilities of these flood scenarios have already been described in the flood scenarios itself. Now one can construct a FN-curve of which an example is shown in figure 2.11.

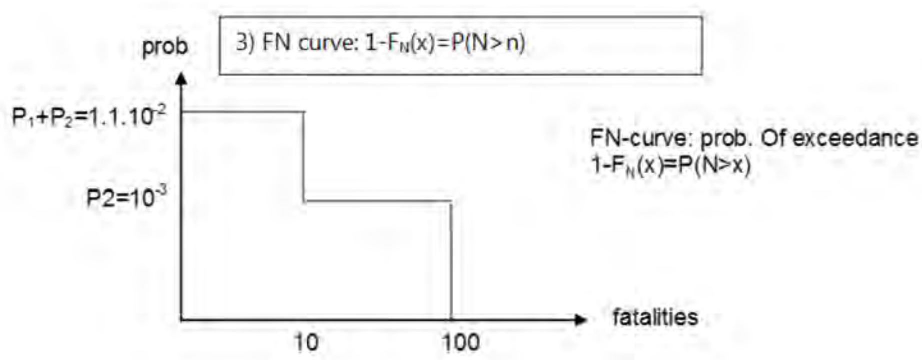


Figure 2.11: Example of an FN-curve (Jonkman et al., 2007)

An FN-curve shows the probability of exceedance of events with certain number of damages. The total risk can be found from this FN-curve which is the surface area below the the curve. The bigger the surface area, the bigger the total risk. The example of figure 2.11 would give a total risk of:

$$\begin{aligned}\text{Total Risk} &= 100 \cdot P_2 + 10 \cdot P_1 \\ &= 100 \cdot 10^{-3} + 10 \cdot \left(1.1 \cdot 10^{-2} - 10^{-3}\right) \\ &= 0.1 + 0.1 = 0.2\end{aligned}$$

2.5.7 Evacuation analysis

If a flood is likely to occur, evacuation can be a measure to prevent or limit the damage of a flood. Limitting the amount of deadly victims in a disaster is the main objective of evacuating. An evacuation is in principle the movement of people, animals and property to a relative safer location(Kolen, 2016). But in this report the term evacuation can be seen as the entire process of alerting, warning, preparing, moving and temporary housing. Although evacuations can have disadvantages; as it is costly, can cause a crisis in the society and can cause a risk of fatalities, according to Kolen (2016) investing in evacuations pays off in supplementing prevention measures such as dike reinforcements. This makes it one of the reasons that evacuation has been taken into account in the process to find a flood proof framework.

Although evacuation performs as a measure against flooding, the evacuation analysis is seen as a separate analysis. One of its reasons is the complexity to understand the entire process and the necessity for an area to always want to have an evacuationplan. The objective of this chapter is to optimise the current process of evacuation by analysing the four elements of which the evacuation process consists of. Note: Some of the content of the elements vary from the original report, other characteristics for the analysis are added to fit into the size of this report (Kolen, 2016).

- Element 1: Threat and impact
- Element 2: Decision making by authorities
- Element 3: Environment and traffic infrastructure
- Element 4: Citizens response

By analysing these four elements bottlenecks can be defined. As a result an optimization can be done and a advice can be written. To start the evacuations analysis the first sections contains the general policy concerning evacuation at a nation wide level.

2.5.7.1 Evacuations in Myanmar

This section describes the general process and the nationwide players concerning evacuation. It is assumed that the information of this section is generic for every study area. Therefore it is recommended to read this section and if mistakes are found to improve the section. It is *not* the objective of this section to analyse the actors and process at a nationwide level evacuation again.

Nationwide actors

In this chapter the most critical actors at a nation wide level are introduced concerning evacuations. The ministries, departments, organisations concerning evacuations are shortly described, for the entire overview of actors concerning floods see appendix A.1.2.

- Department of Meteorology and Hydrology (DMH)
  The DMH department is responsible for providing data concerning floods and cycloons. Might the forecast form a serious threat, DMH is responsible to warn the region and local authorities (Myint Thein, 2016). This makes the DMH an important player. Although every disaster plan is made at a local or regional level, the DMH will provide the warning level to the national authorities.

- National Institution for Disaster Management
  The committee will be responsible for supporting the government in organising and directing natural disasters. It concludes several sub committees with different members of different departments to implement the mitigation measures, and implement the disaster plan. The National Institution for disaster management's main objective is to help writing the disaster management plan for the districts, townships and villages. The national institution consists of a rescue committee, recovery committee and international relations work committee and a national disaster management work committee. The most important committee, the National Disaster Management Work committee, consists of subcommittees as information, emergency communication, damage and loss, transportation and road clearance, mitigation and emergency shelters and security committee.

- Myanmar Red Cross Team
  The Myanmar Red Cross team in cooperation with local authorities have the main objective to carry out the rescue operations providing food, water, blankets, clothes, medical care and other basic necessities to the flood affected victims(Fridolf, 2016). An other objective of the Red Cross team is that they assist in evacuating to higher ground or to temporary sited as monastries and schools (Fridolf, 2016). The Red Cross Team is aiming to support 20 percent of the flood affected population and has therefore chosen several townships and cities to build a strong disaster plan (Fridolf, 2016). If one of these township is the same as the investigation area than, a local disaster plan is assured.

- Armed Forces
  Armed Forces are ready to carry out prompt actions in disaster relief together with civilian organisations (Myint Thein, 2016). Commander-in-Chief quotes: 'If there is a natural disaster in the respective area, the military units must be deployed immediately '. There can be concluded that the armed forces are one of the executives of the disaster plan. The following activities are carried out by the armed forces, such as: search and rescue, humantarian assistance, healthcare and hygience work, transportation of troops and materials, relief and rehabilitation work and security task (Myint Thein, 2016).

- Relief and Resettlement Department (RRD)
  This department belongs to the Myanmar Ministry of Social Welfare, Relief and Resettlement. The RRD was established to provide aid for victims of natural disasters to ease their suffering and take precautionary steps to minimize loss of lives and damage to property of the victims of natural disasters (Prevention web, n.d).

- Other important players
  The department of Relief and Resettlement, Department of Health, Department of Irrigation, Myanmar Police Force, Directorate of Water Resources and Improvement of River Systems and Myanmar Red Cross Society are organising the disaster management courses in states and devisions (Myint Thein, 2016). Because each of these departments are represented in the National Disaster Committee the department on itself is left out of the scope of this analysis.

General process

As what is stated before, the evacuation process consists of the entire process of alerting, warning, preparing, moving and temporary housing. The process of an evacuation begins with the alerting and warning phase.

Alerting and warning

As described above the Department of Meteorology and Hydrology (DMH) is responsible for these two phases. The operational procedure of an early flood warning is performed according to the sequence which is listed below (Myint Thein, 2016). The DMH collects the data at hydraulic network stations placed at multiple places in the entire country. The 'Data receiving centre' receives and collects the data by using the telephone, radio or computer. The data will be checked and edited adjusted by the DMH if necessary. The next step is doing the actual flood forecast. By using simple and multiple regression event models a forecast can be created. Other models that DMH uses to forecast the waterheight is the HBV model for upstream catchments (Myint Thein, 2016). When there is a reasonable chance that a flood occurs caused by rainfall upstream the procedure 'Dissemination of flood forecasts and warnings' starts. The warning will be send through radio, television, newspapers. Also the warnings will be send to local authorities, and related ministries and departments. Flood alert is the next step in the sequence. Hydrologist are send to the affected area to measure the water level every hour. The hydrologist will take part in the flood committee of the affected township (Myint Thein, 2016). The last step performed by the DMH is sending a flood investigation team to the affected area. The team will scan the flood marks and analyse the damage caused by the floods. The results are submitted to the township authorities.

Preparing

The second phase is preparing for the evacuation. This can be seen as a short term but also a long term plan. In July 2013 the government ratified the disaster management law prescribed by the RRD. It contained certain actions that are needed to be taken by the authorities when a disaster occurs (Taw, 2016).
The RRD had determined a couple of criteria to test the preparedness of a city which are listed below. More factors or criteria can of course be added:

- Stockpilling relief materials
- Developing disaster preparedness plans (Local or Regional)
- Hazard Mapping and risk monitoring
- Awareness raising.
- Capacity developing
- Drills and exercises
- Disaster monitoring

Every township should at least have looked at the criteria stated above.

Moving

Moving the flood affected people depends on the destination, route, the available road capacity and the number of evacuees (Kolen, 2016). Some of the people decide to move one floor up if the water level has risen too high in theri houses. This can be called as vertical evacuation. Others are moving out of precaution to temporary houses outside the flooded area. If the water level is at a higher warning level the elderly will already be transported to shelters. How the moving of the affected population is organised is stated at a local level; There is not a national policy how the affected population should be moved.

Temporary housing

There are several forms of temporary housing. Some people move to friends, family or monasteries out of precaution before the flood arrives. Others are waiting until the water level is considered as too high and will move to a shelter or to higher grounds. One of the most popular temporary houses are the relief camps at monasteries. There is capacity for a lot of people, it is peaceful, and monasteries are normally provided with enough food due to donations. Other examples of temporary sites are relief camps at schools or churches. Where the shelters are located is determined at a local and regional level and not at a nationwide level.

2.5.7.2 Analysing current situation

In this section the current evacuation process is analysed. The elements are discussed in a specific order. Note: What can be a problem for foreigners in analysing the current situation is that all of the local reports are written in Burmese. If there is a lack of data, it is recommended to interview experts. If there is a problem related to the Burmese language, it would be wise to take a guide along.

Element 1: Threat and impact

In the original report of Kolen (2016) this subsection is made to analyse the threat and impact of the flood and to make several disaster scenario's. This element is used to analyse the available time until the flood strikes and to get insight in the size of the disaster. To give an overview of the size of the disaster a flood map, that indicates the impact of the disaster, can be created. In section 2.5.6, this is already done. If there is a lack of time the website Myanmar Informartion Manegement Unit (2016) provides a lot of (undetailed) impact maps concerning floods in Myanmar.

Element 2: Decision making by authorities

This chapter contains the processes concerning the local and regional authorities and their responsibilities. To start the decision making an overview must be provided of all the local actors concerning evacuation. The responsibilities and tasks should be clarified.
The next step is to look into the process of evacuation again. How is the warning, preparing and the movement of the people organised at a local level. Who determines how to evacuate and when? It is important to pay extra attention to communication. For example, questions needs to be answered: How is there communicated to the potential affected people? Is there extra help provided for hospitals and prisons? By looking into the details of the communication, bottlenecks can be found. It is recommended for a foreigner of Myanmar to gain this information by interviewing an expert.

Element 3: Environment and traffic infrastructure

In this section the infrastructure and surroundings are investigated concerning evacuations. This section will be divided in several sections.

Aid dependent buildings
A detailed look should be given to important buildings or dense areas. Buildings as hospitals, elderly homes and prisons should be marked in the impact map. There should be checked if these aid dependent buildings are located in a flood affected area and if they have their own evacuation plan.

Analysis evacuation routes

In this section the evacuation routes should be determined. Sometimes the destinations and routes are provided by local authorities if not, most logical shelters and destinations should be chosen to give a educated guess about the evacuation routes. The objective of this section is to look for bottlenecks and see if routes or roads will have a capacity problem. When the bottleneck is found the vehicle movement time to leave the city can be determined. This time estimation can be useful to make a timeline in the last step of the evacuation analysis. There are several assumptions and techniques that have to be used to estimate when the total city should be evacuated. The best method is to use transport models as Omnitrans to give a precise estimation. There is however an other way to give a rough estimation by simple reasoning.

The first assumption that will be made is: everyone has to evacuate. Although a part of the population will choose to move to the second floor of their house, this is seen as not an option. Another assumption is that everyone will take the car to evacuate. Although the survey estimated that around 68 percent of the people will evacuate by car, to simplify the majority is generalized. The next step is to determine the amount of cars that will be used to evacuate. This can be estimated by dividing the total population by the number of household, assuming that the population will evacuate with their own household.

The second step is to determine the capacity of the evacuation road. This can be determined by the number of lanes. One rule of thumb is that a single lane has 2000 pcu/lane at a highroad in Holland. For a two lane highway it is around 4000 pcu/lane. This is based on the fact that a car has a following distance of 2 seconds per car. Pcu is a measure unit to determine the intensity and capacity of a road, the abbreviation is standing for personal car unit. In Myanmar there should be looked if the road has the same quality. Probably the quality is lower compared to the highway of the Netherlands taken bumps in the road into account. So a downgrade is given to 1200 vehicles/hour/lane, based that there is a following distance of 3 sec. This downgrade is also taken into account for the driving conditions as heavy rain, darkness, and the drivers unfamiliar behaviour in an unknown situation (Opper et al., 2010).

Now the vehicle movement time can be determined by dividing the total demand in cars by the capacity of the bottleneck. What should be added is the free flow travel time. This is the time that the last car has to drive over the the road and who will not experience the congestion. This is dependent on the length of the road/bottleneck and the free flow travel speed. For example if a road/bottleneck is 40 km long and the free flow travel speed is 80 km/h, it will take 30 minutes for the last car to leave the area.

Another step is to determine the Traffic Safety Factor (TSF) to complete the total evacuation time. A Traffic Safety Factor takes into account to allow for the delays that would cause a complete shut done of a lane because of a major traffic accident. The TSF should be 1 hour for a vehicle movement time of 3-5 hours. For every 3 hours longer than the 5 hours already mentioned, a 0.5 TSF should be added. To conclude the total vehicle movement time for the evacuation can be estimated by the following formula:

$$\text{Vehicle movement time} = \frac{\text{demand in cars}}{\text{capacity of the road}} + \text{free flow travel time} + \text{TSF} \tag{2.1}$$

Element 4: Citizens response

The citizen response can be investigated through multiple ways. One way is to use evacuation models the other way is setting up a survey. If there is not a lack of time nor experience both techniques are recommended, because they complement each other.

Model approach
There are two common types of model approaches to model evacuation namely transport modelling and human based modelling. Because it requires some knowledge to understand the models and programs they are not discussed in detail. One evacuation method is transport based modelling. It gives insight in route selections, flow rates and uses theories as Dijkstra. Also evacuation strategies can be tested to prevent severe congestion at the time of contraflow operations, modified traffic control, route guidance and staged evacuation. Note: To do this analysis it requires (a lot of)local data like the demand of the population who will evacuate and until what time. Also the data for infrastructure as topology, geometry, traffic management and more (Pel, 2016). If traffic data is missing, making an evacuation model would be a time consuming challenge.
The other modelling technique is human based modelling. It can give an insight why people did not manage to evacuate on time in some cities. Several scenario's can also be created varying in lead time, warning distance and social parameters. Policy and strategy measurements can be tested and a forecast can be done about their effects on human behaviour. Useful model programs are: Agent based modelling.

Survey approach
A literature study is a good way to get an insight in the general behaviour of the people during an evacuation. But a survey could give better insight and a detailed overview of how people in a specific area behave when being evacuated. There are two types of survey approaches: a revealed choice behaviour approach and a stated choice behaviour approach. With revealed choice behaviour you ask what ones actions have been in the past. With stated choice behaviour however you ask people would do if something would happen.

Revealed choice behaviour can be gained by interviewing experts or by conducting a survey with the flood affected victims. By interviewing experts the revealed behaviour of the population during an evacuation should be asked. Revealed choice behaviour could also be analysed by interviewing or asking the flood affected victims what they have done during evacuation. This method is preferred over the stated choice behaviour method if possible.

Stated choice behaviour can be obtained by asking certain hypothetical if-questions like: 'What would you do if...?' (Pel, 2016). Multiple interview techniques would complete each other but a choice can be made to choose either of the two or both. If experts of evacuations are not present or if a disaster did not occur in the pas time period, the option stated preference is left.

In the appendix B.1.3 an extensive survey set-up is discussed for the case of Nyaungdon. To set-up a survey several steps must be followed. The first step concerning the survey set up is to define the goal of your research: What is the objective of the survey? What factors needs to be investigated further on? The second step is to do a literature study. This way the knowledge can grow concerning what behaviour can be expected during evacuation. Also the current knowledge gaps that needs to be elaborated in more detail can be determined. The third step is to define the explanation of data collection. When did you collect the data and are the people in the sample representative for the population? Fourth, the investigation results are presented. What are the relations between the findings and are they significant? Finally a conclusion can be written down and the research question can be answered.

Timeline

The objective of this element is to make an evacuation timeline, because it is useful tool to give an overview of all the information that is provided and to give insight in the several phases of the evacuation(Opper et al., 2010) (Albers et al., 2012). The timeline that will be used in this framework consists of the elements listed below.

- E_n represents the total time required to complete an full evacuations of all people assuming that they will take their own vehicles.
- L represents the time lost due to flood closer or failure of evacuation routes.
- E_a represents the actual time available and wherein the evacuation must be completed.
- S stands for the safety factor. That will be available as a reserve of additional time available to deal with interruption or uncertainty.
- T_d stands for the time the decision is made. From the warning level until preparation time that is needed to inform the local authorities.
- T_w is the population or crowd is informed about the evacuation and emergency services start the procedure.
- T_b the first household are evacuating. Between T_w and T_b there is a phases of public acceptance (Albers et al., 2012).
- T_t time when everyone is warned.
- T_c Is the beginning of the flood and is reached the area
- T_s is the slack time given to evacuate until the last road is un-drivable.
- T_e is the end of the evacuation. And must be defined between T_c and T_s (Albers et al., 2012).

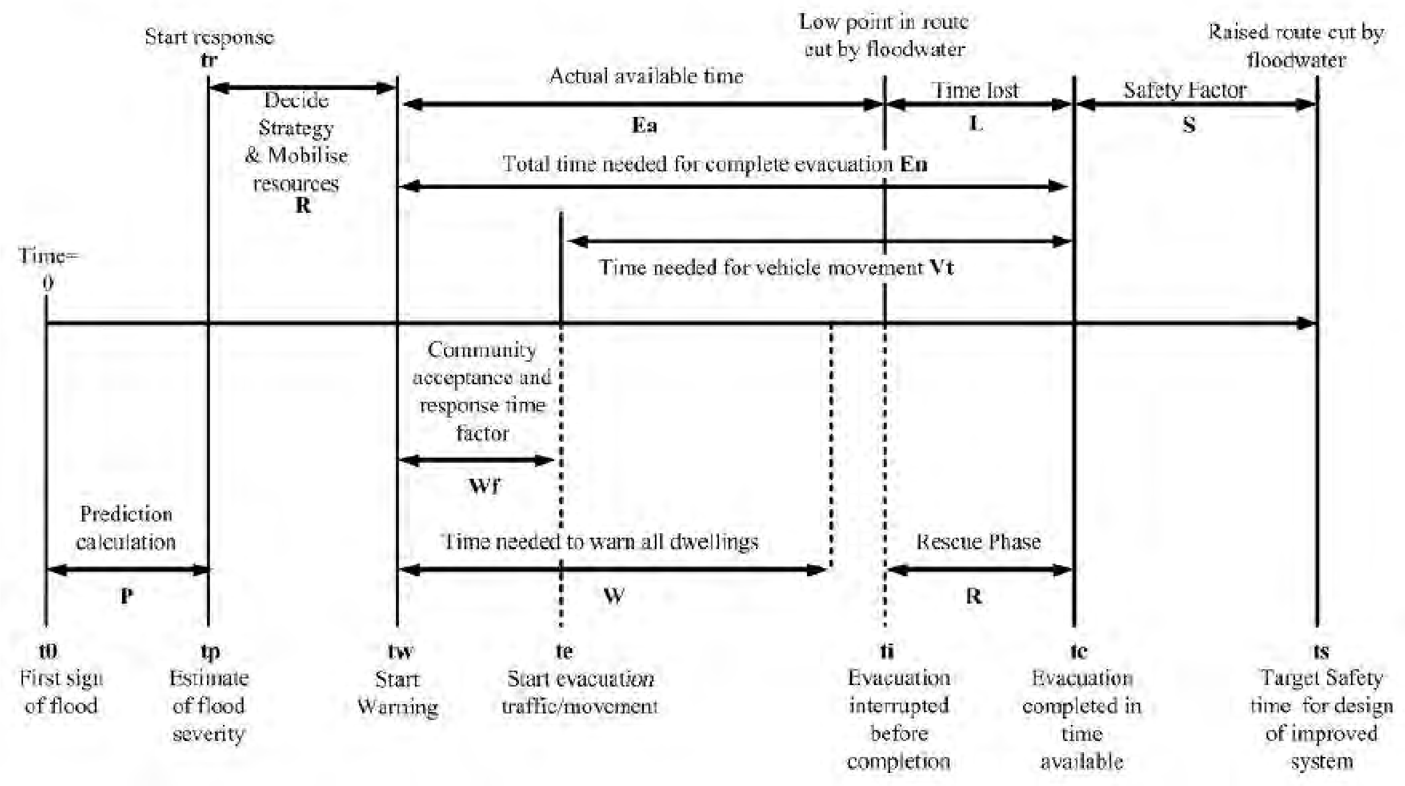


Figure 2.12: An evacuation timeline made by Opper et al. (2010)

If it is not possible to add all the different elements of the timeline, then the result is an incomplete timeline. The missing elements could possibly give insight in certain bottlenecks of the organisation for an evacuation. This is not necessarily the case, but a complete timeline would at least exclude that possibility. In figure 2.12 an example is shown of how a certain timeline might look like.

2.5.7.3 Define Bottlenecks

The main goal of this section is to find the bottlenecks in each of the four elements. Although the elements are already analysed, it should be checked if the questions below can be answered.

1. *Threat and Impact*
   Is there an impact map or flood map that can be used as impact map? Are different impact or evacuation scenarios taken into account?

2. *Decision making by authorities*
   Is the communication between actors well arranged? How are the responsibilities defied? Is there an evacuation or disaster plan?

3. *Environment and traffic infrastructures* Are evacuation routes provided? Can capacity problems be found? Are there aid dependent buildings?

4. *Citizens response* What is the behaviour of the people? Are they willing to evacuate? What are the reasons to evacuate or not? What transport mode will they choose?

5. *Evacuation timeline* Is information lacking? How much time does the population have to evacuate?

2.5.7.4 Conclusion

A conclusion should be drawn taken all the bottlenecks and analysis into account. In the development of alternatives the evacuation packages can be formed based on the conclusion.

2.5.8 Future scenario analysis

The future scenario analysis is a method to get insights on different plausible scenarios for a certain area.

Scenarios are descriptions of journeys to possible futures. They reflect different assumptions about how current trends will unfold, how critical uncertainties will play out and what new factors will come into play, (UNEP, 2002).

Scenarios are always based on assumptions about how the future might look one day (Kosow & Gaßner, 2008). These assumptions should be based on trends and developments of Myanmar. Such an approach has been used in the Mekong Delta plan, where a development strategy was formed for the Mekong delta, considering two uncertainties and thus developing four strategies (Ministry of Infrastructure and Environment et al., 2013).

Enserink et al. (2010) have elaborated the process of developing future scenarios. This process, which will be used in the case studies, has been described along with examples from the Mekong Delta Plan below:

- *Step 1: Determine key question*
  For the Mekong Delta Plan the key question could be: "What is the long-term vision and strategy for a safe and sustainable delta?"

- *Step 2: Determine the contextual factors*
  The contextual factors are all the factors that might be of influence for an area/region. For the Mekong Delta Plan this could be: rice farms, city populations, roads, mangrove forests, population density etc.

- *Step 3: Cluster the contextual factors into driving forces*
  The contextual factors could all fall within a certain subject. These clusters can be seen as a driving force. Driving forces are forces that could drive a scenario into a certain direction. Regarding the Mekong Delta Plan a driving force could be economy (in which rice farms would be included)or population growth (in which city populations would be included).

- *Step 4: Classify the driving forces according to their impact and uncertainty*
  All the different driving forces should be ordered in relation with each other on an uncertainty scale and an impact scale. This way an overview can be created of the importance of certain

driving forces. After that the two most important driving forces have to be chosen which are the driving forces that are both high on impact and also highly uncertain. Impact refers to the influence a driving force has on the answer to the key question and the uncertainty refers to the range of variations the driving force can have in the future. Scenarios with low impact or low uncertain are less important for future scenarios.

		Uncertain	
		Low	High
Impact	Low	Change in politcal regime	Sea level rise
	High	More erosion at coasts	Economic Growth and Population Growth

Table 2.6: Classification of driving forces

- *Step 5: Design a scenario matrix*
  When deciding on two driving forces one can make a scenario matrix, see figure 2.13. For this example the two most important driving forces were economic growth and population growth. These forces will be used on the axis of the scenario matrix. This creates four different scenarios, namely scenario A, B, C and D.

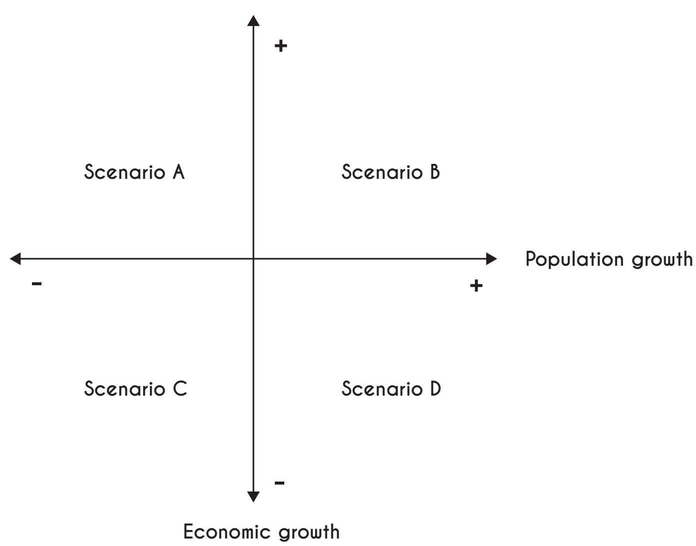


Figure 2.13: Example of a scenario matrix

- *Step 6: Detail the scenarios*
  The four scenarios can then be elaborated and this is useful for the development of solutions to the problems that might arise regarding flooding in the future.

An important final remark must be made about the future scenarios analysis. A future scenario can either be used for exploring scenarios or normative scenarios. Exploring scenarios have a purpose of exploring the future outcomes, but normative scenarios can use back-casting. The Mekong Delta

Plan is a normative scenarios which makes use of back-casting. They advice the government of Vietnam to lead their country towards certain scenario instead of solely exploring the possibilities. This is a example of back-casting, there is a desired scenario.

2.6 Phase 2: Development of alternatives

The development of alternatives can be divided in three parts, the earlier mentioned layers; prevention, spatial solutions and crisis management. For every layer one should brainstorm about the possible alternatives in the specific area of interest. So one should develop alternatives for layer 1: prevention, layer 2: spatial solutions and layer 3: crisis management. Figure 2.14 shows the general structure of the development of alternatives. For inspiration one could turn to section 2.3.1: existing measures. It is important to think about the possible alternatives during the research, although many of the existing measures are not applicable in every situation. The applicability of an existing measure follows from the analyses. To judge the applicability knowledge of hydraulic measures is required.

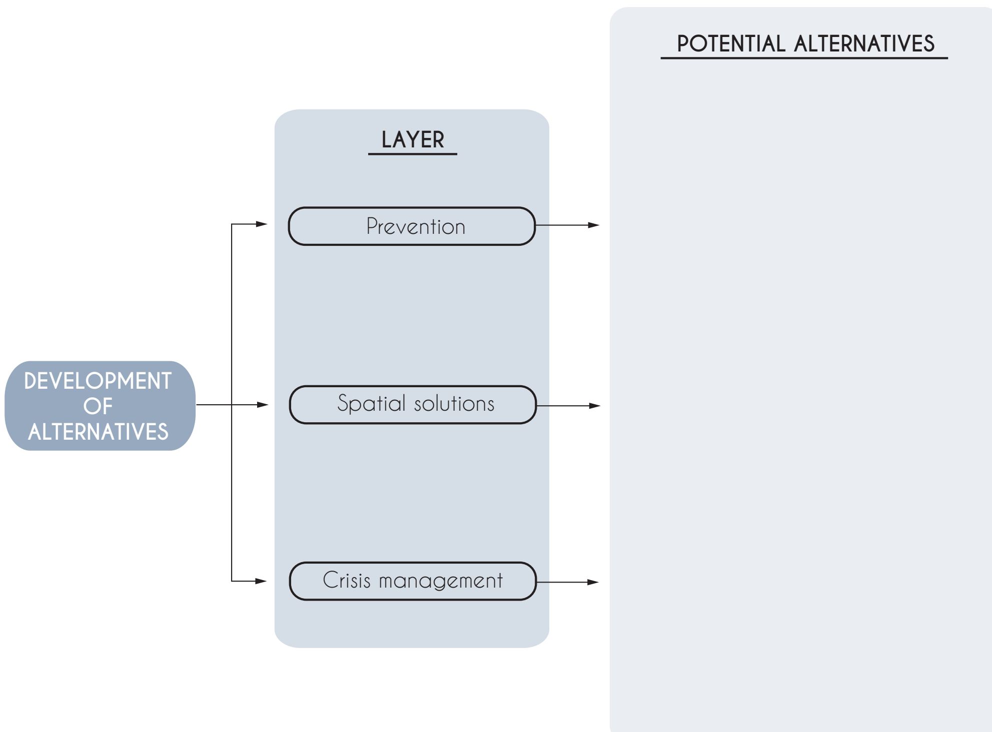


Figure 2.14: Structure Phase 2

Firstly, there should always be an alternative without additional measures, this is called the null solution. This alternative only includes the existing measures regardless of the future scenarios. Furthermore, the new developed alternatives should be specified like elaborated below.

For the layer 1 measures one should give an estimation of the dimensions of these measures. Section 2.5.1.5: hydrology gives the critical water levels. From this the height of the protection measure can be given. One should know what the driving force for this water level is, this can be one force or a combination of forces. Next to the height of the measure, an estimation should be given of the length, width and location. In the implementation phase these dimensions are specified in more detail.

For layer 2 it is important to specify which spatial changes should be executed. The location and way of change should be mentioned. In the case of (re)location the specifications of the buildings are necessary as well.

Layer 3 can be subdivided into evacuations and temporary defences. Several options of evacuations can be specified. A possibility to do this is to make different packages of elements consisting of a few measures. Examples of measures are defining shelters, setting up traffic management plans and early warnings. Other ways of specifying the evacuation options are also possible. The second part of layer 3 consist of the temporary defences. The way of application, the location and the length over which the defence will be applied are important factors to mention.

2.7 Phase 3: Assessment

2.7.1 Multi-criteria analysis

2.7.1.1 Method

To compare different possible alternatives they have to be evaluated on the basis of a multi-criteria analysis. This analysis is divided in five parts: Determining the criteria, rating the alternatives, determining and implementing weight factors, ranking the alternatives and creating packages. The approach to be followed in these parts is described in the following subsections.

2.7.1.2 Criteria

To determine the criteria first an objective has been created. To analyse the objective and define it in more specific terms the method of an objective tree has been used. The objective is defined in more lower-level objectives, which are defined in terms of targets that are concrete, measurable and can be expressend in some unit scale. These lowest-level objectives provide the criteria. A suitable unit scale should be specified for each criterion. In this framework several actors play a role and therefore the criteria and objectives trees of different actors have been combined (Enserink et al., 2010).

The main objective in this framework is formulated as follows: "Efficient improvement for a flood prone area". This main objective is defined in several criteria by an objectives tree with five levels. This objective tree can be seen in appendix A.1.4. The criteria that are generated by this tree are the following:

- Material damage [€/danger level]
- Immaterial damage [affected people/danger level]
- Probability of flood occurrence [1/year]
- Initial costs [€]
- Operational costs [€/danger level
- Maintenance costs [€/year]
- Implementation time [days/measure]
- Available space [m^2]
- Aesthetics acceptance [% of dissidents]
- Disturbance for local residents [affected people]
- Preservation of biodiversity [number of species/m^2]
- Hindrance for ships [hindered ships]
- Accessibility by roads [hours/kilometre]

2.7.1.3 Rating alternatives

In order to rate the alternatives in the multi-criteria analysis one should construct a table as depicted below in table 2.7. Herein the criteria that have been derived from the objectives tree are listed on the left hand side of the table. Next to the criteria their scales are shown to indicate how these criteria are measured. All other columns show the different alternatives that have been determined. For now they are blank, but in cases as Nyaungdon and Dala they would contain all the alternatives developed in chapters 5 and 12.

Once this has been done, the table could be filled in with numbers or words that match the scale. In case exact numbers cannot be filled in, words can also indicate if a certain criteria has been met or not. This method is especially useful in case a certain value is not known in detail. In this case words like; more, hight, low, good can be used to rate a certain criterion.

Criteria	**Scale**	Alternative 0	Alternative 1	Alternative 2	etc...
Material damage	€/danger level				
Immaterial damage	affected people/danger level				
Probability	1/year				
Initial costs	€				
Operational costs	€/danger level				
Maintenance costs	€/year				
Implementation time	days/measure				
Available space	m^2				
Aesthetics acceptance	% of proponents				
Disturbance for local residents	affected people				
Preservation of biodiversity	species/m^2				
Hindrance for ships	hindered ships				
Accessibility by roads	hours/kilometre				

Table 2.7: Table to rate alternatives

With all these different sorts of rating there is a need to combine them and come up with one final score in order to distinguish them from each other and determine which alternatives score the best.. This is done by normalising the scores so the scores for the different criteria can be compared to each other. After the criteria are rated with comparable scores, the scored are linked to colours ranging from red to green. This way a score-card is obtained. With this a visual overview of the table is realised, combining a lot of different criteria into one universal scale. Examples of these tables can be seen in appendices B.2 and C.2.

2.7.1.4 Weight factors

The main reason for creating weight factors for each criterion is that the criteria differ in level of importance. A higher weight is given to criteria that problem owner finds more important. In this section a short explanation is given on how to determine the weight factors.

The weight factors are based on the pairwise comparison method (Mendoza & Macoun, 1999a). The method includes a one-to-one comparison between each of the criteria, also called indicators.

The comparison is made by experts judgements. The expert team is asked to make a comparative judgement on the relative importance of each pair of the indicators. If experts are not available to help an educated guess should be made. The indicators can be scaled relatively with a score ranging from 1 to 9. Giving a rank 1 means that the indicators are of a equal importance. To give the rank 9 means that an indicator is extremely more important than the other indicator. If the indicator is compared with itself, the scale is always 1. To make it more clear an example shall be given: If the indicator "initial costs" is compared with the indicator "preservation of biodiversity", the initial costs of the measure can be seen as more important, so this will get the scale 8. As a consequence the preservation of biodiversity will get 1/8. For the pairwise comparison method one can generate a comparison matrix. This is already done in appendices B.2 and C.2 . For each scenario the weights are determined. If for instance a population and economic growth is predicted, the importance of cost can decrease or increase.

Th next step in determining the weight factors is to calculate the sum of each column. This step is followed by the step to normalise the elements in each column, by dividing each indicator by the column sum. Now a row sum can be calculated. The row sums are the weighted factors for this report. Note : This method is dependent on the view of the experts. Multiple experts are required to give a more certain classification on the relative weight factors. Also the problem owner can have a different view on ranking criteria on importance level than the experts. In the original report of Mendoza and Macoun (1999a) the weighted factors are determined in a more more detailed method.

2.7.1.5 Ranking alternatives

To complete the analysis the weight factors generated in section 2.7.1.4 and the values of each criteria for the measures, described in section 6.2 are needed. The value of each criteria is multiplied by its weight factor. The calculated column sum gives the total score for each measure. These sums can now be ranked in a sequence. The highest score can be ranked as the number 1, 2, 3 etcetera. The number one alternative, means that with these weight factors and these values it would be the best relative alternative for in a particular scenario. For each scenario this method should be used to see if the measures score differently.

2.7.1.6 Creating packages

This section is all about combing measures into one package. In order to create packages of different alternatives to protect a certain area from flooding, it is necessary to have the knowledge obtained from the multiple analysis performed in phase 1. Simply performing a multi-criteria analysis without background knowledge will probably result in poor decision making. The rating of this analysis is completely customizable, therefore someone who has performed his/her own analysis could weigh certain alternatives different than has been done for these cases in this report. Furthermore the multi-criteria analysis is meant to give a certain advise for possible solutions that could be used, it cannot be said with 100% certainty that the answers provided by this multi-criteria analysis are the best. Always keep that in mind before proceeding to the next phase of a project, and always ask yourself if the outcome should be questioned or not.

Although one measure can be ranked as the relative best alternative, a closer look should be taken if this alternative leaves certain gaps. Measures should be combined that complete each other and compensate each others shortcomings. To choose which elements complete each other, a close look should be taken to the scorecard created in appendices B.2 and C.2. With the use of colours the shortcomings can be determined. Note: all of the measures can cost money, so if there is a constrained budget this should be taken into account.

Although one measure can be ranked as the relative best alternative, another look should be taken to what will happen if this alternative fails. For example: a prevention method like heightening a dike can be ranked as number 1. Although it works as it lowers the material and immaterial damage, there is still a probability that the dike will fail. There should be thought of a back up plan. One of these back up plans can be found in layer 3: crisis management. An evacuation plan is preferred as a temporary defence can fail as well. It should be checked whether the Null solution already contains a evacuation plan, if not it is recommended to have at least an evacuation plan. Without an evacuation plan the area would be in chaos when a disaster is happening. It is the question if this is allowed by the local authorities.

2.7.2 Cost-benefit analysis

The cost-benefit analysis is an analysis which can show if a package has a relatively more positive or negative effect on the study region. This is expressed in monetary values. The steps of the method have been described below.

2.7.2.1 Method

1. Analyse the null alternative
2. Identify the effects caused the solutions
3. Select the relevant effects
4. Monetise the effects
5. Present the results and perform a sensitivity analysis

These steps are used very often in large scale civil engineering projects in the Netherlands (Rijksoverheid, n.d.). The effects that the steps refer to can be anything ranging from initial costs of construction to the decrease of the livelihood of the area.

2.7.2.2 Implementation with framework

Some results that come from other parts of the framework can be used in the cost-benefit analysis as well. An example is the flood risk analysis. This analysis could calculate the risk of an area in monetary value per year. The flood risk analysis can also give an insight in the reduction of the risk when a certain solution is implemented.

The solution that will be tested with the cost-benefit analysis follow from the multi-criteria analysis. The multi-criteria analysis has provided solutions for four scenarios that result from the future scenario analysis. This means that the cost-benefit should also recognise that four different scenarios could unfold for a certain region. In the cost-benefit analysis these scenarios cannot be judged to be better or worse than another scenario.

2.7.2.3 Current restrictions

As described this framework has a feedback loop. The amount of detail of the parts of the framework are largely depended on the case studies. As described in the case studies, the cost-benefit analysis has not been performed for these two studies. The main cause is the lack of data in these regions on how the effects of the solutions will have effect in terms of monetary values. Too much assumptions would have to be made and this would not have produced a realistic outcome.

2.8 Phase 4: Implementation

After choosing a package of measures, these measures can be implemented in the research area. Nevertheless, since the future cannot be predicted with great certainty, it would not be wise to implement a measure package as soon as the Assessment phase is finished. The packages should be implemented in small steps over a large time span, only choosing for so called "no-regret solutions". These solutions are activities that yield benefits in all possible future scenarios, even in the absence of climate change for instance. In many locations, the implementation of these actions constitutes a very efficient first step in a long-term adaptation strategy (European Climate Adaptation Platform, 2016).

2.8.1 Future scenarios and adaptive management

Since the future consists of large uncertainties, a future scenario analysis has been performed in section 2.5.8 in the Analysis phase of this framework. These scenarios represent a set of different, plausible future conditions of the research location. For each scenario a package of measures is provided as an outcome of the Assessment phase. In this phase the future scenarios are implemented into an adaptive management approach. This approach involves a strategy that can be modified to achieve a better, more suited, performance as one learns more about how the future is unfolding (European Climate Adaptation Platform, 2016). This strategy will thus be modified as new insights are gained, whether it is from experience or from research.

2.8.2 Analysing the packages

In order to implement the scenarios into the adaptation strategy, first the future scenarios have to be compared to each other. Big differences and even more important, similarities have to be pointed out. In an area where little future changes are expected, the future uncertainty is conveniently confined. For this case it is likely that the measure packages will show many similarities. Naturally, the opposite case is also possible: when an area is facing big changes in the future, predictions are very uncertain and there will be a wide range of scenarios, resulting in a wide range of measure packages.

2.8.3 Future adaptation strategy

The analysed packages can now be implemented into a flexible future strategy. For the near future only measures can be taken that appear in the packages of all future scenarios. These will be the no-regret measures. As time elapses, certain scenarios will be more likely to occur, while others can be excluded. This way a gradual selection will take place in what measure-packages to implement, resulting in the most appropriate solutions for the future state of the research area. This is also depicted in figure 2.15. Another thing that can be seen are the decision moments: these are the moments at which the key players as DWIR and the Irrigation Department look back at the past few years and the development of an area is evaluated. Based on this, certain measures will be left out. It is important to take other actors of the power interest matrix in to account during this decision making moments. Context setters as multinationals should be kept satisfied for instance and Subjects as humanitarian organisations have to be kept informed.

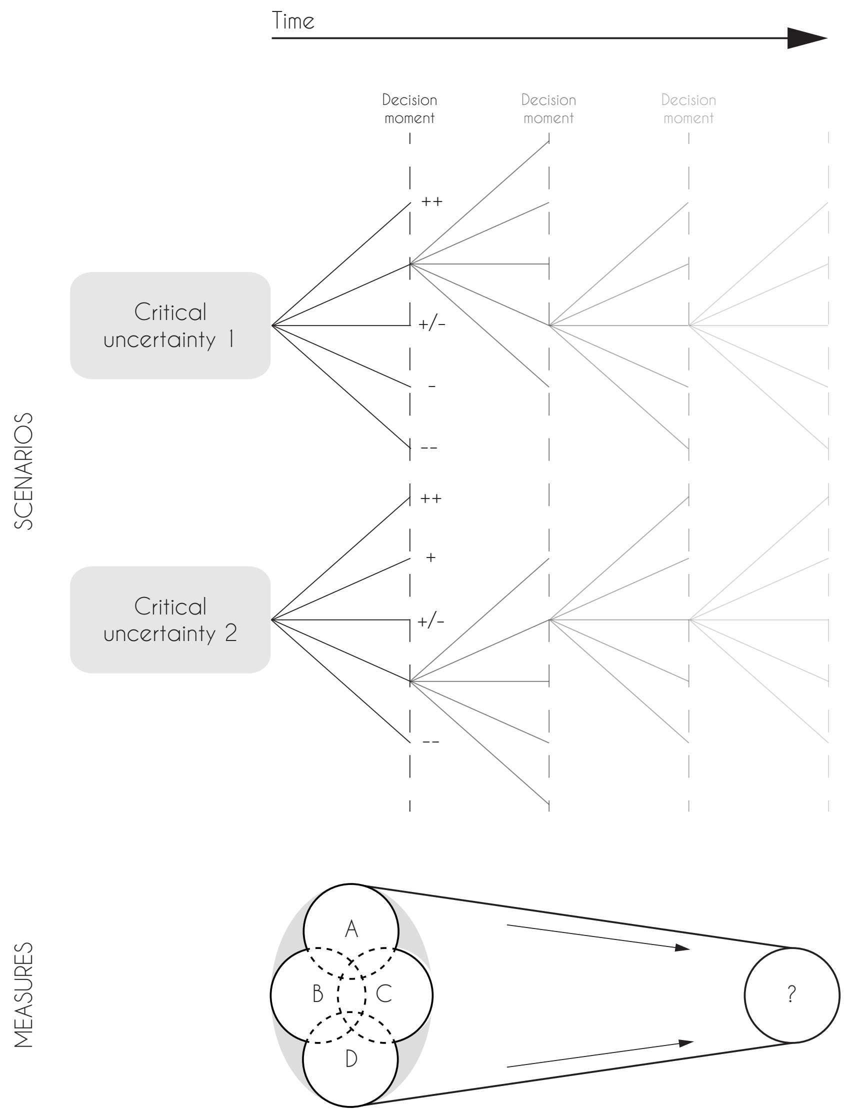


Figure 2.15: Adaptation Strategy

Part I

Case 1: Nyaungdon

3 | Introduction

Nyaungdon is a township located next to the Ayeyarwady river and has regularly experienced flooding in the past. Therefore a dike around the township has been constructed to protect it in the future. Recently a part of this dike has been heightened in order to meet the new safety requirements, which are based on a flood in 2015. Although this dike has been heightened, there are still concerns with the flood safety of the township. Subsequently, the framework has been used to find an answer to the research question:

What are suitable measures to make Nyaungdon flood proof?

To find the answer, the framework has to be run through, according to its four phases: analysis, development of alternatives, assessment and implementation. Besides finding an answer to the research question, the implementation of this case also has a second goal. Namely it functions as a "test case" to create and improve the general framework, by using a feedback loop.

4 | Phase 1: Analysis

In this chapter a detailed analysis is given for Nyaungdon, concerning the flood safety of the township and its surroundings. To do so, multiple analyses are performed to get inside in the current situation, starting with a geography analysis.

4.1 Physical geography

This section treats all physical geographic features of Nyaungdon required by the framework. This includes the topography, the bathymetry of the river, the climate, the hydrological data and the human geography.

4.1.1 Topography

Nyaungdon is a small township located at the river junction of the Pan Hlaing River and the Ayeyarwady river. The town is located at the outer bend of the junction and it is protected by a dike along the river side. The map shown in figure 4.1 and figure 4.2 give an indication of the altitudes of Nyaungdon and its surroundings. Different sources give different values for the mean elevation level of the town of Nyaungdon, varying from 15 to 16 metres. Since no clear indication is given for which value approaches reality the best, a value of 15 m will be chosen as an estimate. As explained in the general framework chapter, the satellite data have a vertical accuracy of 16 metres. This must always be taken into account.

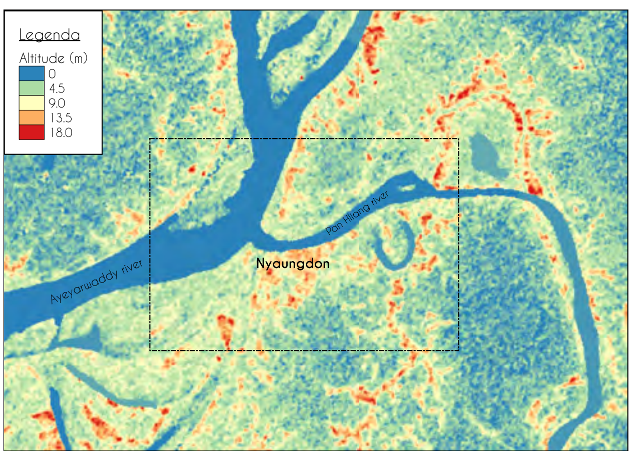


Figure 4.1: Altitude map Nyaungdon area

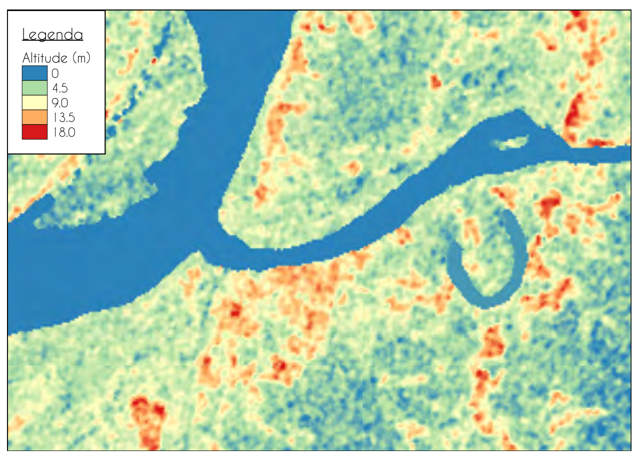


Figure 4.2: Altitude map Nyaungdon township

The Ayeyarwady river is a dynamic braided river, with a rapidly changing path, making its behaviour often unpredictable. The river planform in braided rivers is mainly controlled by bar formation and migration. These bars are accumulations of sediment inside the river channel, sometimes emerging during low water and submerging during high water. Near Nyaungdon not only bars are formed by the river, but also relatively large islands.

Figure 4.3: Braided Ayayerwady

4.1.2 Geomorphology

Figure 2.7 shows that the soil of Nyaungdon can be classified as Gleysol, defined as wetland soil saturated with groundwater. Unfortunately, the exact composition concerning the amount of sand and clay is not known. Consequently, a soil survey will be necessary to determine the applicability of the chosen measures.

4.1.3 Bathymetry

As shown in figure 4.1, Nyaungdon is mainly located along the the Pan Hlaing River: a branch of the Ayeyarwady river after its bifurcation. Figure 4.4 shows the bathymetry of the river section located along Nyaungdon Township. Along the bend near the township the river clearly has a greater depth than at the other side, along Anauk Kyun island. This is probably due to erosion near the bifurcation and bend.

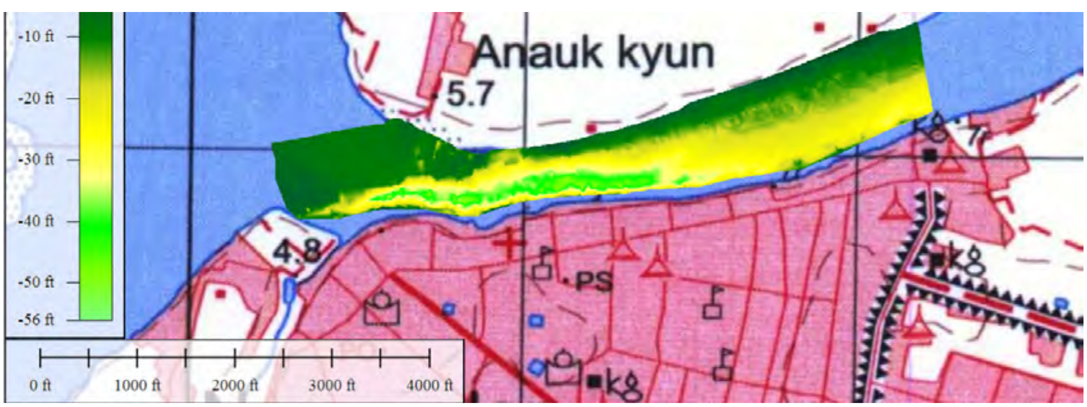


Figure 4.4: Bathymetry Pan Hlaing River, Nyaungdon

The graph of figure 4.6 shows more a detailed bathymetry of four cross sections near the bifurcation. The location of these cross sections is indicated in figure 4.5. The distance on the horizontal axes begins at reference level 0: this is the riverside of the top of the dike. As shown in figure 4.6 after about 150 m distance from the dike the bathymetry becomes steady for all cross sections, with a level in between 3 and 2 metres below Relative Level. Unfortunately the graph does not provide detailed information for the entire cross sections. After 150 metres the bathymetry has to be estimated using figure 4.4.

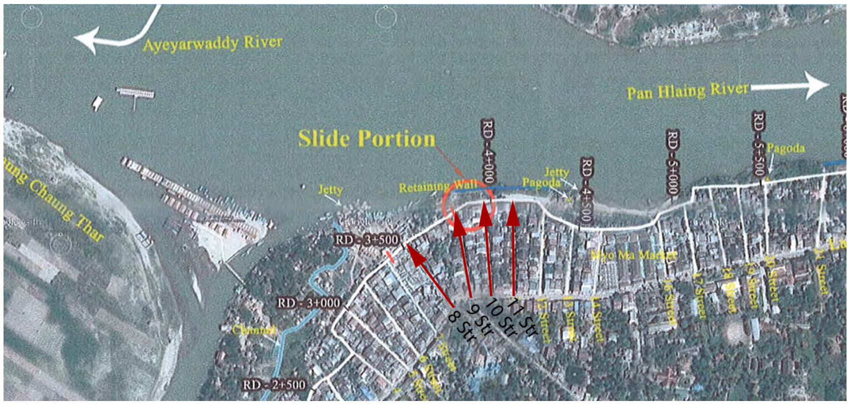


Figure 4.5: Location map Nyaungdon (Department of Irrigation and Water Management Utilisation, 2016)

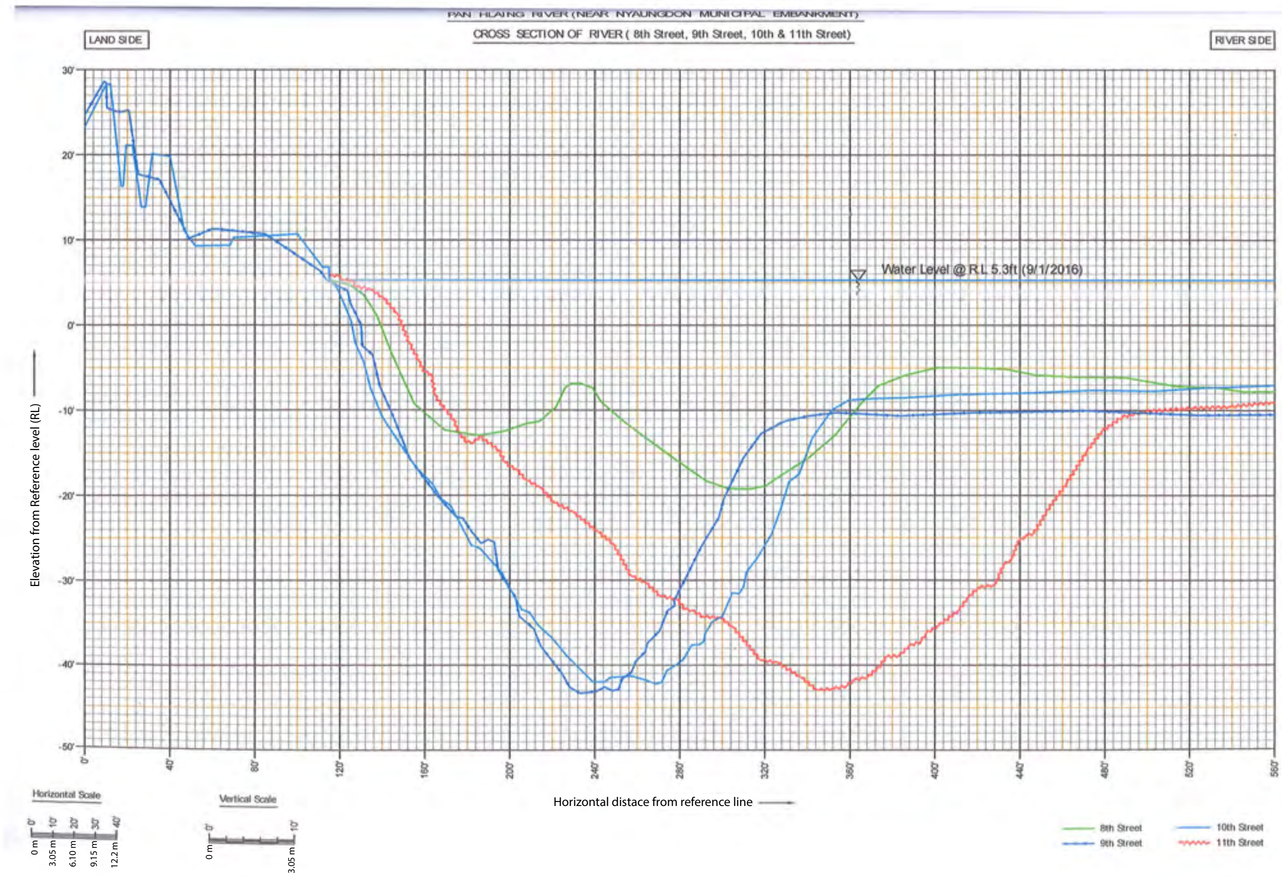


Figure 4.6: Bathymetry Pan Hlaing River
(Department of Irrigation and Water Management Utilisation, 2016)

4.1.4 Climate

Nyuangdon has a humid tropical monsoon climate, dominated by the South Asian summer monsoon. The township features a lengthy rainy season from May to October where a substantial amount of rainfall is received, and a dry season from November to April, where little rainfall takes place. However, Myanmar's monsoon pattern is being affected by climate change; estimates suggest that global warming has shortened and shifted the monsoon pattern for the past 30 years, resulting in a more intense rainy season. Changes to the weather patterns, including increased storminess and decreased rain, has resulted in a decrease in annual rainfall (Sovacool, 2012). The intensification of the rainy season is likely to result in more severe floods. Besides the frequency and strength of cyclones and related floods seem to be on rise. (Bucx et al., 2014). According to the Asian Development Bank, "many more people" in Southeast Asia died as a result of natural disasters between 2001 and 2010 than during the previous decade, primarily due to the 2004 India Ocean tsunami and 2008's Cyclone Nargis. Nargis hit Myanmar with resulting waves of more than 6 metres in the coastal zones in May 2008. This cyclone was the strongest ever, killing a total number of 138,373 people and leaving about 2.4 million affected. However this cannot be directly related to climate change (Ministry of Social Welfare and Relief and Resettlement, 2012).

Besides the periods of heavier rainfalls the Myanmar's National Adaptation Programme of Action (NAPA) to Climate Change included the following climate change predictions for the period until 2050:

- An increase in temperature of 1.4 ºC in the Ayeyarwady region, compared to the temperatures in 2001.
- An increase in rainfall of approximately 250 mm in the Ayeyarwady Delta, compared to the rainfall in 2001 (Ministry of Transport, 2012).

4.1.5 Hydrology

Considering the necessary hydraulic data for this case study, mainly the water levels are of great influence. Floods occur primarily due to extreme high water levels in the monsoon season. The town of Nyaungdon distinguishes two important high water levels:

- Warning level: +22.5 ft MSL / +6.6 m MSL
- Danger level: +24.5 ft MSL / +7.5 m MSL

In case of the warning level, the administration department of the office has to be informed about the high water level. When the danger level is measured, the chairman of the administration department of Nyaungdon Township organizes a meeting gathering all the chairman of the area, to discuss a further approach for the dangerous situation (Administration Committee Nyaungdon Township, 2016).

The Department of Meteorology and Hydrology, DMH, gathers hydraulic data for several measuring stations in Myanmar. No water level measurements have been performed for long periods in Nyaungdon in the past. Fortunately, water levels in Hinthada, a town upstream from Nyaungdon, have been recorded for the period of 1969 until 1986. The travel time of a flood wave from Hinthada to Nyaundon is approximately one day, as shown in figure 4.7. This graph also indicates the ratio between the water level due to a flood wave upstream in Hinthada and downstream in Nyaungdon. On the 20th of September a water level of 46 ft or 14.0 m was recorded in Hinthada. A day later, the peak of the flood wave arrived in Nyangdon, causing a water level of 24 ft or 7.3 m, which is close to the danger level. Hence the ratio of the water levels between the two towns caused by the flood wave was 1.9.

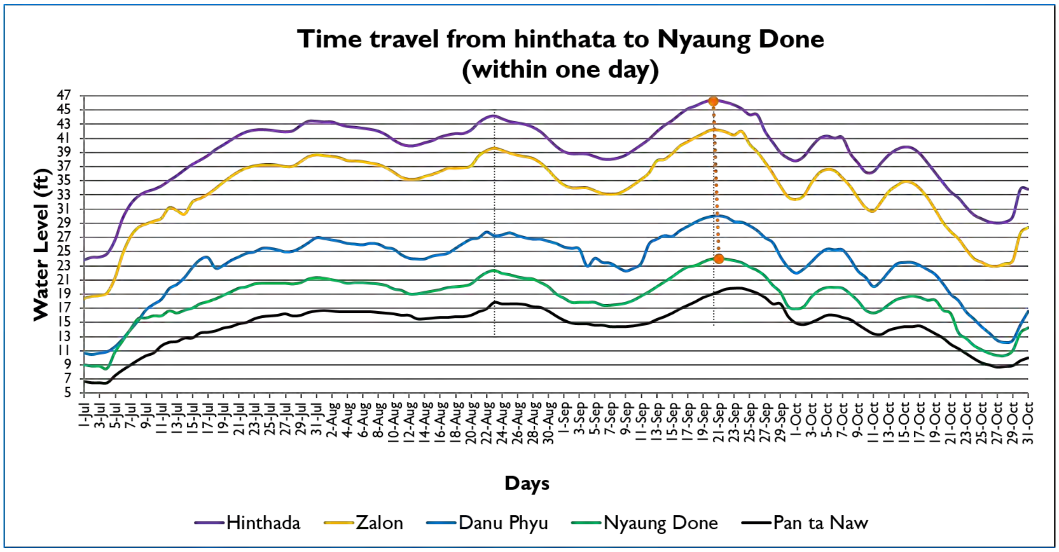


Figure 4.7: Travel time flood wave
(Kyaw Zayer, 2016)

The danger level in Hinthada is set to 46.55 ft or 14.2 metres, considering the earlier stated ratio between the water levels in both townships. According to the DMH data this water level occurred every year in the period of 1969-1986, mainly in the months of July until September. The maximum water level that was recorded was +18.17 m MSL in August 1974. If the danger level in Hinthada is related as stated to the danger level in Nyaungdon, it follows that the danger water level in Nyaungdon was also yearly reached.

However, this is contradicted by figure 4.8. This figure shows that for the period of 1985-2015 danger water level was only reached in 16 out of 31 years. This makes the earlier made assumption, which states that it occurred every year in Nyaungdon, very doubtful. The reliability and accuracy of the data for the first period should therefore be questioned.

The values of the water levels for the entire period can be found in appendix B.1.1. The roughness of the assumption due to the short period of the has to be remarked.

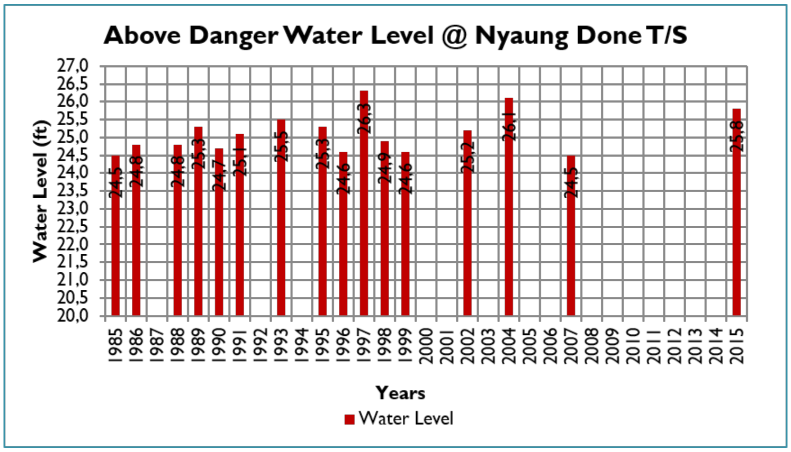


Figure 4.8: Danger water level in Nyaungdon
(Kyaw Zayer, 2016)

In section 4.1.4 it was mentioned that an increase in rainfall is expected of 250 mm per year. Since this increase in precipitation is likely to occur during the months with the most severe rainfall, it is assumed that June, July and August will experience an increase of 83 mm each. Using the DMH data it can be derived that an increase of 83 mm rainfall causes a water level rise of 0.2 metres approximately. Therefore it is assumed that in the future the water levels in the months June until September will rise with 0.2 m due to the increase of rainfall.

4.2 Socioeconomy

4.2.1 Population

Nyaungdon area has 197851 inhabitants, 47010 families and around 46700 housings. This area contains 308 villages, divided in 44 "groups of villages", including Nyaungdon township. Nyaungdon area has a relatively high percentage of educated inhabitants compared to the rest of Myanmar: in July 2016 the Administration Committee of Nyaungdon township ascertained that over 96% of the population finished primary school education (Administration Committee Nyaungdon Township, 2016). The average percentage for the entire country of Myanmar is 89.5% (Department of Population, 2015).

Nyaungdon township has around 40.000 inhabitants: most of them are farmers or fishermen. Over the past decades a continuous struggle against the river has taken place in order to maximize the harvest of rice and other crops, and to improve water quality. The improved water quality was needed for the fishermen, because they noticed a drastic decrease in the species of fish. Since 1920 the first dikes and water control structures have been constructed resulting in controlled ‘islands’ in the braided river, where many farmers cultivate their rice. Also the surrounding area next to the river is controlled by irrigation channels combined with water control structures. Flooding of the river has positive and negative impact on these islands. Once flooded, the people that live and work on the islands cannot leave for several days, and their harvest will probably be destroyed. But flooding also provides fertile soils onto their fields which is needed for future harvests. So flooding is not always considered as a bad thing, especially not by the farmers that have already adopted their way of living by the annual flooding of their village (Maung Nyunt & Tun Tun, 2007).

4.2.2 Economy

Three main sectors can be distinguished in the industrial structure of Nyaungdon. The first one is fishing, as stated in the section above. Moreover, this is also the main export product of the township. The other two sectors are agriculture and live-stock; mainly applied for own use, although sometimes also small trades are made with the surrounding villages (Administration Committee Nyaungdon Township, 2016).

Until 1985 the rice growing area increased, mainly due to improvement of the drainage system and protection of the land by embankments. In 1986 an "Island Reclamation Project" was initiated. This also caused an increase in winter crops, paddy's and cultural land. Besides, the aquaculture area increased with almost 300% and the fish production consequently increased from 28.8 tons in 2003 to 82.01 tons in 2007. The impact of this project has been huge for the local community as well as the national economy (Maung Nyunt & Tun Tun, 2007).

4.3 Infrastructure

Nyaungdon is connected to its surroundings by Pathein Road and by the Irrawady and the Pan Hlaing Rivers. During a study of the main infrastructural elements of Nyaungdon township the roads have been divided into four categories: asphalt, concrete, gravel and soil. All asphalt and concrete roads are two lane roads, including Pathein Road highway. The gravel and soil roads differ from one to two lane roads. The map indicating the division of the roads is shown in figure 4.9. This map also indicates the embankments surrounding the township. Besides these infrastructural elements also important public buildings as hospitals, schools and pagodas are marked.

Figure 4.9: Infrastructure Nyaungdon

4.4 Current measures against floods

After visiting Nyaungdon several current measures are noticed, which can be divided in three layers with the multi-safety layer approach. Before listing the current measures in the three layers of prevention, first the ideal profile for a dike in Nyaungdon is described. According to the engineer within the irrigation department of Myanmar who is situated in Nyaungdon, the ideal profile of a dike should not be affected within the boundaries of 20 ft (6 m) at the land side of the dike. Also the dike may not be affected within 40 ft (12 m) at the river side of the dike. Furthermore the height of the dike should be designed at 32 ft (9.7 m) above Mean Sea Level. This level is called the Authorised Crest Level (ACL). It was determined on the basis of the water level during the flood that occurred in 2015. These dimensions have recently been described by the irrigation department to act as guidance in dike renovation projects and maintenance.

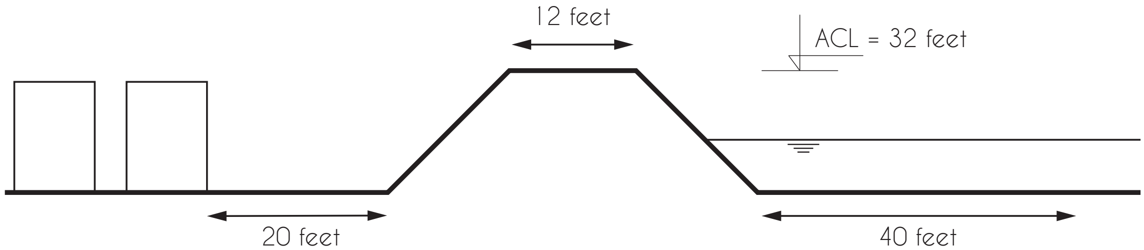


Figure 4.10: The ideal designed profile for dikes in Nyaungdon

In figure 4.10 all dimensions and overall layout of the dike are shown. Although these new design rules now exist, most of the dikes in Nyaungdon area and Nyaungdon township itself are below the standards. Nyaundon area has about 124.000 metres of dikes of which only around 100 metres meet the new standard crest level described above. These dike have recently been heightened in 2016 reducing the amount of floods compared to 2015. Still lots of floods occur during the rainy seasons. The main problem most these dikes are facing is the constant eroding character which makes it harder to strengthen the dikes or heighten them. Another problem are the boundaries in which the dikes should not be affected. These boundaries are not always lived by, and houses are built practically in the dike causing major problems when heightening the dikes
Below the 3 prevention layers are listed which are present in Nyaungdon to prevent floods. Starting with the dikes which will be elaborated in more detail since multiple layout of dikes are present in Nyaungdon.

4.4.1 Layer 1: Prevention

The measures that are protecting Nyaungdon against the river water meanly consist of dikes. The main dike has a length of about 11300 ft. (3445 m) and reconstructed in april 2016 (Department of Irrigation and Water Management Utilisation, 2016). Figure 4.11 shows the actual location of the dike.

Figure 4.11: Dike ring in Nyaung done

Because of the different shapes of the dike profiles it is impossible to come up with a general layout of this dike. As a consequence three different dike profiles are distinguished, which are described and illustrated below.

4.4.1.1 Profile 1: Earth Work

The earth work dike is mainly constructed away from the cross section between the two rivers, see figure 4.11. They suffer from severe erosion throughout the year and need revetments and other erosion prevention measures to make sure these dikes do not breach. These dikes have a slopes of 1:2 and a height of approximately 3 m (Department of Irrigation and Water Management Utilisation, 2016). The schematic cross section of this dike is illustrated in figure 4.12. This is the only cross section of which the dimensions are known, all the other schematic cross section have approximately the same dimensions, although the exact dimensions are not known.

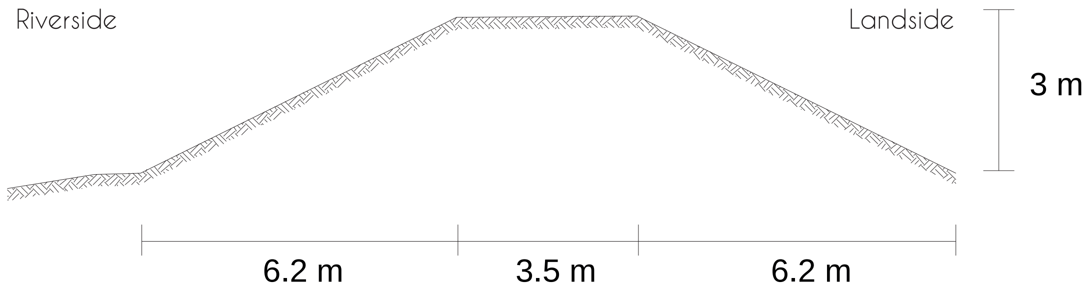


Figure 4.12: Schematic cross section of the earth work profile

4.4.1.2 Profile 2: Brick work

The Brick work dike has two small concrete walls in the dike profile. The top wall has been constructed to meet the new standards of the dike profile. Since there was no room to heighten the dike with sand, this was the best solution, otherwise houses had to be broken down to make room for the higher dike. The houses are built so close to the dike that is was impossible to heighten the dike without making a small concrete wall at the landside as well (Department of Irrigation and Water Management Utilisation, 2016). Figure 4.13 shows the schematic cross section of the dike. The slopes of the dike are assumed to be 1:2. This assumption is based on a report written by the department of irrigation. It cannot be said that if all the slopes along the total dike have the same slope since the profile varies over the dike length, and the information of all different cross section is limited. The inner and outer slope of this dike profile are depicted in figures 4.15 and 4.14 below.

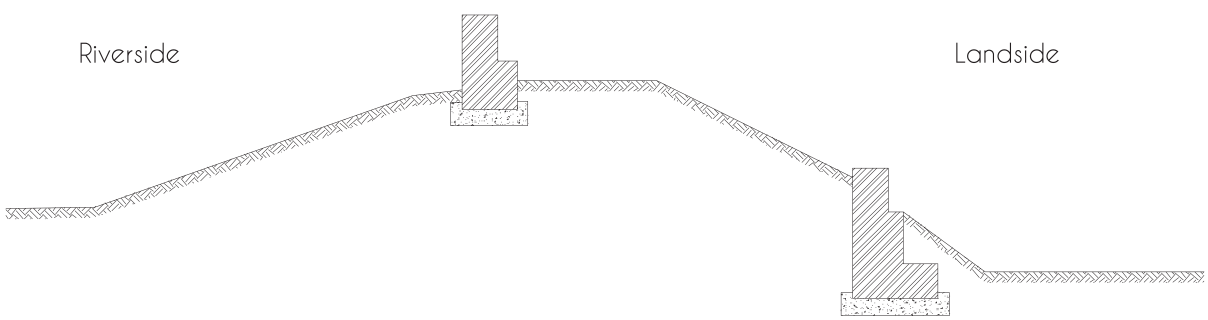


Figure 4.13: Schematic cross section of the brick work profile

Figure 4.14: Outer slope dike (by Ilse Caminada)

Figure 4.15: Inner slope dike (by Nick Stoop)

4.4.1.3 Profile 3: Strong dike

Some parts of the of the embankment are eroding due to high flow velocities. These parts are defended with the strong dike profile. This profile consists of stone pitching with rock and are filled with concrete within the strong dike profile. This part of the dike has been strengthened recently according to the new design rules as well. Two dike profile types are distinguished, as can bee seen in figures 4.16 and 4.17. the cross section of type 2 is the transection between the brick work dike and the strong dike. In this part of the strong dike, the houses are also constructed to close to the dike itself. No room was left for a better improvement of the dike, so again the concrete wall has been placed on top. The pictures of the current state of the strong dike can be found in figures 4.18 and 4.19, in which it is very clearly noticeable how close houses have been constructed next to the dike.

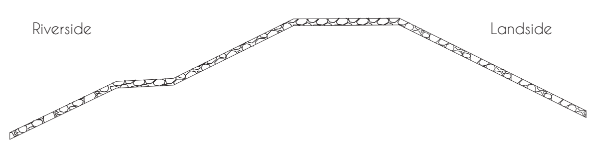


Figure 4.16: Schematic cross section strong dike type 1

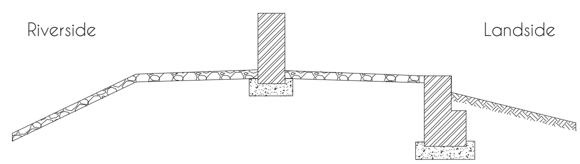


Figure 4.17: Schematic cross section strong dike type 2

Figure 4.18: Outer slope strong dike type 1 (by Nick Stoop)

Figure 4.19: Strong dike of type 2 (by Ilse caminada)

4.4.1.4 Shared exceptions

The three elaborated dike profiles are generalised. There are some slight and some large exceptions which influence the functioning of the dike. These have already been mentioned. The four most important objects which affect the functioning of the dike the dike are located in or close to the dike. These four objects are listed from important to less important below:

1. *Houses on both sides of the dike*: This is the most important problem around Nyaungdon. The houses inside the boundaries where nothing should be constructed. They highly affect the flow velocities over and around the dike causing all kinds of erosion problems. When erosion patterns start to grow they can undermine the profile and therefore the function of the dike. The profile of the dike is designed to stay the same, anything that will affect this profile is considered to be a problem.

2. *Small pagodas*: Pagodas have been constructed on top of the dike at some points along it. They do not necessarily affect the strength of the dike at that specific point. They might even strengthen it. Still, because of the local strengthening of the dike, the soil around it will suffer from erosion caused by this pagoda. The high flow velocities will not affect the pagoda, but only the soil directly next to it, generate an erosion spot which will only grow larger if no maintenance occurs.

3. *Trees*: The main problem with trees is that they grow roots. These roots cannot be controlled at all, and they cause local weak spots in the soil. Also the effect of 'piping' can be supported by the tunnels generated because of these roots. Besides the same effect like the case of the houses in front of the dike will affect the dike. Because of structures in the dike profile flow patterns will develop other that designed, causing al kinds of erosion patterns.

4. *Garbage*: This is a small problem in comparison with the other three. Still the garbage that is thrown into the river side of the dike can cause al kind of flow patters once the water reaches this garbage, and can again generate erosion along the dike.

The main problem is that the profile of the dike is undermined by all kinds of objects that affect the flow patterns over and along the dike. The dike should be free of any obstructions as designed, unfortunately this is not the case at the moment. Figure 4.20 shows an example of these objects wherein the first three points listed above can be seen. This pagoda is constructed on the inside the slope of the dike. This is not the case for all pagodas, some are constructed on top or even at the other side.

Figure 4.20: Objects in a dike profile (by Ilse Caminada)

4.4.2 Layer 2: Spatial planning

The current measures by using spatial planning and adaptation of building in Nyaungdon are houses on stilts. These are built on both side of the dike. Figure 4.21 shows an example of a elevated house in Nyaungdon. This house is build at the undefended side of the dike. Houses on the land side of the dike are all constructed normally without stilts.

Figure 4.21: An elevated house in Nyaungdon (by Ilse Caminada)

Most of the people believe that Nyaungdon township will not flood and everyone strongly believes that the dike is strong enough. Even the people living almost inside the dike on the protected side of the dike have not constructed their house on stilts. These part of the dike however are the weakest part of the dike since the profile is strongly influenced by these houses.

Inside Nyaungdon a drainage system is present which transports the water outside the town. Although it has not thoroughly been inspected, it seemed to work well and the drainage wells were covered with concrete slabs to cover it from garbage and other trash to block it.

4.4.3 Layer 3: Crisis Management

In Nyaungdon some part of the dikes were strengthened with sandbags behind the dike. This is a temporary defences that will increase the stability of the dike at a very specific point, probably at a point where piping has occurred. This temporary defences of sandbags is depicted in figure 4.22.

Figure 4.22: Temporary defence of sandbags (by Ilse Caminada)

An evacuation plan is available in limited state. It is not a plan in which is described how people have to evacuate the area, and where to. But it consists more of a to-do list for the chairman of Nyaungdon township when the water level reaches a critical level. If it does reach this level, he has to gather all the other chairmen of villages in Nyaungdon area to discuss what has to happen and how. There and then it will be decided what the plan will be and how they will execute it. Besides this, also an early warning system is present: every morning the water levels in the upstream townships Mandalay and Hinthada are asked. This is described in more detail in section 4.7.

4.5 Actor analysis

In this section an actor analysis is done specified at the case of Nyaungdon. In subsection 4.5.1 an overview is given of all the actors involved. In subsection 4.5.2 the formal chart is discussed again. In subsection 4.5.3 the Power and interest grid is made at a local level again.

4.5.1 Overview of all the actors involved

In this subsection an overview of the local and regional authorities are discussed. Some of the national authorities like the Irrigation Department are discussed again. Although it is not a new actor, it has an important influence in making Nyaungdon flood proof. An extra specification in the multinationals and the local population group was not necessary to analyse for the situation in Nyaungdon.

4.5.1.1 Irrigation Department Nyaungdon

Kyaw Zayyar Tint is the deputy, an assistant engineer, of the Irrigation department of Nyaungdon. The Irrigation Department includes an administration office who investigates, collects and transports the hydraulic data. Every morning this department measures the water level and reports to the ministry. Next to that every morning this department asks the water level of other Irrigation Departments in townships as Hindada and Mandalay upstream, located by the Ayeyarwady river. With trend lines the Irrigation Department in Nyaungdon can predict the future water level at a warning level or danger level. If the Irrigation department predicts a dangerous level the ministry and the chairman are warned. In 2016 the Irrigation Department was responsible to build the dike to protect the citizens of Nyaungdon from flooding. It has the power to realise permanent measures against flooding.

4.5.1.2 City Development Department

The department of the City Development is responsible for the urbanisation in Nyaungdon. It approves or disapproves the building of houses or offices. Its approval has influence on the effects of a flood. In the current situation the houses are standing at the waterside of the dike and several houses are standing less than 6 metres of the dike. As a cause of this placement the function of the dike is negatively influenced by these houses, see section 4.4. The city development department claims it cannot remove the houses although it knows houses have a bad influence. It claims that the houses are paid off.

4.5.1.3 Evacuation Committee

In Nyaungdon a committee is formed by members of different departments as the Irrigation department, the health department, the fire department, crisis managers and deputies. The committee is described in more detail in section 4.7. It has the objective to lead the disaster management procedure.

4.5.1.4 Chairman of Nyaungdon

The chairman of Nyaungdon plays a big role in the decisions of the township. Moreover during a disaster the chairman plays a crucial management role, see section 4.7. He organises general meetings with the other chairmen to make a disaster plan when a flood is predicted.

4.5.1.5 Good Neighbors International, GNI

The GNI is a Korean NGO, a non governmental, non profit, humanitarian relief and development organisation (Good Neighbours international, 2010). In Nyaungdon it has influence on multiple sectors. They provide education, food, health, (social) protection, shelters and WASH (clean drinking water) (Good Neighbours international, 2010).

4.5.1.6 Caritas (CACH)

Caritas is an international NGO, that provides help to people in need and poverty at home or abroad regardless of their political or religious beliefs, gender of ethnicity (Myanmar Informartion Manegement Unit, 2016). In Nyaungdon they mitigate the damage of floods.

4.5.1.7 Karuna Mission Social Solidarity KMSS

KMSS is a faithbased social network at the service of the catholic church (Karuna Mission Social Solidarity, 2016). In Nyaungdon the KMSS helps with the disaster reduction and protection of flooding. Their goal is to reduce the risks and harm to communities by minimizing vulnerability and strengthening capacity and effectively respond to disasters (Karuna Mission Social Solidarity, 2016). In Myanmar they help the population evacuate from villages, move patients and medicines and support financially as well.

4.5.1.8 UNICEF

UNICEF also cooperates with the Nyaungdon township. Its main objective is education and child protection but when floods appear UNICEF does even more. Its program targets are helping with nutrition, health and WASH (clean drinking water).

	Interest	Desired situation/objectives	Expected or existing situation	Causes	Possible solutions / sources
City development department	To regulate the building of houses in Nyaungdon	Every house is built at a safe flood proof area.	The houses are still built in unsafe areas and are placed at the water side of the dike.	The houses are paid off and can not be removed.	Give a financial incentive to stimulate the people to move out their house to a safer place.
(Local) Evacuation Committee	Evacuate the flood effected people.	Evacuate in time and have as low casualties as possible.	The organisation is not sufficient enough.	The chance that a flood occurs is too low.	Prepare and organise the evacuation better. Seek help by experienced NGO's.
Chairman	Implement the policy of the council	Floods will effect the welfare of the people ad the neighbour townships.	The neighbour townships need information from Nyaungdon chairman.	The other townships have a lack of technology and knowledge to do water level measures on their own.	Support and give information every time when it is necessary.
Good Neighbours International (NGO)	Give help to the population in third world countries.	The NGO does not have to provide a lot of help to Nyaungdon.	Nyaungdon when flooded cannot safe itself.	There is a lack of emergency supplies.	The GNI will provide help to mitigate the damages of floods.
Caritas (NGO)	Give help to the population in third world countries.	Help the city of Nyaungdon to help in basic needs.	The floods will effect the welfare of the people.	The disaster plans are not sufficient enough and there is a lack of supplies.	The Caritas will help to prevent supplies to mitigate the damages of floods.
Karuna Mission Social Solidarity (NGO)	Provide help to third world country to make disaster reduction plan.	Help the city of Nyaungdon to prepare itself for an disaster.	The plan should be implemented when flood occurs.	There is a lack of knowledge about disaster plans.	When flood occurs KMSS will help to implement the disaster plan.
UNICEF (NGO)	Give help (to children) in third world country.	Provide the economic welfare and growth for children in Nyaungdon.	The floods will effect the the welfare of the people.	The disaster plans are not sufficient enough and there is a lack of supplies.	UNICEF will help to prevent supplies to mitigate the damages of floods.

Table 4.1: Overview actors Nyaungdon

4.5.2 Formal chart

In the figure below the formal chart is adjusted to the situation of Nyaungdon. The humanitarian organisations are filled in for the situation of Nyaungdon. Different is that some of the NGO's also help in disaster plans. So the humanitarian organisations not only mitigate but also cooperate with the ministries and local authorities to make a disaster plan. The ministry of Social Welfare, Relief and Resettlement and the Irrigation Departments send deputies to the local and regional authorities. Why it is chosen to see the evacuation committee at a regional level is because of the fact that it is also responsible for the evacuation of other township around Nyaungdon.

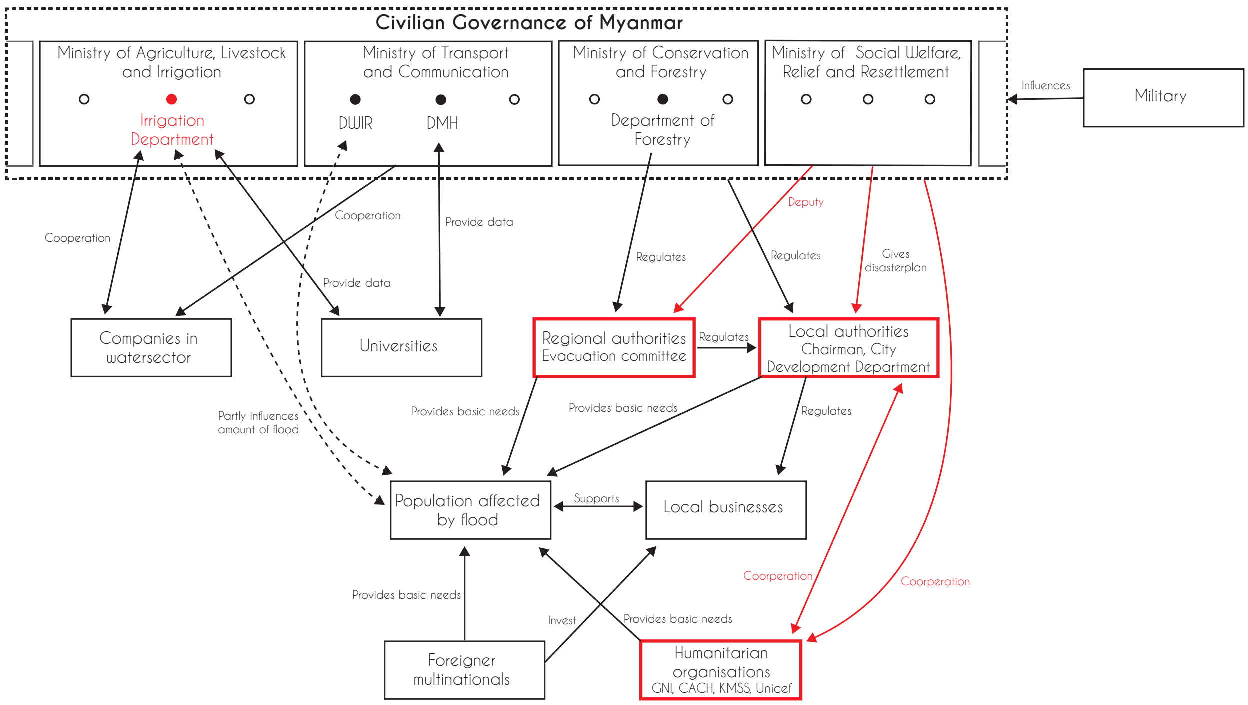


Figure 4.23: Power interest matrix of Nyaungdon

4.5.3 Power and Interest of actors

In this figure the power and interest grid is adjusted to the situation of Nyaungdon. The City Development Department is striking: although they are not against flood protection they negatively influence the function of the dike by accepting the houses at the waterside of the dike. The department has the power to remove the houses but decides not to do so. It is chosen to take all the humanitarian organisations together although some of the NGO's like KMSS have more power and have more interest in Nyaungdon. The Irrigation department, regional and local authorities still keep their role as key players. They should always be taken along in the policy decisions concerning flood protection in Nyaungdon.

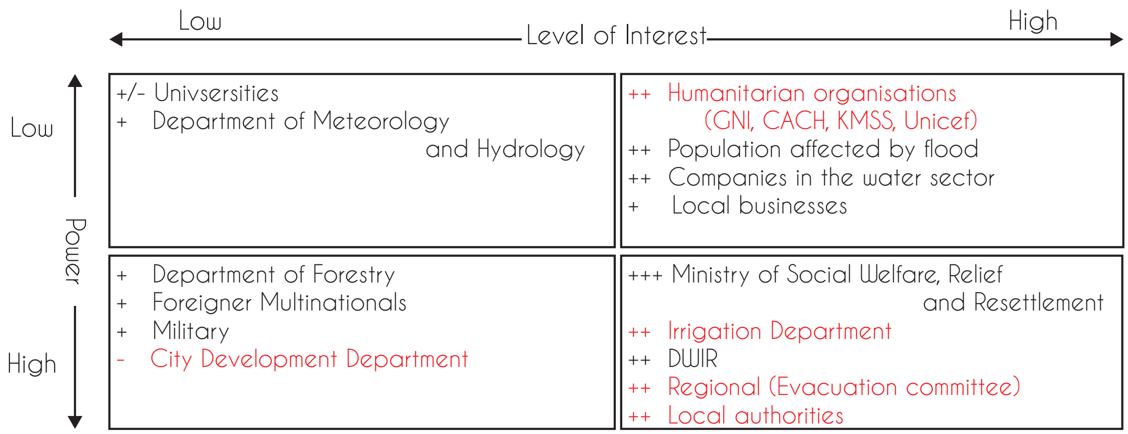


Figure 4.24: Power interest matrix

4.6 Flood risk analysis

This section contains the flood risk analysis of Nyaungdon. The general approach for a flood risk analysis is described in section 2.5.6. For this case water level rise due to high discharges is the most import hydraulic condition, since Nyaungdon is located near a river area and is far-away enough from the coast to neglect tidal influences. These hydraulic conditions are described in section 4.1.5, however section 4.1.5 excludes the probabilities of occurrence of these water levels. Therefore this analysis starts with a flood hazard analysis which describes these probabilities.

4.6.1 Flood hazard analysis

The water levels that have been measured in Nyaungdon, appendix B.1.1, can be used to do an extreme value analysis. This extreme value analysis, also known as the extreme value theory, is very useful to find values for unusual big floods. If one has data of water levels for a sufficient amount of time, one can say something about for example a 1 in 100 year flood. Probabilistic calculations are quite complex and this section might contain information which is difficult to explain in a short manner. If one desires to know more about probabilistic calculations one can find many information about this subject or read a reader about probabilistic calculations by for example Jonkman, Steenbergen, Morales-Nápoles, Vrouwenvelder, and Vrijling (2015).

Different types of probabilistic distributions can be used to do such an extreme value analysis, such as the Gumbel, Weibull or exponential distribution. For this case the Gumbel distribution has been used, since this distribution is often used in practice.

The Gumbel distribution is written as:

$$P(H' < H) = \exp\left(-\exp\left(-\frac{H-\gamma}{\beta}\right)\right) \tag{4.1}$$

H stands for the water level and H' stands for the water levels based on the data set. If one chooses a very large H one can expect that P goes to 1. The values for γ and β can be found by a regression analysis on the data (Verhagen, d'Angremond, & van Roode, 2012). First the Gumbel distribution has to be rewritten to produce a linear equation:

$$\begin{aligned} H &= \gamma - \beta \cdot \ln\left(\ln\left(\frac{1}{P}\right)\right) \\ &= \gamma + \beta \cdot G \end{aligned} \tag{4.2}$$

G is the Gumbel invariant is written as:

$$G = -\ln\left(\ln\left(\frac{1}{P}\right)\right)$$

In this extreme value analysis a peak over threshold (PoT) value can be chosen. This is especially of interest if one has a large data set with both extreme values and very common values. This peak of threshold value filters out these extreme values that enables a more reliable extreme value analysis. For this extreme value analysis a peak over threshold value of 7 metres has been chosen. This is 0.5 metres below the danger level and is assumed the be extreme. This gives the following data:

Years measured	30
Threshold value	7 m
Amount of extreme events	23
Amount of extreme events per year N	0.77 (-)

Table 4.2: Extreme value analysis data and assumptions

Appendix C.1.2 contains the table with the calculation for plotting the Gumbel invariant G against the water level H. The following figure shows the results of these calculations:

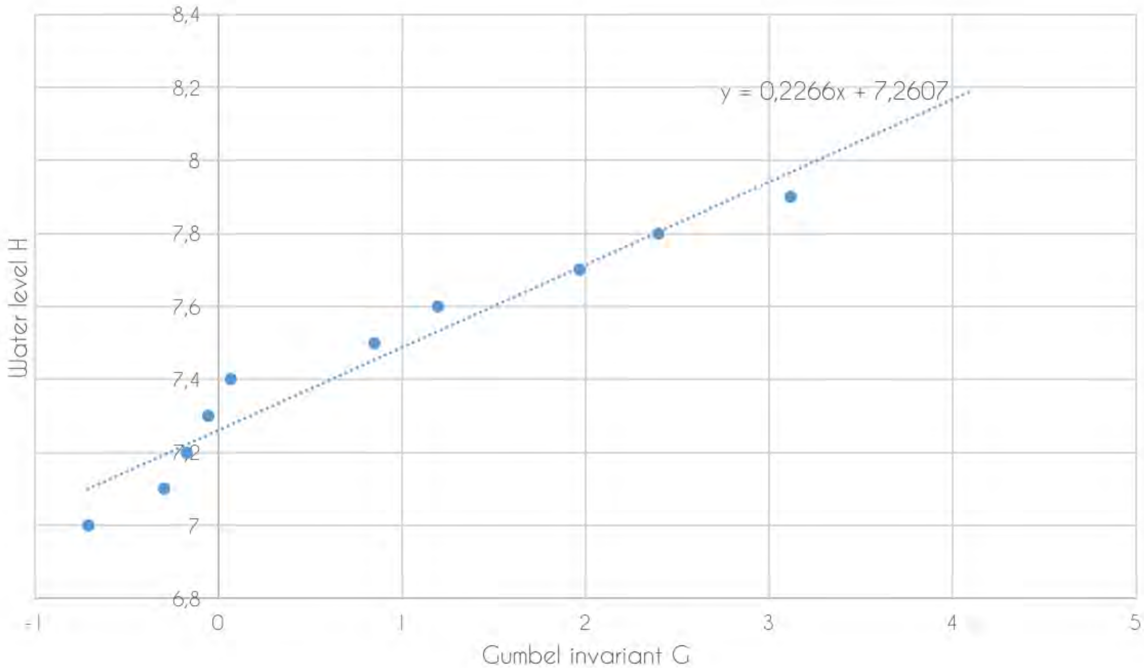


Figure 4.25: Gumbel distribution with trend line

The values of the trend line equation are corresponding to γ and β can be used to find values for water levels with different probabilities. These are, as can be seen in the figure, respectively 7.2607 and 0.2266. Some other definitions will now be introduced to complete equation 4.2:

$$Q = Q(H' > H) = 1 - P$$

Q is the general probability of exceedance. With this value one can also find the probability of exceedance of a year Q_s:

$$Q_s = Q \cdot N$$

This value can now be used to to define a certain exceendance value, say for example 1 in 100 year, and find the corresponding water level:

$$H = \gamma - \beta \cdot \ln\left(\ln\left(\frac{1}{1-Q}\right)\right)$$

$$H = \gamma - \beta \cdot \ln\left(\ln\left(\frac{1}{1-\frac{Q_s}{N}}\right)\right)$$

$$H = \gamma - \beta \cdot \ln\left(\ln\left(\frac{N}{N-Q_s}\right)\right) \tag{4.3}$$

This equation enables calculations of water level H for certain probabilities of exceedances Q_s. The other way around, if someone wants to calculate a probability of exceedance for a certain water level, one can use the following equation:

$$Q_s = -N \cdot \exp\left(-\exp\left(-\frac{H-\gamma}{\beta}\right)\right) + N \tag{4.4}$$

To summarize all the needed values to calculate with equation 4.3 and equation 4.4 are:

γ	7.2607
β	0.2266
N	0.77

Table 4.3: Value for calculations

Some values for the probabilities and water levels that are calculated with the values above are shown in the tables below:

Water level H (m)	**Probability Q_S (-)**	**One in X year**
7.5	$2.25 \cdot 10^{-1}$	4.4
8.5	$3.22 \cdot 10^{-3}$	310.1
9.5	$3.92 \cdot 10^{-5}$	25537.4

Table 4.4: Water levels with corresponding probabilities

4.6.2 Flood scenarios

To develop the flood scenarios of Nyaungdon the water levels due to high discharges, which are a result of upstream heavy rainfall, are considered as leading. Moreover hydraulic conditions like local rainfall, sea-level rise and land subsidence should not be disregarded. As a consequence three flood scenarios are developed.

First an important note must be made. The maps which are used to construct flooding scenarios are only able to produce water levels of multitudes of 1 metre. This means one can only construct water levels of 1 metre, 2 metres, 3 metres and so on with respect to the reference water level (MSL). For this case rounding errors have to be introduced because of this constriction. For example, when constructing a 2.7 metres water level one can only construct a water level of either 2 or 3 metres. This could be avoided when using more accurate `SRTM` maps.

- **Scenario 1**
  A water level of 8 metres which is based on the local danger water level. The real danger water level is 7,5 metres, see section 4.1.5, because of the rounding error it is assumed to be 8 metres. This probability of occurrence is $\frac{1}{4.4}$ year and is calculated in section 4.6.1. This probability corresponds to the real water level of 7.5 metres.
- **Scenario 2**
  A water level of 9 metres as a result of high discharge due to upstream heavy rainfall with a probability of occurrence of $\frac{1}{310.1}$, see section section 4.6.1. This probability corresponds to a real water level of 8.5 metres.

- **Scenario 3**
  A water level of 10 metres as result of high discharge due to upstream heavy rainfall with a probability of occurrence of $\frac{1}{25537}$, see section section 4.6.1. This probability corresponds to a real water level of 9.5 metres.

An overview of these flood scenarios is given in table 4.5

	Water level rise due to		Probability
	High discharge due to upstream heavy rainfall	**h(m)**	**1/year**
Scenario 1	X	8	$2.25 \cdot 10^{-1}$
Scenario 2	X	9	$3.22 \cdot 10^{-3}$
Scenario 3	X	10	$3.92 \cdot 10^{-5}$

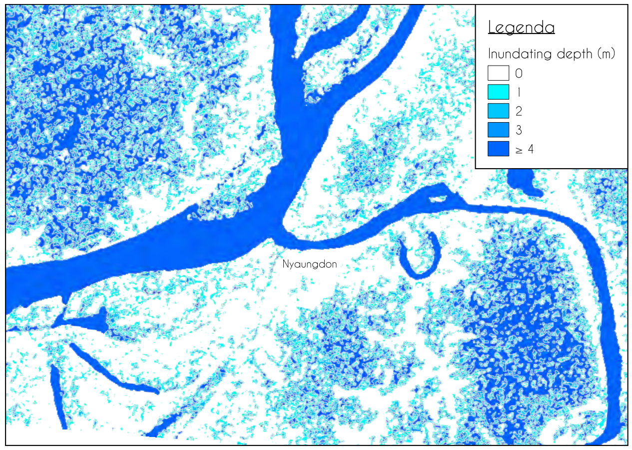
Table 4.5: Overview of flood scenarios in Nyaungdon

4.6.3 Flood damage assessment

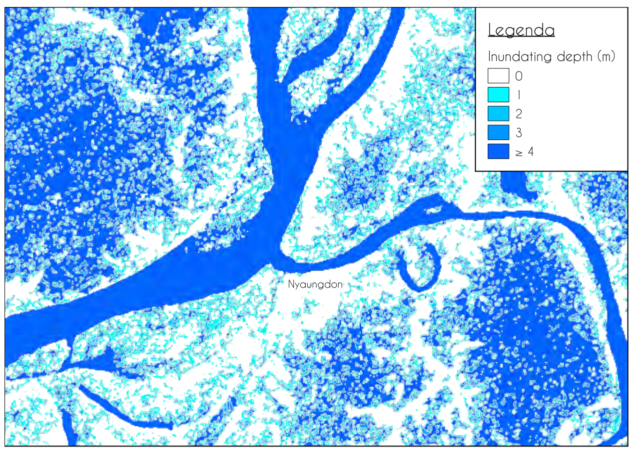
The goal of this section is to visualise the damages in the region of Nyaungdon caused by inundation. This is done by the following three steps, which are clarified in section 2.5.6.2.

4.6.3.1 Determination of flood characteristics

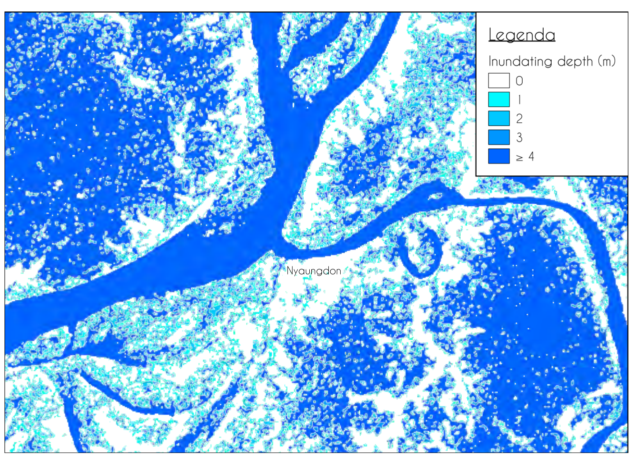
This step primarily aims to sample the inundation areas in the region of Nyaungdon. These areas are modelled in a open-source GIS system named `Qgis` that makes use of digital elevation maps. For this model the open-source `SRTM` data is used which is produced by NASA and published on the website of United States Geological Survey (USGS). The data has a vertical accuracy of 16 metres and horizontal accuracy of 30 metres, see section 4.1.1. Figure 11.15 shows the flood maps for the three flood scenarios.



(a) Flood map scenario 1



(b) Flood map scenario 2



(c) Flood map scenario 3

Figure 4.26: Flood maps for the flood scenarios

No distinctions are made for inundating depths that are equal to or higher than 4 metres, since 100% damage occurs in this stage. Moreover pixels are visible which are caused by horizontal accuracies. Also the vertical inaccuracy can be noticed in inhabited areas. The roofs of the buildings are falsely measured as the ground level. As a result the ground level seems to be higher than it actually is. In real-life the altitudes of the inhabited areas should much lower which is visible in the pictures of section 4.4. This problem can be solved by using more accurate data which is available, but expensive. This subject will be elaborated further on in this report. This flood damage assessment is accomplished based on these flood maps. Despite the fact that this flood map is not entirely realistic, these maps are used to give a better understanding about the approach of the flood damage assessment. This is in accordance with the stated criteria of section 2.2.

4.6.3.2 Assembling information on land use data and maximum damage amounts

Normally, this step includes assembling information on land use as well as the maximum damage amounts. However the maximum damage amounts of each damage category are previously elaborated in section 2.5.6.2, in which it is assumed that maximum damage amounts are similar throughout the whole country. The land use map is constructed in `Qgis` by using a `landsat` image of Nyaungdon. A `landsat` image consists of various bands which make it possible to define several classifications of land use. For simplification four classifications are made in this assessment, but for a detailed research more classifications should be made. The four assembled classifications are: water, buildings, vegetation and bare soil. During mapping it is noticed that some land is non-valuable and useless. Therefore the classification bare soil has been introduced. The final land use map of Nyaungdon is shown in figure 4.27.

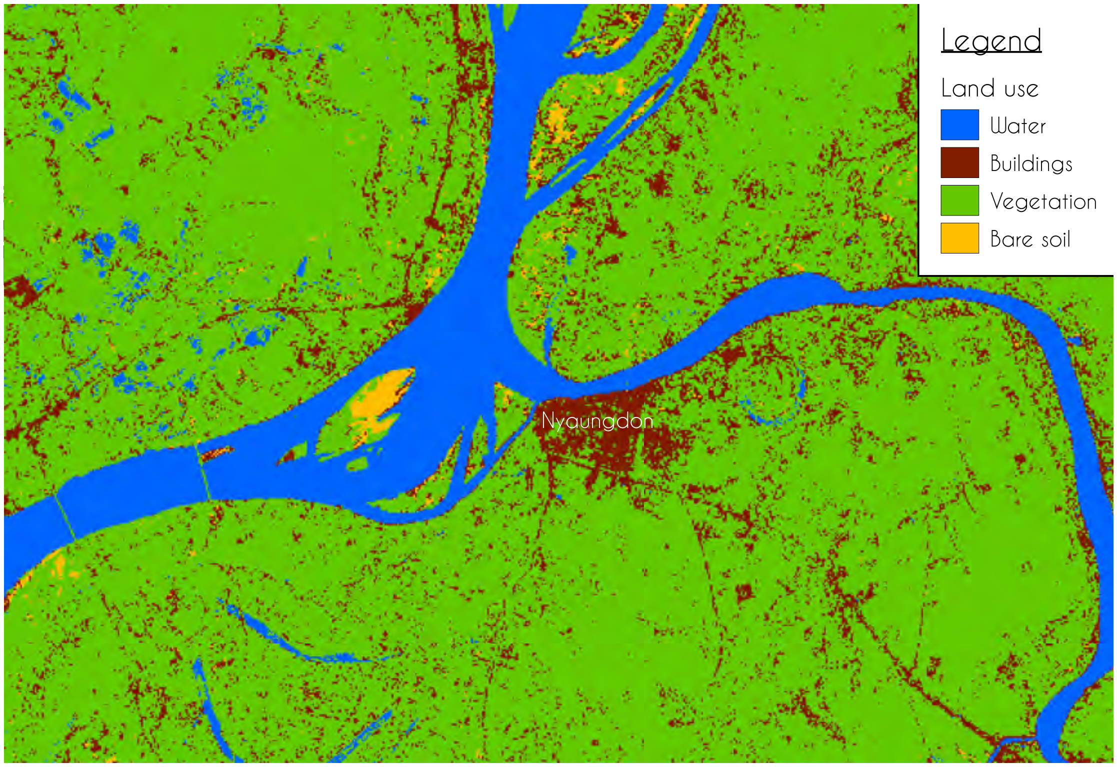


Figure 4.27: Land use of Nyaungdon

This figure gives a global representation of the land use in Nyaungdon. It is clearly visible that Nyaungdon is located in a rural area and most of the present buildings are located close to the township of Nyaungdon. However there is also one error visible, namely that there are buildings on the islands in the river which are barely present in real-life.

4.6.3.3 Application of stage-damage function

In this section the flood map and the land use map are integrated and combined with the stage-damage function to give an insight in the damages of the research area. Section 2.5.6.2 describes the general approach for this step, which is reproduces in this section for Nyaungdon. Therefore in this case the research area are firstly divided in three logical areas, based on their land use and inundating depths. These are depicted in figures 11.17 and 11.18 in which:

- Area 1: The urban area outlined in yellow
- Area 2: The east faced rural area outlined in blue
- Area 3: The west faced rural area outlined in red

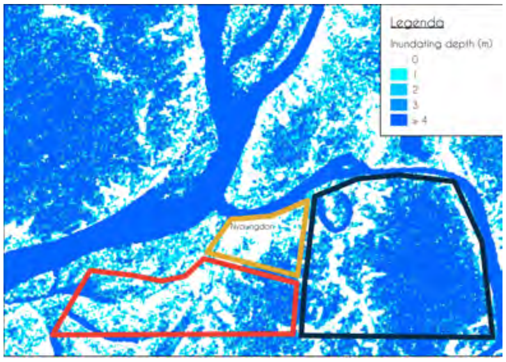


Figure 4.28: A flood map divided into 3 areas

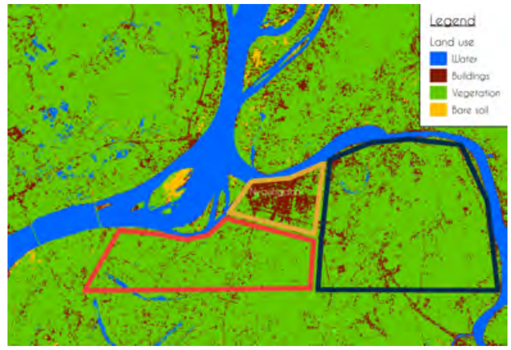


Figure 4.29: The land use divided into 3 areas

Secondly, the surfaces of the 3 areas are calculated by using `Google` maps. Thirdly, the areal percentage of land use and the areal percentage of inundating depths are determined. Finally, these percentages and surface are combined the `Excel`-sheet with the stage-damage function, which is elaborated in section 2.5.6.2. This calculation is done for every flood scenario. This results in the areal and total flood damage for every flood scenario, see table 4.6. Furthermore, the water depth of each flood scenario is plotted against the areal and total damages to give an insight in the gradient of damage, see figure 4.30.

	Water level	Damage of total area	Damage of area 1		Damage of area 2		Damage of area 3	
	h(m)	€	€	€/m^2	€	€/m^2	€	€/m^2
MSL	3	0	0	0	0	0	0	0
Flood scenario 1	8	32,774,114	20,840,846	3.37	7,957,778	0.25	3,975,490	0.21
Flood scenario 2	9	52,976,172	38,347,157	6.20	9,316,938	0.30	5,312,077	0.28
Flood scenario 2	10	63,151,603	45,849,861	7.41	10,070,462	0.32	7,231,279	0.38

Table 4.6: Results of the damage assessment for Nyaungdon

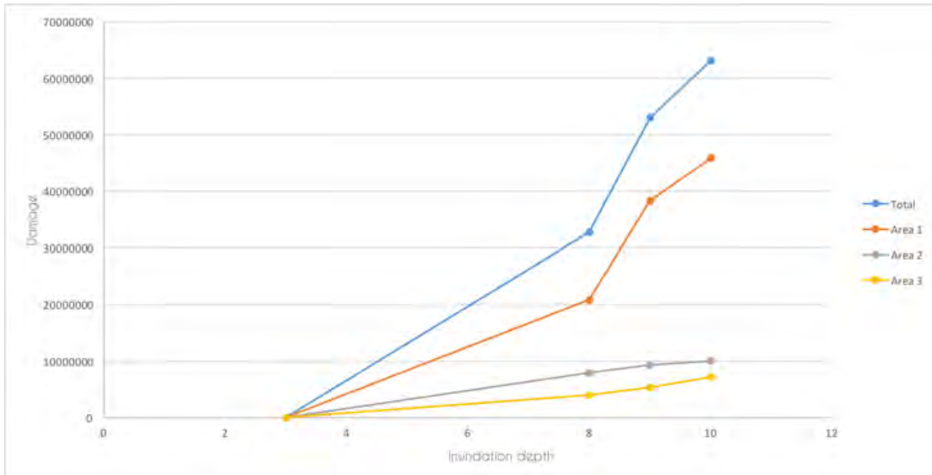


Figure 4.30: Damage against water depth for each scenario

In figure 4.30 it is clearly visible that the damage of area 1 is of high importance for the total damage. As a result the total damage strongly increases between flood scenario 1 and flood scenario 2.

Extra flooding of area 1

In section 4.6.3.1 it is noticed that the ground levels are falsely measured in urban areas due to the vertical inaccuracy of the `SRTM`-data. For an observation on how these errors will effect the total damages, extra inundating is manually added in area 1 for flood scenario 2 and flood scenario 3, since during these flood scenarios the water will flow over the dike. The results of these calculations are exhibited in table 4.7, in which the changed values are given in orange, and figure 4.31.

	Water level	Damage of total area	Damage of area 1		Damage of area 2		Damage of area 3	
	h(m)	€	€	€/m^2	€	€/m^2	€	€/m^2
MSL	3	0	0	0	0	0	0	0
Flood scenario 1	8	32,774,114	20,840,846	3.37	7,957,778	0.25	3,975,490	0.21
Flood scenario 2	9	72,149,750	57,520,735	9.30	9,316,938	0.30	5,312,077	0.28
Flood scenario 3	10	112,752,816	95,451,074	15.43	10,070,462	0.32	7,231,279	0.38

Table 4.7: Results of the damage assessment with extra flooding in area 1

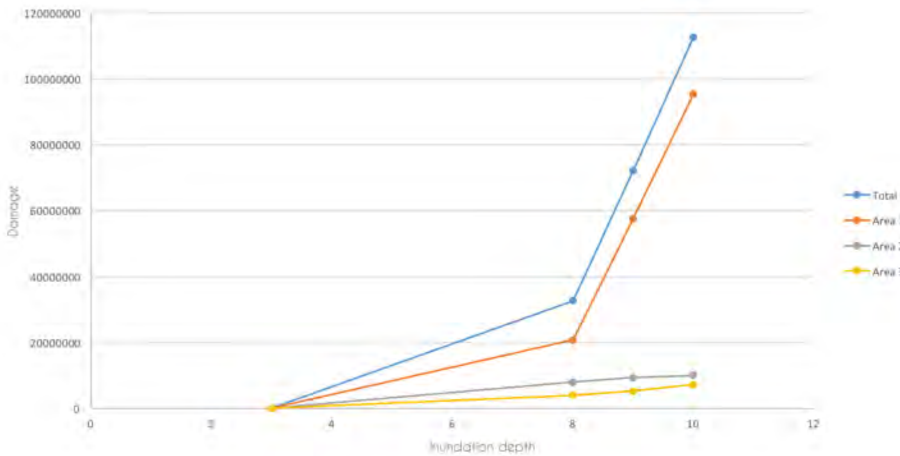


Figure 4.31: Damage against water depth for each scenario with extra flooding

In table 4.7 it can be noticed that total amount damage has strongly increased in flood scenario 1 and flood scenario 2. Furthermore, in figure 4.31 it is also noticed that gradient of the function becomes extremely high after passing the water level of 8 metres. Therefore, it can be concluded that more flooding in area 1 will strongly effect the total damage in a negative way.

4.6.4 Flood risk analysis

The `Excel`-sheet has provided the FN-curve for the case of Nyaungdon which can be seen in figure 4.32 and figure 4.33.

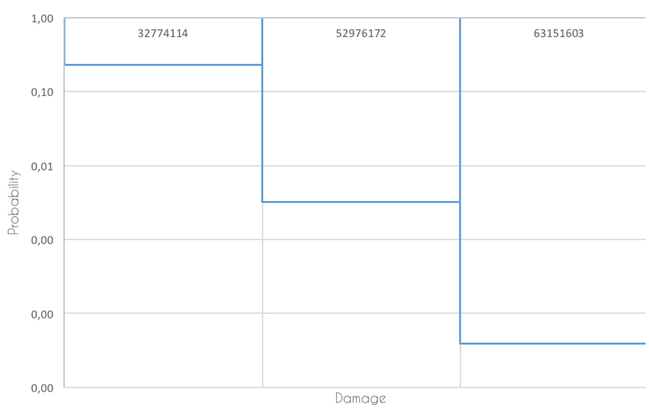


Figure 4.32: FN curve Nyaungdon (main situation)

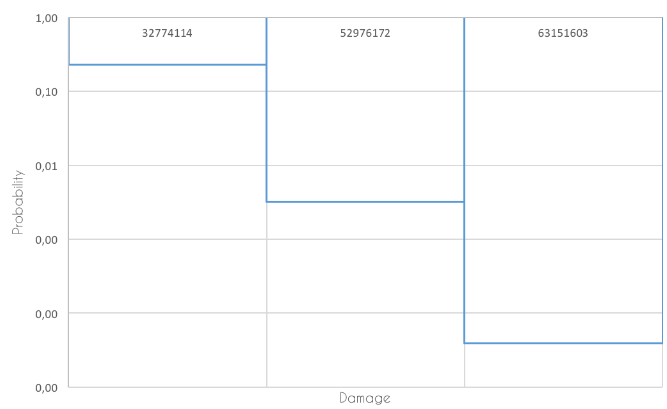


Figure 4.33: FN curve Nyaungdon with extra flooding

The following table shows the data that corresponds with these figures:

	Flood scenario	Damage (€)	Probability (-)
Main situation	Flood scenario 1	32,774,114	0.23
	Flood scenario 2	52,976,172	$3.22 \cdot 10^{-3}$
	Flood scenario 3	63,151,603	$3.92 \cdot 10^{-5}$
Extra flooding regarded	Flood scenario 1	32,774,114	0.23
	Flood scenario 2	72,149,751	$3.22 \cdot 10^{-3}$
	Flood scenario 3	112,752,817	$3.92 \cdot 10^{-5}$

As described in the framework, the total risk of a region is the surface area below the FN-curve. The total risks for these two situations are:

	Total risk (€/year)
Main situation	7,514,207
Extra flooding regarded	7,577,229

Table 4.8: Total risks

It is interesting to see how much a certain area contributes to the total risk of the entire area. Table 4.9 shows how much each area adds to this total risk in percentages of the total risk:

	Area	Per. of total (%)
Main situation	Area 1	0.64
	Area 2	0.24
	Area 3	0.12
Extra flooding regarded	Area 1	0.64
	Area 2	0.24
	Area 3	0.12

Table 4.9: Area contribution to total risk

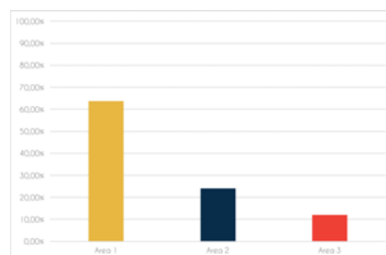


Figure 4.34: Visualisation of table 4.9

Area 1 has the highest contribution to the total risk for both situations. Furthermore the increased amount of flooded areas during flood scenario 2 and 3 do not increase the total risk that much. This can be explained by the fact that these flood scenarios have very low probability.

4.6.5 Applying multi-layer measures

The multi-layer approach has multiple measures within different layers. As described in the framework the prevention layer reduces probabilities of flooding and spatial solutions might reduce the damages. For the case of Nyaungdon some adaptations were made in the `Excel`-sheet settings in order to simulate different situations in Nyaungdon. The `Excel`-sheet then calculates the risks and damages corresponding to these adaptations. For the case of Nyaungdon the following adaptations were simulated in the `Excel`-sheet:

	Description
Adaptation 1	More buildings in area 3, less in area 1 & area 3 has same types of buildings as area 1
Adaptation 2	More buildings in area 2, less in area 1 & area 2 has same types of buildings as area 1
Adaptation 3	Reducing probability of flood scenario 1

Table 4.10: Adaptations

For these adaptations the following values have been found:

	Main situation	Extra flooding	Adap. 1	Adap 2.	Adap. 3
Damage (€)					
Flod. Scen. 1	32,774,114	32,774,114	41,713,640	55,118,664	32,774,114
Flod. Scen. 2	52,976,172	72,149,750	62,303,177	75,659,455	52,976,172
Flod. Scen. 3	63,151,603	112,752,816	77,432,179	86,571,967	63,151,603
Total	148,901,889	217,676,681	181,448,997	217,350,087	148,901,889
Risk (€/year)	7,514,208	7,577,229	9,547,362	12,593,636	3,342,957

Table 4.11: Values of risks and damages

Adaptation 1 and 2 can be seen as spatial solutions, where buildings are moved to another location (relocation). Relocation should of course only be applied if the total amount of damages would decrease, but as can be seen this does not occur. This is due to the fact that area 1 and 2 are actually more vulnerable to flooding than area 1, increasing the damages.

Adaptation 3 reduces the probability of flooding of flood scenario 1 and this could for example be due to a stronger or higher dike. This reduces the risk dramatically.

Many adaptations could be done and combinations between prevention and spatial solutions could also be adapted. For now it can be concluded that prevention has a high importance and that relocation is not preferable. It is recommended to do more research on combinations of spatial and prevention measures. Furthermore it could be wise to try different arrangements of the areas that Nyaungdon was divided into, for example choosing areas next to the river and areas inland. These could show that spatial solutions could contribute to decreasing these risks. It can be expected that spatial solutions that use elevation measures will contribute to risk reduction.

4.7 Evacuation analysis

In this section the current evacuation plan in Nyaungdon has been studied. The four elements are analysed and a timeline of the evacuation process is created. After the analysis, bottlenecks in the evacuation process can be established. In section 4.7.3 a conclusion can be found.

4.7.1 Current evacuation analysis

The current evacuation process is analysed following the steps described in the general framework. The four analyses of the elements are completed with a timeline. The timeline gives an extra overview of the steps that are taken at each time.

4.7.1.1 Element 1: Threat and impact

Element 1 contains an insight in the threat and impact of a possible disaster. This is already done in section 4.6. In this element also a scenario analysis on impacts can be performed. In this analysis it is decided to not specify the threat and impact element even more.

4.7.1.2 Element 2: Decision making by authorities

In section 4.5 an overview of the local authorities concerning floods is already provided. However, this is not done for the authorities concerning evacuation in particular. In this section also the decisions and processes of these authorities are discussed. The information is obtained from interviewing an expert on the process of evacuation together with a guide. The expert was Kyaw Zayyar Tint, assistant engineer in Nyaungdon, who was interview on September 14, 2016. The guide that is taken along was Maritime engineering student Pan Ei Ei. Other possibilities to gain information are excluded as the disaster plan of Nyaungdon is written in Burmese.

Local evacuation committee

In short: The most important authority concerning evacuation in Nyaungdon is the national wide evacuation committee, with 9 subcommittees and 14 different organisations. They have written the local disaster plans for the township Nyaungdon. They have also appointed a local multidisciplinary disaster committee responsible for the organisation and execution of the disaster plan. The local committee contains members of the fire department, crisis managers, the chairman and deputies of all different departments. The disaster plan contains a to-do list to follow when a disaster is foreseen. The disaster plan includes a transportation plan, information plan, response plan, duties plan, mitigation plan and evacuation plan. According to Pan Ei Ei (2016) who scanned the Burmese document, the level of detail is lacking. To quote the translated evacuation plan by Pan Ei Ei (2016): 'Depending on the disaster, evacuation routes to safer places as temporary shelters and relief camps should be planned, and prepared for that'. 'Specify the shelter places based on environment where it is easy to transport water ans waste'. Although the committee has evacuation experience, as the amount of evacuating citizens was 7000 in 2015 for the province Nyaungdon, the committee will guide through the to do list each time a disaster occurs. The committee does not have general meetings and there is currently no budget to optimize the current disaster process. When a flood occurs the committee will plan and organise the evacuation at that time. How the evacuation procedure has taken place in the past is described in the following section.

Early warnings

The Irrigation department receives daily water levels of other Irrigation Departments upstream. They keep track of the water levels of Hinthada which gives them 1 day to prepare for a flood. Knowing water levels in Mandalay gives them 7 days to prepare for a flood. The cause of the raise of the water level is most of the time the upstream monsoon rain as the cyclones have a small impact this far landwards. There are two main types of floods that can affect Nyaungdon, namely (1) a flood caused by upstream rainfall and (2) a dam burst. When a flood caused by upstream rainfall or monsoon is predicted, action by authorities is taken, but the evacuation plan shall not be executed and the communication to citizens is not organised. Only when a dam burst is predicted the authorities will execute a evacuation plan and will communicate this to every citizen. In case of an extremely high water level, this is measured and reported to the ministry and other departments downstream the river.

Preparing by local authorities

When a flood is likely to occur the chairman of Nyaungdon township will organise a meeting with the chairmen of other villages. This is a group of chairmen representing 44 villages. The responsibility to communicate the situation to the citizens is with the chairman of the specific village. The communication to the public is done with microphones on a car who drives round the area. Experience has proven that an advice to leave the area is not always taken for granted by the citizens, as Kyaw Zayyar Tint declared that many people refuse to leave. However whenever a monk would advise to evacuate it is more likely that people would listen. Because there is hardly any preparation done before the disaster, the fire department starts to stock the food supply at the shelters when a evacuation response is decided, instead of doing this in advance. Other preparing procedures executed by the police and fire departments are the closing of schools schools and transportation of elderly to shelters. Also other aid dependent buildings shall receive help of the local authorities. The movement of the population is not regulated, as there is no traffic management and no extra transport provided. According to Tint it is most likely that the people will go to their family or to one of the 24 shelters that are placed in the area around Nyaungdon.

Temporary Housing

If the population chooses to live in shelters, reliefcamps and monastries, they will receive help provided by the NGO's as the Good Neighbours International, Caritas and KMSS in Nyaungdon, see section 4.5. Experience has shown that a lot of food and water provision, for the flood affected population, is organised at a local level. The locals near the shelters will cook and donate to the population of Nyaugdon. How much help they receive depends on their hospitality.

4.7.1.3 Element 3: Environment and traffic infrastructure

In this subsection the environment and traffic infrastructure concerning evacuation around Nyaungdon is analysed. As can be seen in figure 4.9, the important buildings are marked. Take an extra look at the location of the hospital and schools close to the waterfront. Generally, hospitals, prisons and schools need extra help when evacuation is decided as for example the patients of a hospital can not all move on their own. The buildings are aid dependent. Twint (2016) did not know if the schools had their own procedure but he confirms that the hospitals do not have their own evacuation procedure. This is however recommended as they are located in a flood affected area.
There are 24 shelters relief camps where the people of Myanmar can go to. The shelters are spread around the area of Nyaungdon, but what they all have in common is that they are located at higher ground and that they are accessible by the Pathein road. This road is an asphalted, two lane road. The city development department of Nyaungdon states that every citizen has to travel over this road heading east when evacuating. So this road can form a bottleneck. This is remarkable as the

same road is also heading south, but the City Development Department declared that the southwards road would lead to flooded areas. Making the Pathein road heading east the only road to evacuate from Nyaungdon, the bottleneck Pathein Road can be pointed out.

In this section it is tried to give a lower bound estimation of vehicle moving time during evacuation from the Nyaungdon township. This estimate is based on simple evacuations. Nyaungdon has around 40,000 inhabitants. Assuming that they all would travel by car, and assuming the population will evacuate with their household, the number of passengers per car has to be estimated. With the survey conducted in Nyaungdon an estimation of the number of households can be given. Around 60 percent of the household contains 3-5 members in Nyaungdon. Around 15 percent contains less than 2 members and 15 percent 5-7 members. To simplify the results it is estimated that 5 members will share one car, as people also take stuff with them along. This would result of a total demand of 8,000 cars, that will pass through Pathein Road heading east.

Assuming a capacity of 1200 vehicles/hour/lane with only one lane available, the duration of the evacuation would be 6,67 hours. This would give a Traffic Safety Factor of 2 hours added (Opper et al., 2010) as it is classified in the category 6-7 hours. The free flow travel time would be around 16 min so 0.25 hour as the free flow travel speed is 80 km/h and the length of the road to be flood proof is 20 kilometres.

Demand of cars	8000 v
Capacity per lane	1200 v/h/l
Number of lanes	1 l
Free flow travel time	0.25 h
TSF (category depended)	2 h

Table 4.12: Overview parameters

The total time of vehicle movement during evacuation is around 9 hours calculated with equation 2.1.

There are two traffic management measures that can reduce the amount of evacuation time, namely (1) contraflow and (2) transit evacuation. Contraflow is a measure to open and use one direction in a two lane capacity. This would however leave no space for the emergency services, so it can only be executed when no emergency services are needed anymore. If the contraflow is executed the total evacuation time would be 4.58 hours. This is calculated as above, with an evacuation time of 3.33 hours plus 1 hour TSF and 0.25 hour for free flow travel time. Another alternative would be the the transit evacuation. Busses provided by the local authorities would reduce the number of cars and would provide the households who have no acces to a motorized vehicle (Albers et al., 2012).

4.7.1.4 Element 4: Citizens response

In this element the citizens response in Nyaungdon during evacuation is analysed. Therefore a stated preference based survey is handed out on 14 September to 74 people in Nyaungdon. Interviewing experts and asking about the revealed behaviour was not possible as the evacuation committee was not approachable. Revealed based surveys were also excluded since no flood occurred the past year in the township of Nyaungdon, so no flood affected victims could be interviewed. The objective of the stated choice survey was to get insight in the behaviour about evacuation. In appendix B.1.3 the whole survey plus analyses can be found. The appendix also includes a literature study, an analyse on data collection, an analyse on representation, an explanation how to use excel, findings, conclusions and recommendations. In this section only the conclusion of the survey is shown. Note: Statistical knowledge is required to understand the analysis steps in appendix B.1.3.

It can be concluded that the survey brought insight in the behaviour of the people in Nyaungdon. The survey was however not representative because of the amount of women is 75 percent and because of the many illiterates in Nyaungdon. Also the amount of respondents that have experienced an evacuation was around 23 respondents. They are referred to as evacuation-experienced respondents. The amount is not enough to generalize the findings of evacuation to the entire population in Nyaungdon, as the amount should exceed the number of 30 respondents to make it a normal distribution. However the survey did give insight in the evacuation-experienced respondents behaviour. Around 80 percent of the people that experienced evacuation felt panic during their evacuation and 49 percent of the evacuation-experienced respondents did received help. The most popular evacuation location, chosen by 30 percent, was visiting friends and family outside Nyaungdon. The motivations to evacuate of the evacuation-experienced respondents did not differ from the motivations of the not-evacuation-experienced respondents.

When all of the respondents were asked where to evacuate three evacuation possibilities came forward; from moving one floor in their house, to shelters/relief camps, to going to friends and families to Nyaungdon. Around 68 percent of the respondents would chose the car as a mode to evacuate. The motivations to evacuate as 'taken care of elderly/children' is seen as most important to take along, followed by 'excess to transportation' and the 'the height of the water level'. The relative lowest scores for the motivations were obtained by 'work obligations', 'taken care of animals/pets', and 'neighbours leaving', although the scores were not low enough to consider them negligible.

4.7.1.5 Evacuation Timeline

Making an evacuation timeline gives insight into the process of evacuation combining all the information of the elements together. The evacuation timeline is stated in figure 4.35. The cause of the flood is an upstream rainfall in this case.

- **Warning system**
  As is stated above Nyaungdon has knowledge about the water levels of Mandalay and Hinthada. This gives a 7 day forecast(168 hours) and a 1 day (24 hours) forecast of the water level of Nyaungdon. It takes around two hours to check the water level, prepare the data and forecast the results of Nyaungdon.

- **Preparation time**
  Within four hours the chairman has a general meeting with the chairmen of the other villagers. After the decision making the committee will follow the steps in the to-do plan. When an evacuation is decided it has to be communicated to the population, within the socalled 'information time'. This includes the amount of minutes between the warning signal and the announcement to evacuate. According to Opper (2010) it will take a team 5 minutes per

household. For the current situation it is known that the authorities would provide a warning signal by using the microphone, nothing is said about communicating it face to face. What follows is a response time introduced by the population. This includes the time to go home, pack travel items and secure homes, which will take respectively 220 to 450 minutes (Albers et al., 2012).

- **Departures** As it is stated above the vehicle time movement to travel over Pathein road would take around 9 hours. This is a roughly estimated guess assuming that everyone needs to take the Pathein road heading east.

The elements that are chosen to analyse in the timeline, are the following:

- E_a represents the actual time available wherein the evacuation must be completed. In this analysis this is unclear.
- S stands for the safety factor. This will be available as a reserve of additional time available to deal with interruption or uncertainty in the decision process but also when a wrong impact estimation is given.
- T_d stands for the time at which the decision is made: from the warning level until preparation time that is needed to inform the local authorities. Although the flood can be predicted 7 days or 1 day in advance, the decision should be taken after the results of the measurement of Hinthada have come in. The prediction based on the water level in Mandalay has surely a much greater uncertainty. Besides 1 day is enough time to evacuates, as the evacuation requires a 19 hours in total in the current situation, without additional traffic management.
- T_w is the time at which the population or crowd is informed about the evacuation and the emergency services start the procedure.
- T_b is the time at which the first households start evacuating. Between T_w and T_b there is a phase of public acceptance (Albers et al., 2012).
- T_t is the time when everyone is warned.
- T_e is the end of the evacuation.
- T_c stands for the beginning of the flood in the area

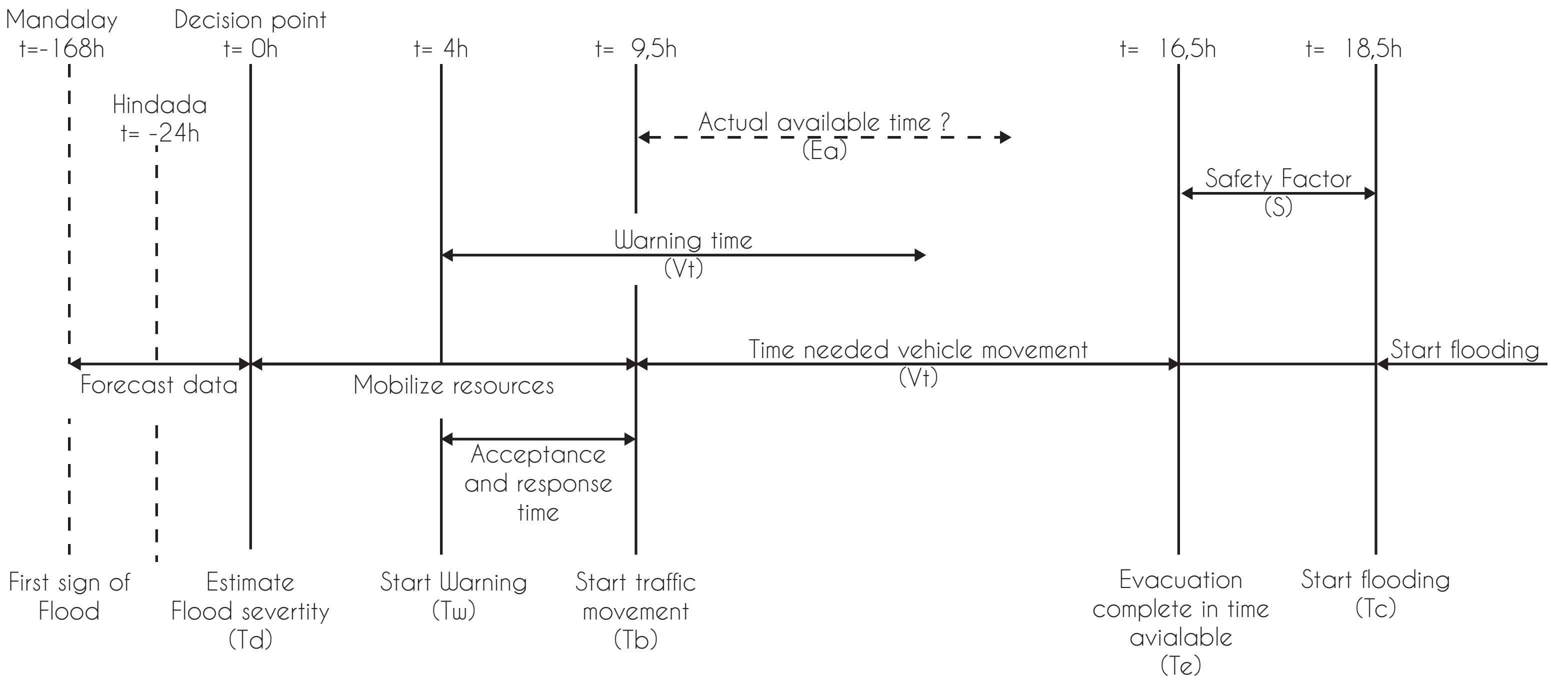


Figure 4.35: Evacuation timeline Nyaungdon

4.7.2 Define bottlenecks

In this section sometimes the analyses of the elements have been combined in order to find the bottlenecks.

- Element 1: According to Twint (2016) only one scenario analysis concerning evacuation is used. However it is likely that there are multiple flood scenarios with different impacts. Although the committee is following a to-do list it can occur that the flood exceeds the limits of the to-do list.

- Element 2: A well organised element is the current local evacuation committee that has shared responsibilities during a disaster. The current disaster plan is well organised as well. However, despite of the experience of the committee, the details of the to-do list are lacking. The list is formulated in a too basic way. Also the possible lack of improvement can be pointed out, as there are no general meetings by the committee and no budget is available. The communication and transparency between citizens and authorities could be improved. Pan Ei Ei (2016): "People don't have information or knowledge about when it is going to flood". Although the advice of the local authorities to evacuate is one of the most important motivations for the population to evacuate, the local authority will only warn the people when a dam or dike has burst. According to Tint (2016) this is not entirely true since he states that people will not listen. He also states that monks could be more included in the disaster committee as they are providing the shelters and have more power and a chance of success in persuading the people to leave the dangerous area.

- Element 3: Problems can be foreseen considering the hospitals and schools as they do not have their own evacuation plan. Also a evacuation time of 7 hours can be reduced by regulating and providing transport to the flood affected people.
- Element 4: Citizens response: out of the survey it is stated that 80 percentage of the evacuation experienced respondents felt panic. Besides 50 percent of the evacuation experienced respondents received help. 68 Percent of the people wanted to evacuate by car.

4.7.3 Conclusion evacuation Nyaungdon

The most optimal form of evacuation is described in section 5.3.1. However a general short conclusion can be denoted. The evacuation plan is analysed with the help of four elements and an evacuation timeline, each highlighting a different aspect of the evacuation. There are several things that need to be changed in the evacuation procedure in Nyaungdon: the main problem in the disaster plan, is the lack of details. They should be extended based on the experience of the evacuation committee. Secondly, the hospital in Nyaungdon township needs to be stimulated to make a separate evacuation analysis.

4.8 Future scenario analysis

The future scenario follows six steps which have been treated for the case of Nyaungdon below.

4.8.1 Step 1 - Determine key question

As the main problem definition of this report is "What is the best way to make several regions in Myanmar flood proof?", it is logical to reframe this question to the region of Nyaungdon for future prospects:

What future scenarios might unfold for Nyaungdon that could influence flood safety?

4.8.2 Step 2 - Determine the contextual factors

In this step the possible contextual factors that could influence the changes of the town are treated. Important factors that could affect the town are population growth and economic growth together with the development of the infrastructure. Also the development of land use and industrial growth could affect the township in the future. Next to human related developments also climate related aspects, such as rainfall, could be taken into account.

4.8.2.1 Population growth

Since 2009 the population in Nyaungdon area has been decreasing from 217,007 in 2009 (Nyaungdon Township Ayeyarwady Division, 2009) to 197,851 in 2016. This decrease in the population is probably caused by the movement of the younger people that try to look for better jobs in the larger cities. Young people try to get better education in large cities and try to find a job elsewhere, causing the decrease in rural areas like Nyaungdon. The table below shows the decrease of population over the years.

Year	2009	2014	2016
Population	217,007	215,906	197,851

Table 4.13: Population decrease in Nyaungdon

This table clearly shows a decrease in population of Nyaungdon area. This does not mean that the city Nyaungdon itself also develops a decreasing character in population growth. It is already a large town with lots of business. So, work people would not have to leave Nyaungdon township. Maybe people move to Nyaungdon township from the surrounding area. Therefore this is a very important factor that could have different outcomes which might affect the future.

4.8.2.2 Economic growth

Information about the economic growth of Nyaungdon is almost non existent, especially not about the township Nyaungdon itself. Still there is some information about the rice production of Nyaungdon area from 1996 until 2004. Together with the implementation of flood protective embankments for the islands and the construction of drainage channels they provide some insight in the economic growth.

Since 1996 four villages have been studied in the area of Nyaungdon, monitoring the amount of rice that has been produced together with the movements in poverty in those same villages. The outcome of this PhD thesis is summarized in table 4.14 below.

Village	Rice production factor [%]	Movement in poverty [%]
Natpay	0.89	7
Tuchaung	075	-5
Htonewa	1.2	1
Tazin Ye Kyaw	1.47	-6

Table 4.14: Economic growth of Nyaungdon area (Garcia et al., 2012)

This table shows that there are changes throughout Nyaugdon that are far from conclusive. Villages that produce more rice become more poor and the other way around is also possible. Next to the fact that this information does not provide any trends that could be used for future scenarios, it also does not say anything about Nyaungdon township itself. This makes it highly difficult to make a good estimate for economic growth for our project location. Although the information is far from conclusive, there have been huge changes in and around Nyaungdon related to irrigation channels and water control structures to improve the rice production (Maung Nyunt & Tun Tun, 2007). Due to investments since 1920 the production of rice has mainly increased in Nyaungdon area. But also an increase in aquaculture can be noticed which also increases the economic wealth of the community. Still, this information is not for Nyaungdon township and can therefore not be used directly to say something about the economic growth, and is therefore an other important uncertainty for a future scenario.

4.8.2.3 Infrastructure

The infrastructure in Nyaungdon will probably not change that much since no new important connections with the city will be constructed such as a bridge. As long as these large connections do not develop in or around Nyaungdon township, the infrastructure will not get a boost either. The existing roads are good enough as they are at the moment, and there is a possibility to reach the township by water as well, which makes the city already well connected for Myanmar standards.

4.8.2.4 Land use

Land use in Nyaungdon is more or less the same for the whole area of Nyaungdon. As earlier stated, most people are farmers with rice as there main product. Most of this land will be used for farmer purposes for the coming years and is very unlikely to change into an other use. Only if townships and villages grow the land will be used for residence or industrial purposes instead of agriculture. But these changes are minimal and will definitely not affect the future scenarios that much.

4.8.2.5 Climate

As described in section 4.1.4 the extreme fainfall might increase with 25 mm in the Ayeyarwady Delta. This is due to climate change and has effect on the area of Nyaungdon.

4.8.2.6 Summary contextual factors

A summary of the contextual factors for the case of Nyaungdon can be found in table 4.15.

Population growth
Economic growth
Land use
Infrastructure
Climate change
Extreme rainfall

Table 4.15: Contextual factors Nyaungdon

4.8.3 Step 3 - Cluster the contextual factors into driving forces

The contextual factors are clustered in table 4.16. Several contextual factors are driving forces by themselves.

Population growth
Economic growth
Land use
Infrastructure
Environmental changes
Climate change
Extreme rainfall

Table 4.16: Driving forces Nyaungdon

4.8.4 Step 4 - Classify the driving forces according to their impact and uncertainty

The impact and uncertainty of the driving forces is shown in the table below:

		Uncertain	
		Low	High
Impact	Low	Infrastructure	Environmental changes
	High	Land use	Population growth Economic growth

Table 4.17: Impact and uncertainty of driving forces

As explained in section 4.8.2 the uncertainty and impact of the infrastructure is quite low. The impact of the land use is of high impact but its uncertainty is low. The environmental changes are of high uncertainty, but their impact on the flood safety are for this case negligible. The population growth and the economic growth do have a high uncertainty and do have impact.

It is not known how the population will grow, although there is a trend in the area of Nyaungdon, it is not easily known for the township. Maybe the township is growing because of people moving to the township, of maybe its population is also decreasing like the entire area. Regarding the economic growth as an uncertain factor, as described in table 4.14 there are four villages that do not show the same trend, so no conclusion can be obtained. Therefore it is of interest to develop multiple scenarios in which the economic growth can be positive or maybe negative.

4.8.5 Step 5 - Design a scenario matrix

Figure 4.36 shows the scenario matrix for Nyaungdon.

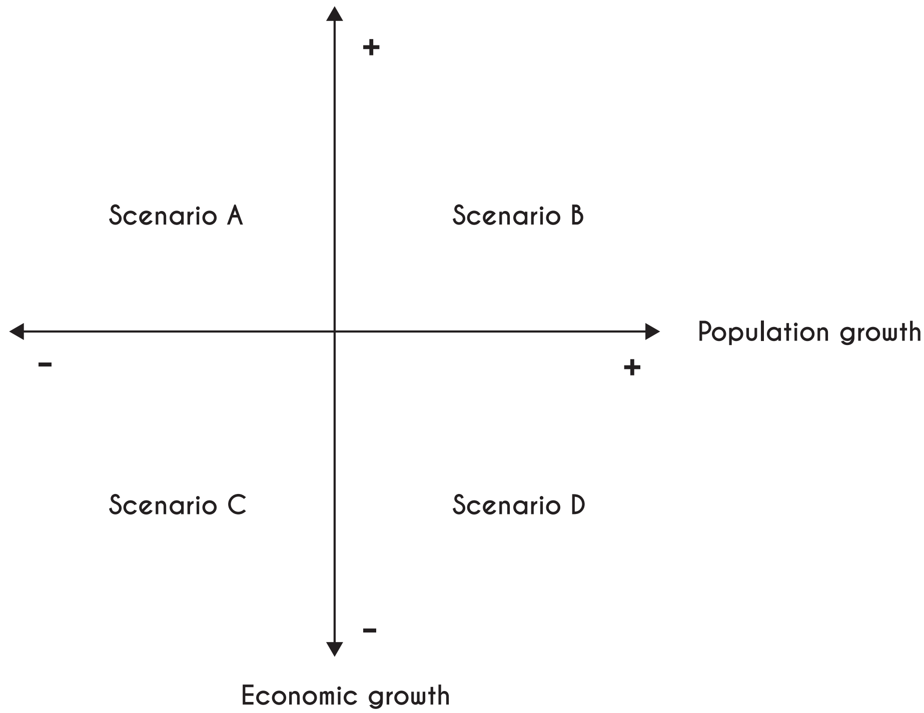


Figure 4.36: Scenario matrix of Nyaungdon

On the x-axis one can see the population growth of Nyaungdon. On the y-axis one can see the economic growth. As stated in Step 4 it is of interest to see both decrease as well as increase of the economy, as its future is very uncertain.

4.8.6 Step 6 - Detail the scenarios

The four different scenarios are elaborated in this section. For all scenarios holds that the amount of growth could differ. No specific point within the scenario will be chosen, so there is always an uncertainty within the scenario.

4.8.6.1 Scenario A

Population decrease & Economic growth

In this scenario the population has decreased and the economy has grown. This could mean that the production of rice has become more effective and that less people are now needed for the production of it. Consequently, more people have left to larger cities in hope to find better work there.

4.8.6.2 Scenario B

Population increase & Economic growth

Both the population and the economy have grown. This might mean that the township of Nyaungdon has become more attractive for more people, and simultaneously has attracted more business related activities into the township.

4.8.6.3 Scenario C

Population decrease & Economic decrease

This scenario is the most negative one in which both the population and the economy have decreased; a likely scenario if lots of people leave to other areas. Everyone could have their own reason for making a move like that, and when lots of people have done so, it becomes a less attractive town for more and more people resulting in an town with a deceasing population and economy.

4.8.6.4 Scenario D

Population increase & Economic decrease

Now the population has grown, but the economy has decreased. This could be possible if all the educated people leave for further education at larger cities, leaving the less educated people behind. The population can grow, but if no one remains to increase productivity or establish new businesses, the economy can actually decrease.

4.8.6.5 Concluding remarks

The scenarios that have been sketched above are not fixed scenarios, as already stated these scenarios are just generated to come up with different solutions for different kind of scenarios. If the economy is decreasing in a certain area it is not possible to come up with a very expensive solution, so a more creative solution has to be found. Otherwise a plan has to be suggested how to get money elsewhere. These scenarios should help to come up with a wide range of solutions from which the best one can be chosen once a certain scenario is developing.

5 | Phase 2: Developing alternatives

This chapter treats all possible measures to prevent and mitigate the effect of floods in Nyuangdon township. As explained in section 2.3, three types of measures can be distinguished, which form the three layers of the multi-layer safety approach. To develop potential alternatives for Nyaungdon, the measures from section 2.3.1 that are applicable for this case have been selected. An overview of this approach with the chosen measures is depicted in figure 5.1.

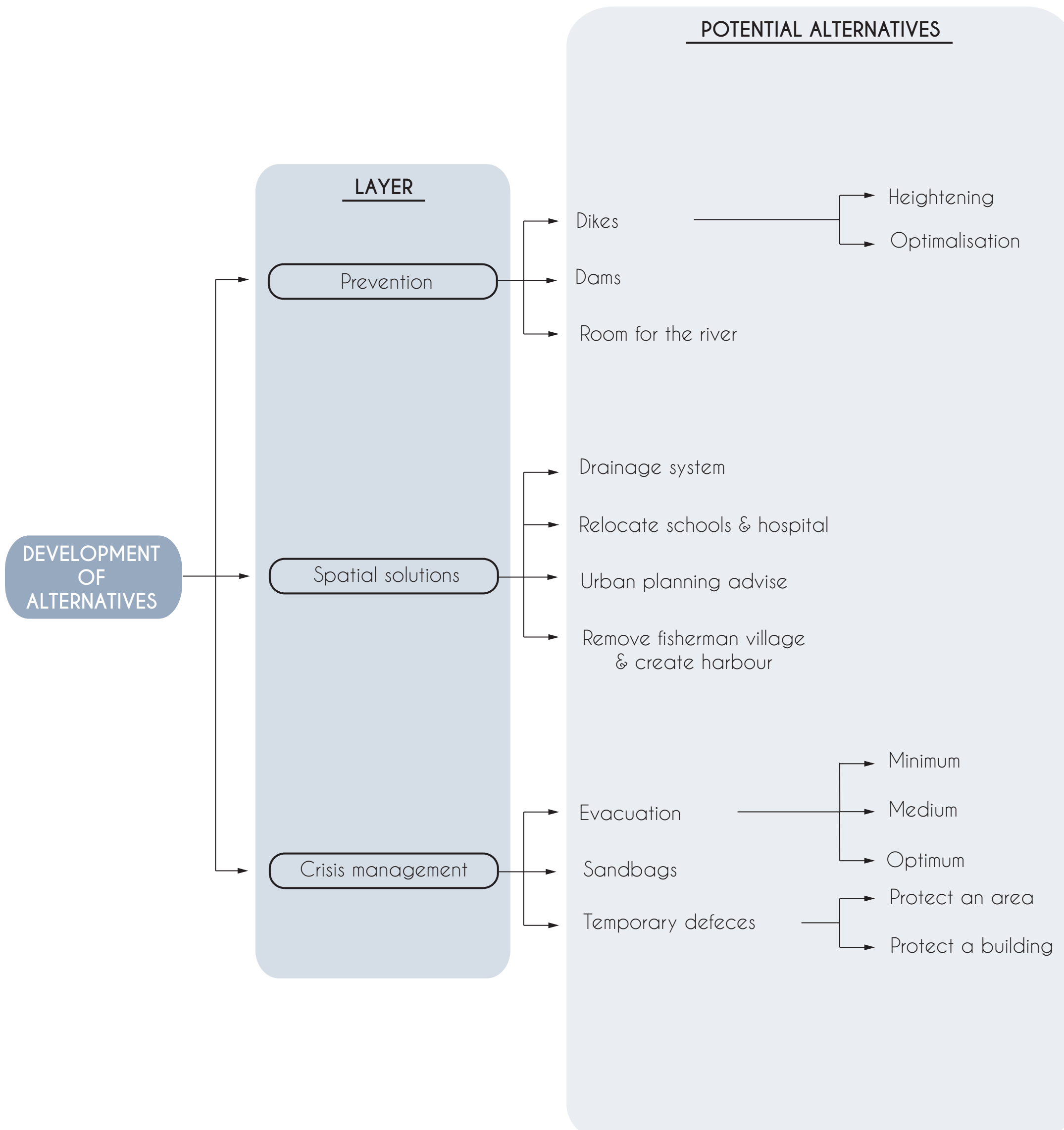


Figure 5.1: Overview development of alternatives

5.1 Layer 1: Prevention

5.1.1 Dikes

Although the township is already surrounded by a dike, this measure is currently insufficient to protect it against potential floods. Several changes that need to be made to the present dike are discussed below.

5.1.1.1 Improvement by heightening

In 2016 a part of the main embankment along the river was heightened to the authorised crest level. This level was determined on the basis of the water level during the flood that occurred in 2015. In the future the entire dike should be heightened upto this level. Heightening the part of the defence along the river has a higher priority than heightening the inland part along Pathein Road and Arzarni Road. Therefore this should be done first.

5.1.1.2 Optimalisation current dikes

Besides heightening several other improvements should be made for the dike to perform its function appropriately. As earlier mentioned erosion is a main problem in the case of Nyaungdon. The erosion of the outer slope can initiate the collapse of a dike. Grass can be sufficient protection, where no significant impacts are expected. In the critical parts other measures must always be taken, such as bank protection, to prevent the disastrous consequences of erosion.

Many non-water retaining objects can be found in the current dike profile such as houses and trees. The presence of these objects can introduce or affect several failure mechanisms (Jonkman & Schweckendiek, 2015). Trees can create a hole initiating erosion and their roots might increase the likelihood of piping for instance. Buildings in the slopes lead to a high concentration of velocities in case of overflowing of water. Besides, structures do not show the same settlement behaviour as the surrounding soil, which affects the integrity of the dike. It is advised to minimise the amount of objects disturbing the dike profile. Therefore no more objects should be placed there in the future. Considering the objects that are already present: those which can be removed should be removed and the dike should be restored at these spots. The currently set boundaries of the dike profile at the river and the land side, as described in section 4.4, are the guidelines to fulfil this condition.

Ideally a dike is a uniform profile with the same width, height and material over its entire length. This is almost impossible to realise in Nyaungdon since this dike is already completed. Nevertheless, in case parts of the dike are renovated in the future, it must be taken into account.

To make sure the dike remains able to perform its preventive function, maintenance is key. Somebody has to be held responsible to detect problems and damages of the dike and make sure these are repaired before the dike fails. Considering the current division of responsibilities the most obvious choice is to hand this responsibility over to the local representative of the Irrigation department.

5.1.2 Dam

By placing a dam in the Ayayerwady River upstream from Nyaungdon, the water level in Nyaungdon can be regulated. An example of this upstream regulation is the use of a so called dry dam. This type of dam contains no gates or turbines and is intended to allow the river channel to flow freely under normal conditions. During periods of severe rainfall it holds back the excess of water, releasing it later at a controlled rate. Unfortunately the use of dams can have negative consequences for the environment. A dam wall can block migrating fish and block sediments that are critical for maintaining physical processes and habitats downstream (International Rivers, 2016). In addition, when a river is deprived of its sediment load, it seeks to restore it by eroding the downstream river banks. This damage could even extend for tens to hundreds of kilometres below the dam.

5.1.3 Room for the river

Another option to prevent Nyaungdon from flooding is giving the Ayeyarwady river more space, upstream from Nyaungdon. This implies deepening of widening it, leading to a larger area of the cross section, and thus reducing the water level in case of the same discharge. Since this measure is taken outside the research area in order to prevent the area from flooding, it is classified as a layer 1 solution. In case the measure would be taken inside the research location, accepting the flood in a part of it and relocating buildings, it would be classified as a Layer 2 spatial solution.

5.2 Layer 2: Spatial solutions

5.2.1 Drainage System

The importance of a proper drainage system is crucial in an area as Nyaungdon. Even if the location is perfectly protected by a dike, the excess of precipitation during heavy monsoons has to be drained in an effective way to prevent a bathtub-effect. At the moment no big drainage related problems are experienced in Nyaungdon. To keep it this way the following recommendations have to be kept in mind: the system should be as closed as possible. This is to prevent congestion and blockage by garbage for instance. Maintenance is also important to prevent this. Besides the capacity has to be large enough to handle the extreme rainfall during monsoon season.

5.2.2 Relocate schools & hospital

As can be seen in figure 4.9 two schools are located outside the embankment ring. These buildings should be relocated to a safer area inside the dike-ring. Their current location is too vulnerable and the damage would probably be too large in case of a flood. Considering the small size of these schools, it is unlikely to be a big problem to relocate them. Furthermore the hospital of Nyaungdon is located directly behind the dike. In case of a dike failure or an extreme high water level this is a very dangerous place. The people in a hospital are vulnerable and it is hard to evacuate them. Next to that the potential material damage is high. It would better to relocate the hospital to the southern part of Nyaungdon township.

5.2.3 Give advise on urban planning in case of expansion

In the field of urban planning the township could improve their resilience to flooding by a number of ways. The most obvious solution, which is already widely used throughout the whole country, is the construction of houses on stilts. In case the township is affected by a flood, the houses will therefore not be damaged. Currently most of the houses in Nyaungdon township are not constructed on stilts, which will result in inundated houses in case of a flooding. It is not possible to reconstruct all of these houses on stilts though. That would be much too expensive, and will not weigh up against the benefits it will provide. People are willing to evacuate towards the second floor if needed, and will therefore not need a house constructed on stilts. Still, if new houses will be constructed it would be wise to construct them on stilts, especially if these houses are to be constructed outside the protected zone of dikes.

Besides houses on stilts there is another measure that could be used as spatial planning in the field of urban planning. It comprises the infrastructural planning of roads. It could be of use to heighten the roads to make sure they can still be used in case of flooding. Especially the main roads in and out of the town should be constructed on a higher level so in case of emergency rescue workers and other traffic can get in and out of the city.

Next to higher roads and houses on silts it could be of use to construct important buildings on higher ground level. They will be protected from high water and simultaneously can be used as an evacuation location for the less fortunate people that live in lower areas. Since important buildings will probably be located next to important roads they can easily be accessed by help organisations and this way people could be given aid more quickly.

5.2.4 Remove fisherman village & create fish harbour

At the moment there are a lot of fisherman who live on the outer side of the dikes. They have accepted the fact that their houses have to be reconstructed once in a while if a flood has destructed their houses, since this is still cheaper than living on the landward side of the dike. But by constructing these houses close to the dike they undermine the effectiveness of the dike. A logical solution for this problem is to relocate the fisherman villages to a better location where they do not affect the dike's profile. This is in agreement with the rules given by the local authorities, that there should not be any structures within the boundaries of the dike, as explained in section 4.4. Despite these rules, it seems that no one actually lives up to them. Besides, there is no one to supervise if these rules are also executed.

Therefore it is necessary to come up with an incentive to stimulate fisherman to construct there house elsewhere such that no supervision is needed at all. An example could be a financial incentive. This could be a two sided measure; one could increase the land values such that it becomes very expensive to construct houses there. Also the land values elsewhere could be lowered to stimulate the fisherman to construct their houses at that specific location. If the government of Nyaungdon could manage to create such an area, still close enough to the river but outside the boundaries of the dike and on the safe side of the dike, people might consider moving there. Other measures can be in the form of punishments like fines if houses are still constructed within the boundaries where nothing should be constructed. In order to maintain a system as such the use of supervision by policemen is needed.

The reason why most of these fishermen live on the outside of the dike is likely because of the accessibility from the river, which is their working domain. Relocating their houses elsewhere will probably affect their way of living drastically. They will not be able to access their boats as easy any more, and lose their mooring location for the boats. Therefore it should be possible for them to moor the boats somewhere protected where they can always access them. Therefore it might be wise to construct a harbour especially for these fishermen and their boats. A place where local market can be facilitated and where the boats are moored safely. This is an extra incentive for the people that have to move their house because of a nearby market. The harbour will of course have to be constructed on the outer side of the dike, and will therefore probably have a negative effect on the dike profile. However, if well designed, these negative effect can be limited to large extends.

By moving the fishermen to another location and simultaneously stimulating them with a safe harbour, a major reduction of structures within the dike's boundaries could take place. This will reduce the negative effects of these structures on the dike, and will therefore be a good alternative to maintain the dikes in the future.

5.3 Layer 3: Crisis Management

5.3.1 Evacuation

Three different options are considered concerning the possible evacuation-related measures. These options have been elaborated below, where the taken measures have been divided in 3 or 4 different elements. These elements are elaborated in subsection 2.5.7.

Option 1: minimum

1. An early warning system should be present.

2. An evacuation committee should be formed including a clear division of tasks for all the members. Besides this, a To-Do list has to be made by the nationwide committee, containing all the steps to be taken in case of an evacuation. The chairman of the township should be responsible for the communication to the chairmen of the surrounding villages and all other parties as the fire department and the health care sector.

Option 2: medium

1. An early warning system should be present.

2. An evacuation committee should be formed including a clear division of tasks for all the members. The committee should have regular meetings to discuss the approach for an evacuation. Besides a To-Do list has to be made by the nationwide committee, containing all the steps to be taken in case of an evacuation. The chairman of the township should be responsible for the communication to the chairmen of the surrounding villages and all other parties as the fire department and the health care sector. In addition clear communication on the evacuation approach towards the population is required.

3. Shelters should be defined in advance. Additionally, a general traffic management plan should be set up in advance. Next to this a more detailed evacuation plan should be made for special buildings like the hospital and the prison.

4. The fire department, health care parties, NGO's and local authorities should be prepared in advance due to the fact that they are provided with information on what to do in case of an evacuation.

Option 3: optimum

1. Besides the early warning system, several scenarios should be elaborated in an analysis.

2. The local evacuation committee should have regular meetings with all the members and crisis-managers to discuss the approach for an evacuation. The division of tasks and several plans should be made for the different scenarios. Occasionally evacuation drills should be performed to prepare the members. The communication towards the inhabitants of the township should always be transparent.

3. Shelters have to be defined in advance and should be stocked with supplies like food and water. Additionally, a traffic management plan should be set up in advance and its reliability should be verified by several traffic models. A detailed evacuation plan should be made for special buildings like the hospital.

4. The fire department, health care parties, NGO's and local authorities are prepared in advance due to the fact that they are provided with information on what to do in case of an evacuation. Moreover, inhabitants should be informed to prevent panic and release the amount of stress in case of an evacuation.

5.3.2 Sandbags

The sandbags, which are a type of temporary water defence are treated independently. The other more innovative temporary defences are elaborated below. This has been done since the sandbags are the traditional water defences that have been used over centuries already. They are heavy, small and take way more time to set-up a entire dike.

As can be seen in Nyaungdon, some sandbags have already been placed, to strengthen the dike at specific locations. But if the threat of the flood has disappeared the bags are not removed anymore. Therefore it might be a consideration to use the green soil bags, which are regular sandbags filled with seeds for grass. So, if given enough time, these sandbags can be used to strengthen the dike just by placing the bags where needed. Nature will run its course; by waiting long enough the grass in the bags will grow and strengthen the dike by itself.

Regular sandbags can still be used, but not on larger scale since it is impossible to heighten the dike over a couple of hundreds of metres within a limited time period.

5.3.3 Temporary defences

Within the domain of temporary water defences there are two levels of protection: protecting a complete area with the use of these temporary defences, or protecting important buildings only. As explained in section 2.3.1, there are multiple types of temporary water defences like inflatable barriers, membrane barriers and modular barriers. They are described in more detail below.

5.3.3.1 Protecting an area

In the case of protecting an area, one should take note that a lot of temporary water defences should be present at the location. In the case of Nyaungdon this means that 3445 metres of temporary water defences should be stored somewhere. Depending on the type of barrier chosen for such a measure, a certain location with sufficient storing capacity is therefore needed.

5.3.3.2 Protecting individual buildings

In the process of the development of alternatives one should always consider to protect the most valuable or most strategic important locations. This might mean that larger areas of the township Nyaungdon will flood, but evacuation locations could therefore be secured. This might save a lot of money, although some parts of Nyaungdon will be flooded, everyone could safely be evacuated to certain areas of larger buildings that have been protected. A cost-benefit analysis should support the determination of such a decision. Also the differences between the possible temporary defences should be considered to use the right barrier for the right problem, since not all barriers perform the same under different circumstances.

6 | Phase 3: Assessment

6.1 Method

To compare the possible alternatives they have to be evaluated on the basis of a multi-criteria analysis. Preferably also a cost-benefit analysis should be performed. Unfortunately insufficient information is available to complete even a simplified version. Therefore the cost benefit analysis has been left out. The performed multi-criteria analysis is divided in four parts: rating the alternatives, determining weight factors, ranking the alternatives and creating packages. The criteria that are used in this analysis have already been developed in the general framework. Therefore this analysis starts with rating alternatives.

6.2 Rating alternatives

The value of an alternative is determined by comparing each measure with each criteria. It is chosen to rate the alternative by using words varying between very high and very low. Since it is almost impossible to rate the alternatives with detailed numbers. The next step is to visualise the rating with colours. The colours vary from dark green (favourable outcome) to red (unfavourable outcome). By doing this a scorecard is created, which can be found in table 6.1. This scorecard provides a quick overview to see which alternative scores good on each of the criteria. The numbers or the words are replaced by scaling the values from 1 to 5, in which 5 is the optimum score. This way the values are normalised as well.

Criteria \ Measures	Weight	Null solution: current measures	Heighten dikes	Optimise dikes	Dam	Room for the river	Drainage system	Relocate schools & hospital	Advise on urban planning	Remove fishermen & create harbour	Evacuation optimum	Evacuation medium	Evacuation minimum	Sandbags	Temporary defences (area)	Temporary defences (building)
Material damage	2,348	1	5	5	4	4	2	3	3	2	1	1	1	4	4	5
Immaterial damage	3,289	1	5	5	4	4	2	2	3	2	5	4	3	4	4	2
Probability	2,346	2	5	5	4	4	2	2	2	2	2	2	2	3	4	3
Initial costs	1,089	5	2	2	1	1	2	2	5	2	4	4	5	4	2	2
Operational costs	0,855	5	5	5	5	5	5	5	5	5	2	3	4	3	4	4
Maintenance costs	0,734	4	4	3	4	1	3	5	5	5	5	5	5	5	3	3
Implementation time	0,528	5	2	2	1	1	3	2	5	2	3	4	5	4	4	4
Available space	0,527	5	2	4	4	3	4	4	5	3	5	5	5	5	5	5
Esthetics acceptance	0,250	5	3	4	2	4	5	5	5	4	5	5	5	4	4	4
Disturbance for local residents	0,301	5	2	5	4	1	5	4	5	1	5	5	5	5	5	5
Preservation of biodiversity	0,223	4	4	4	1	5	4	4	4	4	4	4	4	4	4	4
Hindrance for ships	0,244	5	5	5	2	4	5	5	5	5	5	5	5	5	5	5
Accessibility by roads	0,266	3	3	3	3	3	3	3	4	3	4	4	3	3	3	3

Table 6.1: Scorecard Nyaungdon

What is immediately striking is that all of the prevention measures, which are incorporated in layer 1, score good on reducing the material damage, immaterial damage and probability. A further detailed explanation of the reason behind each colour and value is written in the appendix B.2.

6.3 Weight factors

The weight factors are based on the pairwise comparison method (Mendoza & Macoun, 1999b). Because experts who should make a comparison are lacking, the estimation is done by the researchers of this report themselves. For every scenario different weight factors are given to the criteria. The scenarios differ in economic growth and population growth. The scenarios are elaborated in section 4.8. These are in shortly describe below.

- scenario A: population decreases (-) economic growth (+)
- scenario B: population increase (+) economic growth (+)
- scenario C: population decrease (-) economic decrease (-)
- scenario D: population increase (+) economic decrease (-)

The outcomes of the weight factors per scenario can be found in table 6.2. How the relative values for the indicators are given can be seen in appendix B.2. What is striking is that immaterial damage has the highest weight. This makes sense, as the inhabitants of Nyaungdon believes it is more important to protect the people. Moreover can be noticed that the available space does not have a high weight. That is mainly because the measures do not require much available space. So it will not be a problem.

	scenario A	scenario B	scenario C	scenario D
Material damage	2.48	2.32	2.41	2.25
Immaterial damage	3.26	3.75	3.20	3.74
Probability	2.29	2.12	2.14	1.99
Initial cost	1.06	1.06	1.26	1.20
Operational cost	0.85	0.81	0.96	0.89
Maintenance cost	0.73	0.68	0.83	0.76
Implementation time	0.53	0.50	0.49	0.47
Available space	0.52	0.49	0.51	0.48
Aesthetics acceptance	0.25	0.26	0.23	0.25
Disturbance for local residents	0.30	0.29	0.29	0.29
Preservation of biodiversity	0.22	0.22	0.21	0.21
Hindrance for ships	0.24	0.24	0.23	0.23
Accessibility by roads	0.26	0.26	0.24	0.24

Table 6.2: Overview weight factors Nyaungdon

What should be noticed is that the grey coloured indicators have been adjusted in each scenario, namely immaterial damage, initial cost, operational cost, maintenance cost, aesthetics acceptance and disturbance for local residents. This is because they are effected by a change in economics and population change. As the scores are relative, consequently the other indicators change in weight as well. What also needs to be noticed, is that the material damage is not adjusted in economic growth or decrease although more buildings probably will be built in a economic positive environment. This is however not taken into account in the analysis of Nyaungdon, as there is no drastic expand of number of buildings expected.

6.4 Ranking alternatives

In an excel sheet the weight factors and the values for alternatives are combined into the total scores. The ranking of alternatives can be given per scenario, see table 6.3. The top-3 alternatives are marked in grey.

	scenario A	scenario B	scenario C	scenario D
Null solution: current measures	14	14	13	14
Heighten dikes	2	2	2	2
Optimise dikes	1	1	1	1
Dam	5	5	6	6
Room for the River	7	7	7	8
Drainage system	13	13	14	13
Relocate schools & hospital	12	12	12	12
Advise on urban planning	6	6	5	5
Remove fishermen & create harbour	15	15	15	15
Evacuation optimum	9	8	8	7
Evacuation medium	10	10	10	9
Evacuation minimum	11	11	11	11
Sandbags	3	3	3	3
Temporary defences (area)	4	4	4	4
Temporary defences (building)	8	9	9	10

Table 6.3: Overview ranking alternatives Nyaungdon

It is noticeable that the ranking of the measures does not differ per scenario. This is mainly because the scenarios do not have a extreme insecurities. For example: an economic increase or decrease is likely to happen, but will not drastically influence the city of Nyaungdon in the coming years, as Nyaungdon is a already developed city.

The top-3 alternatives are optimising dikes, heightening dikes and sandbags. This seems logical, as the current dike is not optimal and can be improved. The dikes can be heightened as the water level rises in the future. Sandbags form a low-cost temporary solution to strengthen the currently present measures. The alternatives that follow in the ranking are temporary defences and a dam. The dam scores high as it is a prevention measure, but scores the lowest in this particular layer. It can be concluded that temporary defences score well, despite of their high costs, as they prevent material and immaterial damage and they reduce the probability of floods.

6.5 Creating packages

In this section multiple alternatives are combined into packages. It is recommended to consider a solution which consists of measures from the 3 layers. Therefore the top-3 measures should not be implemented instantly. In this case the optimisation and heightening of the dikes are both layer 1 measurements with almost similar features and high costs. In table 6.3 it is clearly visible that the layer 1 measurements, prevention, are highly ranked and layer 2 measurements, spatial solutions, are lowly ranked. These results are in accordance with the conclusion of the risk analysis, see section 4.6.5. In this analysis it is concluded that a prevention measure is of high importance and relocation is not preferable. Moreover, Nyaungdon is an already a developed city, so spatial measures are hard to implement. Therefore the layer 2 measurements are of less importance and left out in the created package. Consequently, a package can be made by combining a layer 1 measure with one or more layer 3 measures.

Looking at the scorecard that is written in appendix B.2, a package of the following measures can be composed:

- **Layer 1**: Optimise dike
- **Layer 3**: Sandbags and evacuation medium

Optimising dikes is chosen, as it is the number one prevention measure, combined with two layer 3 crisis management measures. The first one is sandbags, as it is a temporary defence to reduce mainly monetary damage and strengthen or heighten the dike, if it is likely that a flood will occur. The second layer 3 measure is a medium evacuation, to reduce the immaterial damage although the null solution already contains a minimum evacuation package. The optimum evacuation has not been chosen as the other measures cost a considerable amount of money as well. Therefore a balance between cost and flexible back up plan is made.

7 | Phase 4: Implementation

This chapter contains an advise on the adaptation strategy on the implementation of the solution package for the flood related problems of Nyaungdon. As described in section 2.8, differences in future scenarios are likely to lead to different measure packages per scenario. The similarities between these packages have to be found to create an adaptive strategy. However, this is completely different for the case of Nyaungdon. As shown in the previous chapter, the outcome from the Assessment is the same for all future scenarios, consisting of:

- **Layer 1**: Optimise dike
- **Layer 3**: Sandbags and evacuation medium

Since these measures are appropriate for all scenarios, they can all be considered to be no-regret measures. Therefore an extended adaptation strategy with many decision moments is probably superfluous in this case. Nevertheless, one should not forget to involve important actors such as key players, context setters and subjects in this phase, as described in figure 4.24.

In the analysis of Nyaungdon it has been pointed out that the current state of the dikes should be improved on many aspects. It is advised to start doing this as soon as possible, since the current dike might fail. Firstly, the existing dike should be adapted to the already present rules and guidelines, as described in section 4.4. These rules consider profile boundaries, in which nothing may be constructed. Moreover, the authorised crest level is regarded, which should be adapted in large parts of the embankment of Nyaungdon. Once these improvements had been made, the dike should be improved to prevent erosion. Weak spots might have to be redesigned, in order to strengthen and stabilise them. After this other improvements might be needed. This has to be considered based on the development of the dike in time. Therefore an eye should be kept on the state of the dike over the years.

In the meantime the current evacuation plan should be upgraded to the medium evacuation plan. Since the current plan already contains many elements, this is not likely to cost a lot of time or money. However, the quality will be considerably improved by the additional elements.

Sandbags are the second crisis management measure included in the package. These are likely to play a big role while the dike is being improved, in case a dike strengthening or heightening is needed. Hopefully, they will not be needed in the future, once the dike is optimized to the set standards.

8 | Conclusion Nyaungdon

In the introduction of this case it has been discussed that the township of Nyaungdon has regularly experienced flooding in the past, despite the current prevention measures. Consequently, the following research question has been formulated:

What are suitable measures to make Nyaungdon flood proof?

To conclude, Nyaungdon can be made flood proof for all the four scenarios by implementing one general package of measures. This general package contains three different measures: optimisation of the current dike, sandbags and a medium evacuation plan. An extensive adaptive strategy for the implementation phase will not be necessary, since there is only one package. It is recommended to firstly focus on optimising the dike and preventing erosion problems. This conclusion follows from the conclusions of the four phases of which the framework consists. The main conclusions of the phases are given below.

Phase 1: Analysis

Since the problem owner is the government, key players with a high level of interest and power in the decision making process will be: the Ministry of Social Welfare, Relief and Resettlement, the Irrigation Department, DWIR, regional and local authorities. In the process of choosing and implementing flood protection measures in Nyaungdon, it is also important to keep the subjects as humanitarian organisations and the population informed. Moreover, context setters as the Department of Forestry, multinationals, the military and the City Development Department should be kept satisfied.

From the flood risk analysis it can be concluded that the township is the part with the highest flood risk of the entire area. Implementing prevention measures is the best way to reduce this risk. Spatial solutions as relocation do not have sufficient contribution to reducing the risk.

The problems that are found with the evacuation process analysis are the amount of details in the local disaster plan and a lack in communication between the population and the authorities. Other problems can be defined by analysing the evacuation routes. With the current evacuation process and infrastructure it would take 9 hours for all the inhabitants to evacuate from the township, assuming that they would travel by car. This can be improved by implementing two measures, reducing this to approximately 4.33 hours.

To investigate the future situation, two driving forces with high impact and high uncertainty have been identified namely, the population growth and the economic growth. With this, future scenarios have been created. The range between these scenarios is limited, since no extreme changes are expected for the research area.

Phase 2: Development of alternatives

Within the three layers of the multi-layer safety approach several alternatives have been created to make Nyaungdon more flood proof.

Phase 3: Assessment

As a result of a multi-criteria analysis, a package of measures has been chosen, according to the set criteria and to the corresponding future scenarios. This package consists of: optimization of the current dike, sandbags and a medium evacuation plan.

Phase 4 : Implementation

Since the package of measures suits all future scenarios, no extended adaptation strategy with many decision moments is required. Nevertheless it is important to still take important actors as the key players, the subjects and the context setters into account. It is wise to heighten the entire dike to authorised crest level as soon as possible. After this, the erosion problem should be addressed.

9 | Recommendations Nyaungdon

This chapter consists of several recommendations considering the case study of Nyaungdon. The recommendations are case specific, recommendations regarding the framework have been treated in the framework part of the report.

The recommendations for the case of Nyaungdon have been treated below with their corresponding sections. Besides some general remarks have been made.

9.1 General

It might be wise to do research on the flood safety of a larger region than only Nyaungdon. This would mean that the scope of the entire case would become larger. It is of interest to know how the Ayeyarwady river changes its path for instance, which automatically requires a larger scope. This knowledge is of importance for the erosion rates around Nyaungdon and thus the flood safety. In order to do so one might need satellite images or make use of software like `SOBEK`.

9.2 Phase 1: Analysis

Geomorphology

Dike failure mechanisms are very much dependent on the soil on which the dike is built. Currently, soil surveys are lacking, as described in the analysis of Nyaungdon. These soil surveys do not necessary need to be undertaken all over Nyaungdon, but they could be of great value around the areas of the dikes.

Hydrology

An obvious recommendation regarding the hydrology is that more data should be collected. When designing any measure against flooding one should have sufficient data available. Currently there is no official measurement station at Nyaungdon, only some stations upstream and downstream. One could do interpolation or extrapolation of data from these upstream/downstream measurement stations, but the distances from these stations to Nyaungdon is too large to have accurate and reliable data.

Evacuation process analysis

A main remark for the evacuation process analysis is that all information has been provided by only one source. This is very undesired since this questions the reliability of the provided information, even though the source was very reliable. Preferably, multiple sources would be used in the future, to confirm whether they provide the same information.

Another remark regards the survey in Nyaungdon. The group of respondents who had experienced an evacuation was too small to be representative for the entire amount of inhabitants of

Nyaungdon. On top of that, a big part of the population is illiterate and most of the respondents who filled in the survey were not part of this fraction of the population. This largely diminishes the group of respondents for the performed survey, reducing its representative character. It is advised to conduct a survey on a larger scale, with many more respondents and especially many more different types of respondents. Since a large part of the respondents will be illiterate, it is useful to have several people who can conduct the surveys verbally. In case more statistic information is desired, the survey should be processed with `SPSS`.

Flood risk analysis

There are several recommendations regarding the flood risk analysis. The first one concerns the reliability of the probabilities of the flood scenarios. As earlier described in this chapter, more data enables better and more reliable probabilistic estimations. So it is recommended to gain access to more data if possible.

Secondly, some improvements on the flood map can be done. Other flood maps could be made for different flood scenarios. An example could be a flood scenario where a dike is breached. What would the flood map of Nyaungdon look like in such a case? Software like `Mike`, `SOBEK` or `Delft-3D` might be useful when using such flood scenarios. Before this is possible, a more accurate digital elevation map is required.

The third recommendation is specified on the flood risk analysis. It might be of interest to see more adaptations in the `Excel` sheet and see how this influences the risk of the area. For this case study only three adaptations have been done, but an endless amount of adaptations is possible. Furthermore it would also be of interest to see how the total risk changes, if one applies adaptations to the `Excel`-sheet with a different setup of the areas.

9.3 Phase 2: Developing alternatives

The second phase of the framework is the most creative phase, for which no strict method can be given. The only given guideline to follow is formed by the three layers. In order to come up with good alternatives, an open mind is very useful, since new solutions are often found by thinking out of the box. It might also be effective to involve many experts in this process, so different types of ideas are gained. In addition it would be useful to use the local knowledge of a developing country when developing alternatives. This might lead to new insights.

9.4 Phase 3: Assessment

As stated in chapter 6, it is preferable to complete this phase with a multi-criteria analysis and a cost-benefit analysis. Unfortunately, the cost-benefit could not be performed due to a lack of data. Nevertheless, it is highly recommended to perform this analysis in the future, especially before a measure is implemented.

9.5 Phase 4: Implementation

For this case only the very start of this phase has been elaborated. It is almost needless to say that this phase is far more extensive, reaching from the decision moment, to the moment at which the measure is actually realised in the research area. In order to complete the next step of this phase, more data is needed to calculate the required dimensions of the measures for instance. Once the measures are designed with a considerable detail, a feedback loop from the implementation phase to the analyse phase can and should be realised.

Part II

Case 2: Dala

10 | Introduction

Dala is a township of Yangon located south of downtown Yangon. Currently it is seperated from Yangon by a river and it can only be reached by boat or after a long drive by car. Green light has been given to construct a bridge from downtown Yangon to Dala (Nyein Aye, 2016). The expectation is that this will lead to major developments in Dala (Hammond, 2015a). This case differs from the Nyaungdon case, as yet there is no urgent flooding problem at Dala. Still Dala might face future problems with flooding, depending on the way it will develop. Subsequently the framework has been used to find an answer to the research question:

What are suitable measures to make Dala flood proof?

To find the answer, the framework has to be run through, according to its four phases: analysis, development of alternatives, assessment and implementation. Besides finding an answer to the research question, the implementation of this case also has a second goal. Namely, it functions as a "test case" to create and improve the general framework, by using a feedback loop.

Because the major flooding problems might occur in the future, the future scenarios analysis is of great importance. Furthermore Dala cannot be seen separately from Yangon. The growth of Dala is largely depended on the growth of Yangon. For that reason Yangon will also be described in the analysis phase, as it is likely to have an important influence on Dala. Sometimes Yangon will also be referred to as Greater Yangon. The difference is that Greater Yangon includes more townships than Yangon. This can be seen in figure 10.1, in which the planning area is also referred to as Yangon.

Figure 10.1: Greater Yangon and Yangon (JICA & YCDC, 2013)

11 | Phase 1: Analysis

11.1 Physical geography

This section treats all physical geographic features of Dala and Yangon required by the framework. This includes the topography, the bathymetry of the river, the climate, the hydrological data and the human geography.

11.1.1 Topography

The township Dala is located along the Yangon River. The Yangon River joins the Bago River at the right side of Dala after which it flows towards the ocean. Furthermore at the left side of Dala flows the Twante Canal. Figure 11.1 shows the altitude of Yangon and its surroundings. It is clear that Dala is a low lying area and that large parts of Yangon are situated on a hill.

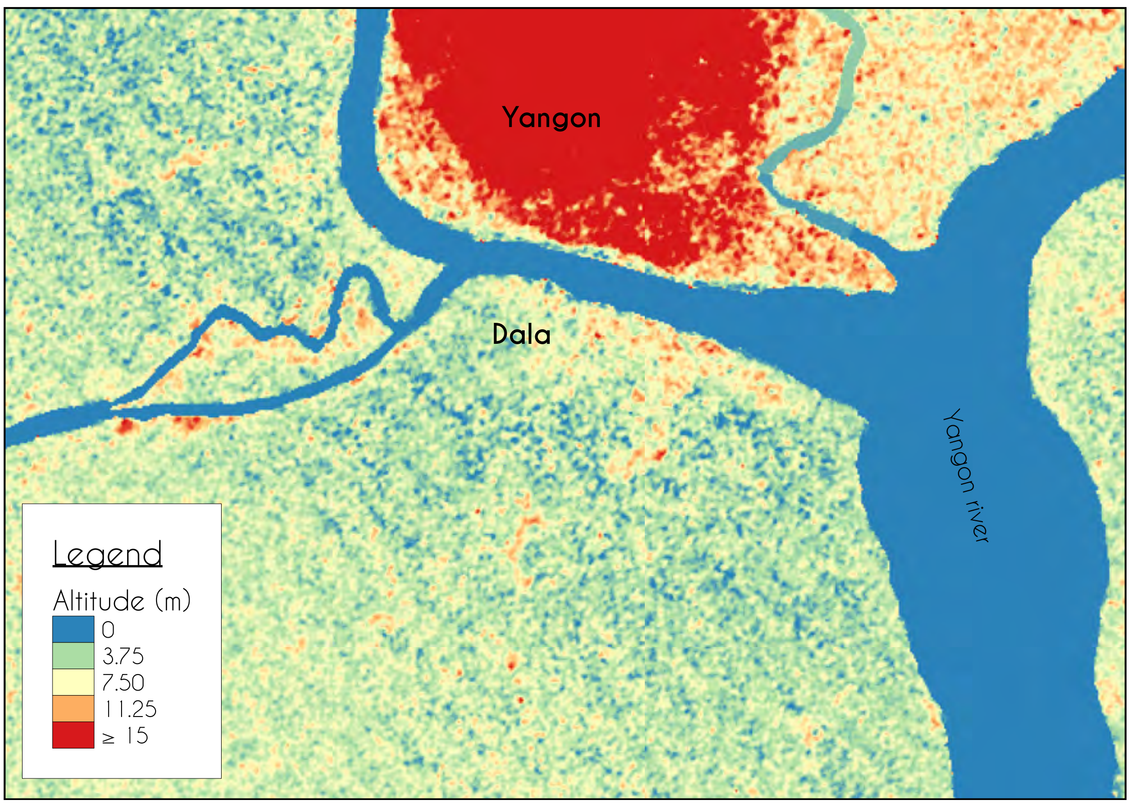


Figure 11.1: Altitudes of Dala and Yangon

11.1.2 Geomorphology

Figure 2.7 shows that the soil of Dala can be classified as Gleysol, a wetland soil saturated with groundwater. Unfortunately, the exact composition concerning the amount of sand and clay is not known. Consequently, a soil survey will be necessary to determine the applicability of the chosen measures.

11.1.3 Bathymetry

JICA, NK, and OCDI (2015) have provided information about the bathymetry around the Yangon port area. This report provided a detailed map of the bathymetry, see figure 11.2. At the left side of Dala, where the Yangon River bends, the water depth varies from 5 metres to 20 metres. This is due to the curvature induced flow which is typical for river bends. From Dala to the confluence, a joining of the two rivers, the center river depth varies from 6 metres to 15 metres. After the bend the river becomes shallower where it flows more downstream. An explanation could be that this is due to lower flow velocities near the confluence, resulting in settlement of sediments.

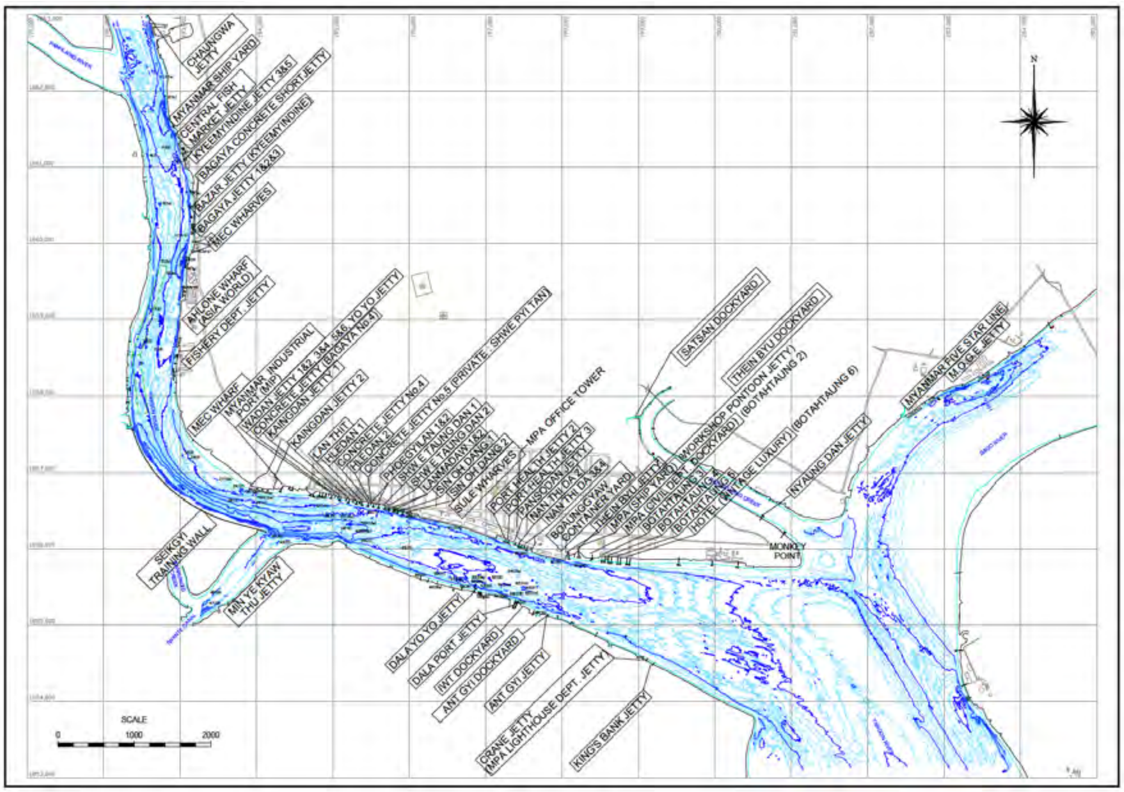


Figure 11.2: Bathymetry around Dala and Yangon (JICA et al., 2015)

11.1.4 Climate

Since Dala is located in the upper part of the Ayeyarwady delta, as well as Nyaungdon, the climate of both locations is equivalent. This tropical monsoon climate has been elaborated in the analysis of subsection 4.1.4. At Kaba-aye Meterological Station, located in Yangon, a mean annual rainfall of 2749 mm has been measured. This includes a maximum mean monthly rainfall of 591 mm in August and a minimum of 3 mm in January and February (JICA & YCDC, 2013). Important features of rainfall in Dala are the short duration and the severe intensity. The 50-year probable

60-minute rainfall exceeds 100 mm/hour, which is remarkably severe. This high intensity is a major cause of inundations problems in Yangon and its surroundings.

11.1.5 Hydrology

JICA et al. (2015) have done some research on the Yangon River, but still little data is present about the hydrological conditions near the Yangon River. The findings of their research have been used for this case.

11.1.5.1 Tidal conditions

The Yangon River is a tidal river and its water levels are thus fluctuating each day. The levels have been measured at Monkey Point, near the junction of the Bago River and Yangon River. More details on the measurements of these tidal levels can be found in appendix C. The measured tidal levels are listed below.

HHWL	Highest High Water Level	+7.1 m
HWL	High Water Level	+6.2 m
MSL	Mean Sea Level	+3.23 m
LWL	Low Water Level	+0.34 m

Table 11.1: Tidal levels at Monkey Point (JICA et al., 2015)

Furthermore some tidal information is retrieved from Elephant Point, which is located close to the ocean. In appendix C.1.1.1 more details on these levels have been given. For this case the value for HWS is taken to be at +7.02 metres.

11.1.5.2 Storm surge

As Yangon and Dala are located near the sea these locations are affected by the storm surges that come with heavy storms. As cyclones are not uncommon in the Bay of Bengal, the storm surges that come with the cyclones have been taken into account. JICA et al. (2015) have done some simulations on the Yangon Port and the storm surge levels that come with cyclones similar to Nargis, some with a course deviation and some with future cyclone predictions.

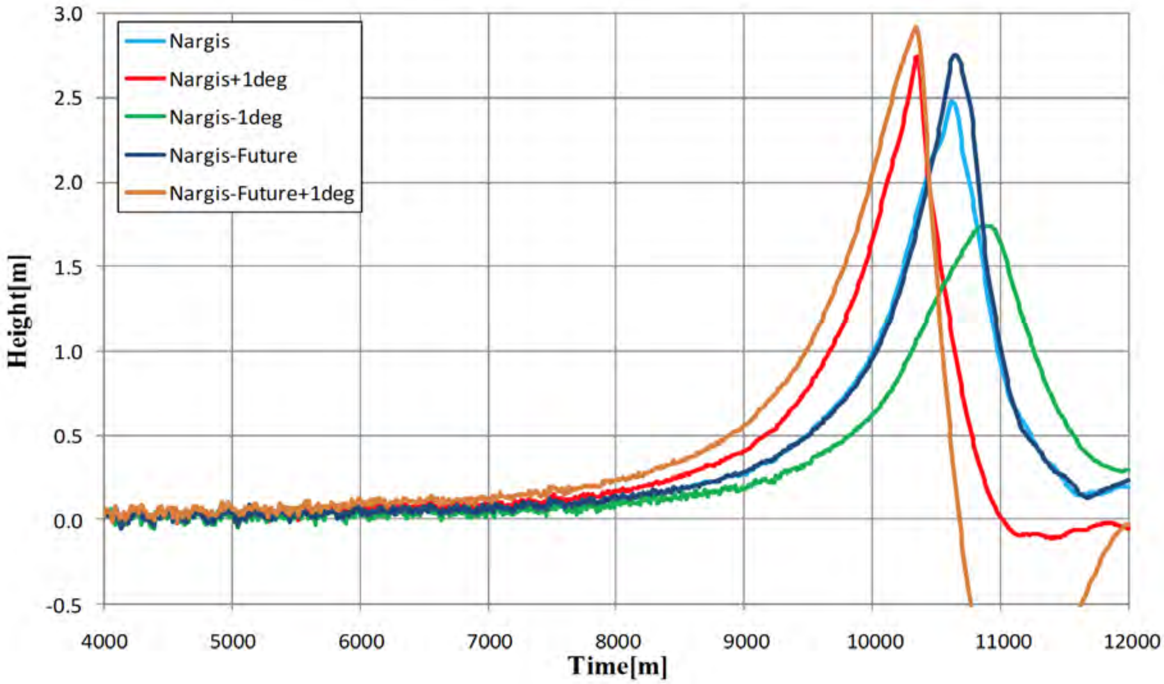


Figure 11.3: Storm surge simulation at Yangon Port (JICA et al., 2015)

In appendix C.1.1.2 it has been elaborated that the storm surge level for a storm surge once in 25 years equals: $SSL_{\frac{1}{25}} = 2.8$ metres.

11.1.5.3 Other hydraulic conditions

Description	Short notation	
Significant wave height	H_s	1 m
Maximum wave height	H_{max}	1.86 m
Wind speed	U	30 m/s

Table 11.2: Hydrological data at Botahteung (JICA et al., 2015)

Above some more other hydraulic data about the conditions near the port of Yangon have been noted. It must be mentioned that there is little to no data about the influences of the Yangon River or the Bago River themselves. The tide dominates the water levels, which makes it very difficult to say anything about the river influences.

11.2 Socio-economy

11.2.1 Population

The population of Dala in 2014 consisted out of 172.857 people concerning the whole area (Department of Population, 2015). From table 11.3 can be seen that the population is highest in the urban area of

Dala, this is in the north of the township close to the Yangon River.

Population				Urban population				Rural population				Urban population (%)
Both sexes	Male	Female	Sex ratio	Both sexes	Male	Female	Sex ratio	Both sexes	Male	Female	Sex ratio	
172,857	84,671	88,186	96.0	119,366	58,358	61,008	95.7	53,491	26,313	27,178	96.8	69.1

Table 11.3: Population in Dala (Department of Population, 2015)

Most people in Dala live in male-headed households with an average amount of 4.5 people. A few people do not live in households but in institutions. See table 11.4.

Conventional households				Population in ...		Mean household size
Number	Male-headed	Female-headed	Female-headed households (%)	Conventional households	Institutions	
37,912	29,502	8,410	22.2	170,363	2,494	4.5

Table 11.4: Households in Dala (Department of Population, 2015)

The past decade Yangon experienced rapid population growth: the average growth rate of Yangon City between 1998 and 2011 was 2.58 %. This is similar to Bangkok. In the New Suburbs and in the South the population growth rates are higher. The Dala region has a growth rate of 6.01% (JICA & YCDC, 2013). Due to the similarity with Bangkok, the future population of Yangon is predicted by looking at Bangkok's population growth. Due to the rapid growth of Yangon, Dala will grow very rapid as well.

At the moment people in Dala mainly live from rice cultivation and most land is utilized as paddy fields. All year round, every high tide during full moon local people experience inundation. The monthly inundation is relatively short and shallow; maximum 1 hour and 1 metre inundation depth. Local people accept the frequent inundations because crops can be grown. (JICA & YCDC, 2013)

Next to this the industrial category plays a role as well. The industrial structure in Yangon Region was composed of the processing and manufacturing sector (37%), the trade sector (25%) and the services sector (24%) (JICA & YCDC, 2013). In the future the Industrial Category will be more important, see table 11.5.

Labor Force in 2011 by Industrial Category				Labor Force in 2040 by Industrial Category			
Total	Primary	Secondary	Tertiary	Total	Primary	Secondary	Tertiary
85,932	386	2,556	82,990	293,951	1,213	8,512	284,226

Table 11.5: Labor Force Allocation of Dala (JICA & YCDC, 2013)

11.2.2 Economy

Dala has a large amount of non-working people which results in a low income community. The labor population in Yangon City was 50.8 % in 2011. In other regions, for example Dala, the population experienced a rapid growth the last few years. Consequently, the non-working population is increasing rapidly (JICA & YCDC, 2013).

New industrial zones are planned to be allocated along the outer ring road. Existing industrial lands within 15 km distance of the centre will be transferred outwards in the future (JICA & YCDC, 2013). Dala will be crossed by the outer ring road (more about this can be read in subsection 11.3) and therefore it can be expected that Dala will experience an increase in industrial activities and therefore jobs.

11.3 Infrastructure

Roads

Dala does not have an extensive road network at the moment. There are two main roads, both made of asphalt, through the urban area of Dala. One is the Dala-Twante Road, this road starts at the ferry terminal and crosses the town and then follows the Twante Canal. In the middle of the town the Dala-Twante Road crosses the Bo Min Yaung Road. This road takes direction to the south, out of town into the more rural parts of Dala. Next to these two roads the urban part of Dala has many more smaller roads mostly made of concrete. In the rural part there are not many roads present. The map of Dala with the most important roads can be seen in figure 11.3.

Figure 11.4: Map of Dala with existing roads and future bridge

In the future there will be some developments concerning roads in Dala. These plans can be seen in figure 11.5. With this Dala will become better accesable, the road network will expand and the transportation will increase. The plan is to make an outer ring road, a circular highway passing around 15 to 30 km radius of the downtown centre of Yangon. This highway will cross Dala (JICA & YCDC, 2013). Furthermore the construction of a bridge is scheduled for the coming years. This bridge will help to develop local businesses, society, health and education in Dala. The Yangon-Dala bridge will take five years to build and completion is planned for 2020 (Nyein Aye, 2016). The bridge will link Phone Gyi Road in Landmadaw, in Yangon to Bo Min Yaung Road in Dala (Herbert, 2015) (see figure 11.3). The majority (65 out of 68) of the local landowners already agreed on giving up their properties in return for compensation. Next to this land also a school, monastery, pagoda and market need to be rebuild because they are located in the area of the bridge (Nyein Aye, 2016).

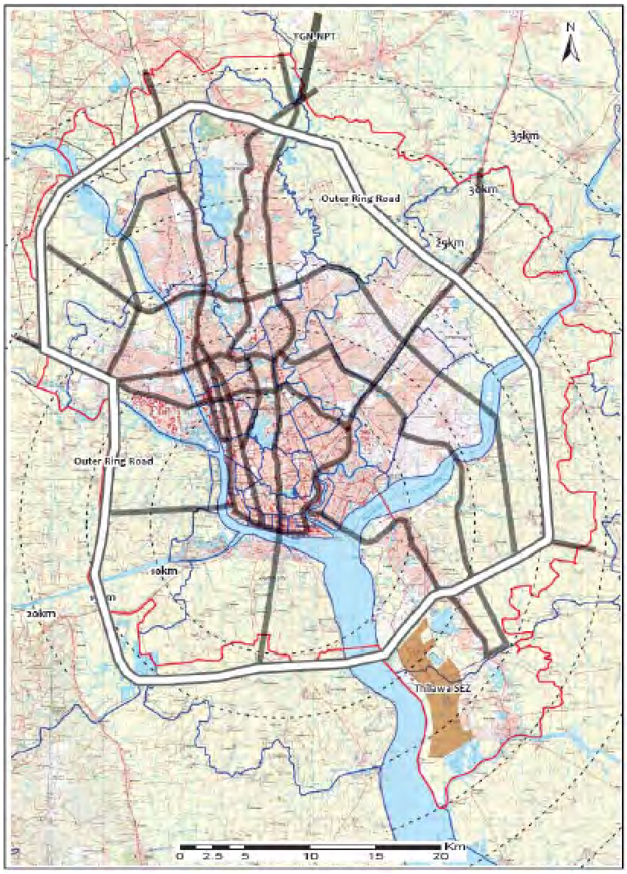


Figure 11.5: Future plans for roads in and around Yangon (JICA & YCDC, 2013)

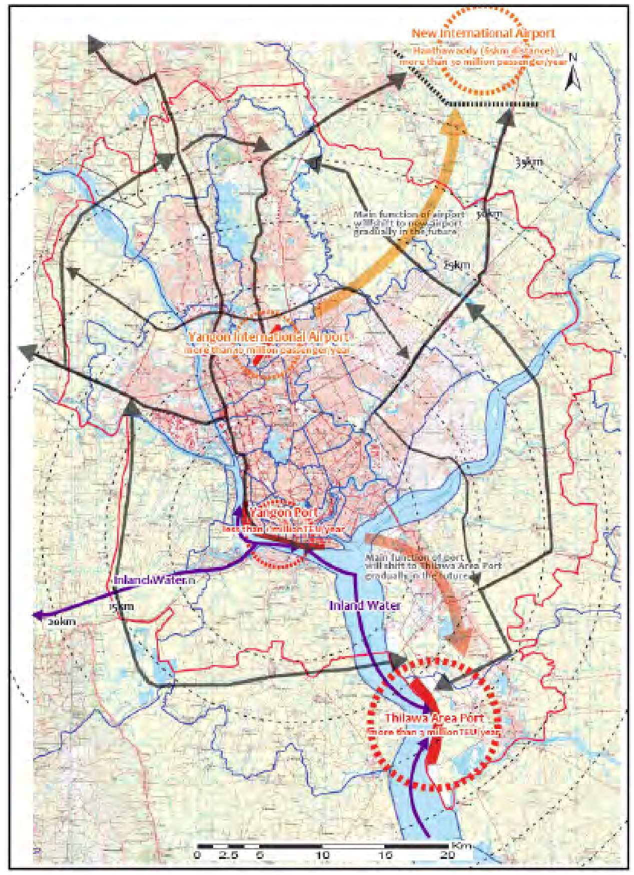


Figure 11.6: Future plans for logistics including waterways in and around Yangon (JICA & YCDC, 2013)

Waterways
Myanmar has a big inland water transport network and Yangon is a riverrine city by nature. That is why water transportation is an essential mode of transportation for passengers and cargoes. Especially the low income communities, like the people living in Dala, use water transportation a lot (JICA & YCDC, 2013). Dala and Yangon are separated by the Yangon River. Currently ferries are sailing between Pansodan Ferry Terminal in Yangon City and the Dala Ferry terminal to provide a connection between Dala and Yangon. The daily amount of passengers is 50,000 to 60,000. The ferries are problematic in safety, comfort and punctuality (JICA & YCDC, 2013). The expectations are that this should be improved a lot because Yangon and Dala will grow and the demand for over water transport will increase. On the short term new ferry ships and a renovation of the terminals are needed, on the long term a bridge will solve the problems (JICA & YCDC, 2013).
The bridge will come with a water pump line to distribute water from Yangon to Dala (Nyein Aye, 2016).

North of Dala the Yangon River flows, this river continues on the east side of Dala towards the ocean. On the west side of Dala the Twante Channel flows. In figure 11.6 these main inland waterways can be seen by the purple lines. At the moment a lot of port activities take place at the south of Yangon downtown. The ports are old, the containerized ratio is low and there are shallow areas in the approach channel. These are reasons why the Yangon Main Port should be expanded and modernized. The Yangon Main Port is located downstream of Yangon, at the river banks of the Yangon River about 32 km from the river mouth (JICA & YCDC, 2013). In this way the vessels do not have to cross the most shallow parts, what makes it better accessible. For the locations of the ports see the red areas in figure 11.6.

Railway

At the moment there is no railway in Dala. Yangon has a railway of 122 km nowadays but this is not sufficient with the expectations for future Yangon. The existing lines should be modernized and new lines, with a length of 232 km, will be constructed. The new railway network will fit with the future urban structure and functions of areas. The goal is to provide all citizens with access to any station within 5 km(JICA & YCDC, 2013), In figure 11.7 the existing and future railways can be seen.

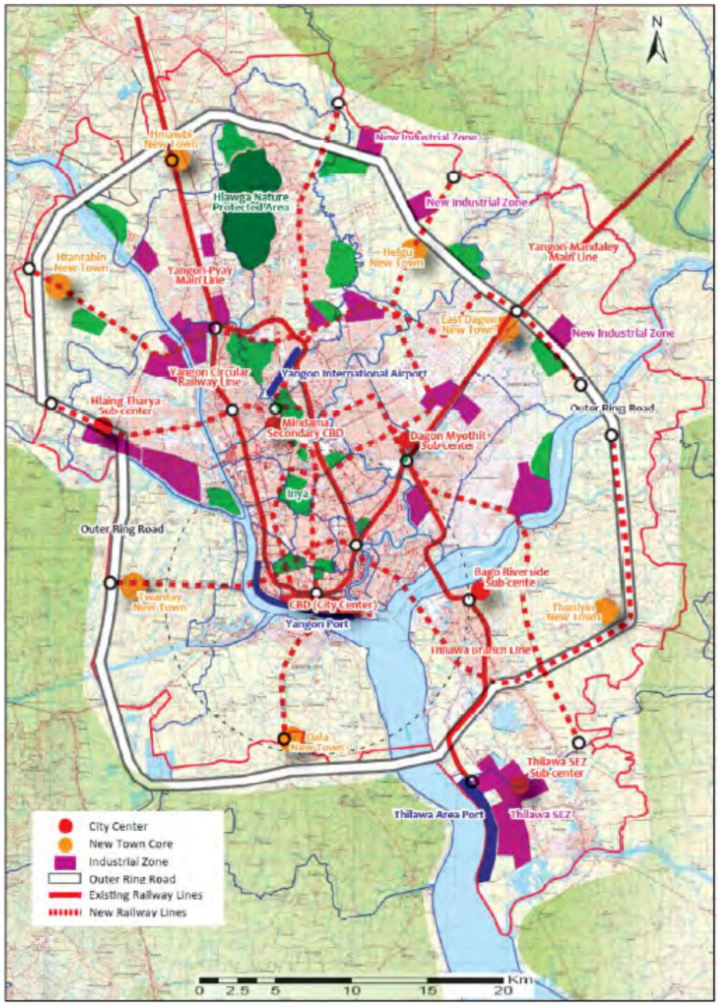


Figure 11.7: Existing and future railways in Yangon (JICA & YCDC, 2013)

11.4 Current measures against floods

Current measures against floods are often related to the economic state of the area they protect. Since Dala is located south of the Yangon River and not well connected with the wealthy and fast growing city of Yangon, there is a huge financial difference between the two areas. Although Dala is a township of Yangon City it does not seem to profit from the wealth of the city. Yangon has just started to invest in certain parts of land for future purposes, but at the moment Dala has to take care of itself the best it can. The current measures against flooding are shown below according to the multi-safety layer approach.

11.4.1 Layer 1: Prevention

Flood prevention measures are barely noticeable in Dala. When visiting the river side of Dala all that could be noticed is a heightened road that simultaneously works as a prevention measure against flooding, but cannot be called a dike.

11.4.2 Layer 2: Spatial planning

As stated above, there is a road which partly performs the function of a small dike. From this road the ground just slopes down into the river. In between this heightened road and the river people have built their houses on stilts, as can be seen in figure 11.8 and figure 11.9. These people live on the water side of the road and therefore have to live with regular flooding which they seem to accept.

Figure 11.8: People living on slope between river and road (by Ilse Caminada)

Figure 11.9: People living on slope between river and road (by Ilse Caminada)

These houses on stilts can be seen all over Dala, which is one of the main spatial planning measures most people took to prevent there houses from flooding. Although most houses in Dala have been constructed on stilts there are still houses that are not protected against high water in this way.

Figure 11.10: Stone house in Dala (by Ilse Caminada)

Figure 11.11: Stone house close to the river (by Ilse Caminada)

Especially the houses constructed out of stone seem to be constructed on ground level which is shown in figure 11.9 and 11.9. This is odd though, since the houses constructed out of stone are much more expensive. One could assume that if you have enough money for a stone house you might want to protect it against flooding as well by elevating the house. An other important measure that has been incorporated through all of Dala are the heightened roads, making sure transport is always possible.

Figure 11.12: Heightened Road (by Ilse Caminada)

Another way to prevent the township from flooding is the construction of a proper drainage system. Lots of plastic bags could block the system causing water to pile up in and around Dala.

11.4.3 Layer 3: Crisis Management

In this final layer of the multi-layer safety approach the crisis management should be discussed. The city Yangon has an evacuation plan which is described very limited in the report of JICA et al. (2015). This document published by JICA shows the aim to limit the congestion in Yangon downtown area during evacuation. Since the township Dala is also part of Yangon it is possible that there is some sort of evacuation plan for this area, although it will probably be less elaborated than for Yangon City itself.

11.5 Actor Analysis

11.5.1 Overview of all the actors involved

Next to all the actors already mentioned in the general actor analysis of Myanmar, a few specific actors play a role in Dala. This actors are described below.

	Interest	Desired situation/objectives	Expected or existing situation	Causes	Possible solutions / sources
YCDC	Make civil projects and new towns possible	Dala be a safe and dry place, a good extinction place for Yangon	Dala has a high probability of flooding and this will increase	Dala is low lying and sea level will rise	Make it possible to protect Dala from flooding
Port Authority	Manage the Yangon River	Keep the Yangon River navigable and the ports accessible	The Yangon River can cause problems and measures to prevent this will be planned	Higher probability of flooding and more impact if flooded	Cooperate with the organisations that want to take measures

Table 11.6: Actors Dala

Port Authority
The Myanmar Port Authority is a government agency. It belongs to the ministry of Transport and Communications. The Yangon River, a large waterbody around Dala, is managed by the Myanmar Port Authority. The Myanmar Port Authority decides for a big part what happens with the river; for example it gives permits for construction of ports and port operations (JICA & YCDC, 2013). For changes that affect the river the Port Authority will have an opinion about it and might step in.

Regional authority: YCDC
The Yangon City Development Committee (YCDC) is an organisation part of public services in the city of Yangon. This committee consists of 20 departments with all their own responsibilities, like roads, public buildings, water supply etc. The YCDC partly raises its own revenues and is partly paid by the union government. It is working on the preparation of civil projects and new towns. The expansion of Yangon is a topic of the YCDC and therefore it will be important for Dala. The YCDC will be engaged with the development of Dala and the future bridge (JICA & YCDC, 2013). It will work on the flood prevention of Dala because flooding will influence the development of Dala.

Local authorities
The township Dala belongs to the township group South of CBD. The administrative boundary Dala belongs to is Yangon City and this belongs to Yangon area. Dala belongs to the target area for a Greater Yangon (JICA & YCDC, 2013).

Population group
Nowadays the population in Dala is poor and lives mainly from rice production and some other sources of income, see section 11.2.1. However it is very likely this will change in the near future due to the expansion of Yangon and the better accessibility of Dala. It is very hard to say what kind of population will be living in Dala in the future.

Multinationals
At the moment no multinationals are situated in Dala. However, this might change in the future due to the expansion of Yangon. Dala is close to Yangon downtown so it is likely that Dala will

become a popular location. Which multinationals will settle in Dala is unsure, as well as their function and their character.

Humanitarian organisations
There are a few humanitarian organisations active in Dala. They are active on a lot of aspects. Considering floods, disaster risk reduction and protection are concerned as the most important ones. Below the organisations that are active on these aspects are described in more detail.

The Lutheran World Federation
The Lutheran World Federation (LWF) is a global communion of 145 churches in the Lutheran tradition. It is their aim to lay the foundation for a life in dignity for all, together with local and international partners. They focus on a few topics: Relief, risk reduction, resilience and sustainable livelihoods in changing climates and human rights, protection and peace. In Myanmar the Lutheran World Federation has pro-active partnerships with communities to prepare for disasters and rapidly respond to human need. These emergency operations provide food, shelter, water and other life-saving activities (The Lutheran World Federation, 2016). In Dala they are active on a lot of aspects namely ariculture, coordination, disaster risk reduction, education, health, infrastructure , livelihoods and protection (Myanmar Informartion Manegement Unit, 2016). This is the only organisation in Dala that works on disaster risk reduction.

Children organisations
The protection in Dala is dealed with by different organisations (Myanmar Informartion Manegement Unit, 2016). Most of them focus on children. These organisations are Save the Children, UNICEF and Terre des homes. Save the Children is an organisation that helps children world wide with health, education and protection from harm (Save the Children Myanmar, 2016). So does UNICEF (2016) and Terre des Hommes (2016). For example Save the Children Myanmar played a key role in major humanitarian crisises in Myanmar (Save the Children Myanmar, 2016).

11.5.2 Formal chart

The formal chart of Myanmar is applicable to Dala with some minor changes. The Myanmar Port Authority as a division of the Ministry of Transport and Communication can be added in the box of this ministry. It cooperates with companies in the water sector and regional authorities. The YCDC can be seen as a regional authority. It is an organisation that does a lot for the development of Yangon and with that it influences the local authorities and population of Dala.
The local authorities, population group, multinationals and humanitarian organisations in Dala will fit in the existing formal chart and do not need a change. The general characteristics fit the specific characteristics as far as known at the moment. The specifications of this actors are not clear yet, because Dala will change a lot the coming years.

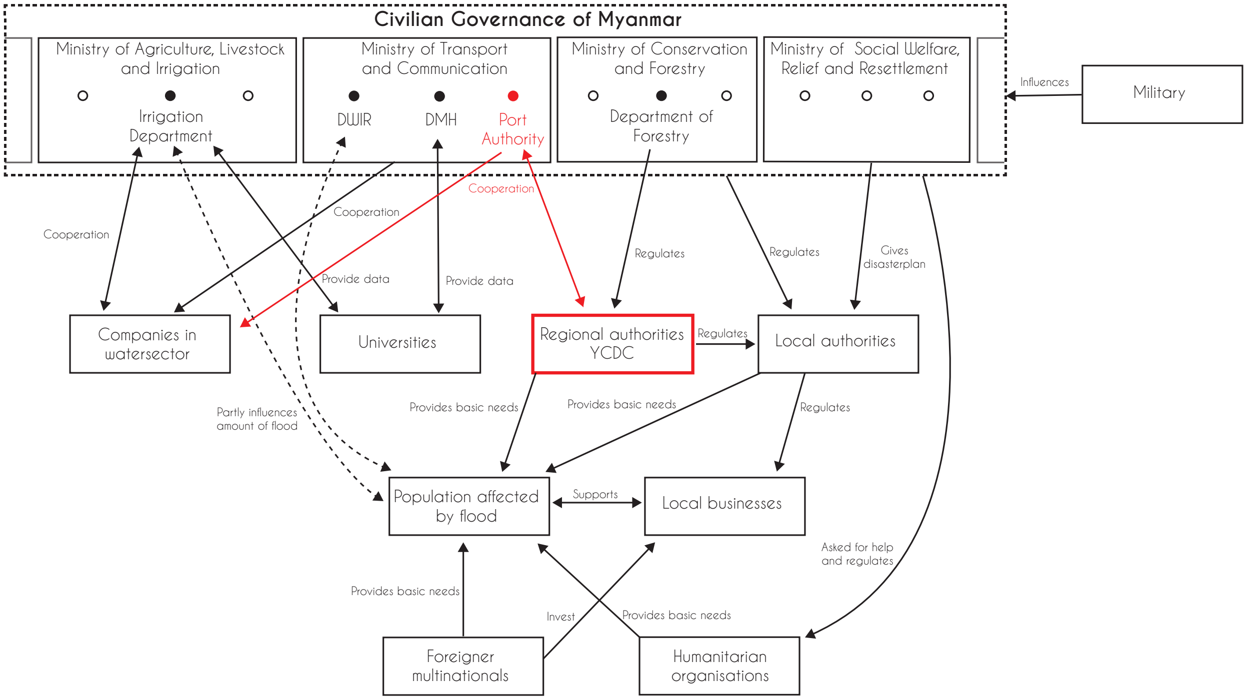


Figure 11.13: Formal chart

11.5.3 Power and interest of actors

The Myanmar Port Authority and the Yangon City Development Committee are added in the power interest matrix. The YCDC is very active in the development of Dala and therefore has a high interest and a high influence. The Myanmar Port Authority has a low interest, their main focus is on managing the Yangon River and not on protecting Dala. However if measures are taken that will influence the Yangon River, the navigability or the ports the Myanmar Port Authority will intervene. They have a power to influence the decisions because they decide on what happens with the Yangon River. The Myanmar Port Authority is a so called 'sleeping dog'. The other actors in Dala again will fit in the existing power interest matrix.

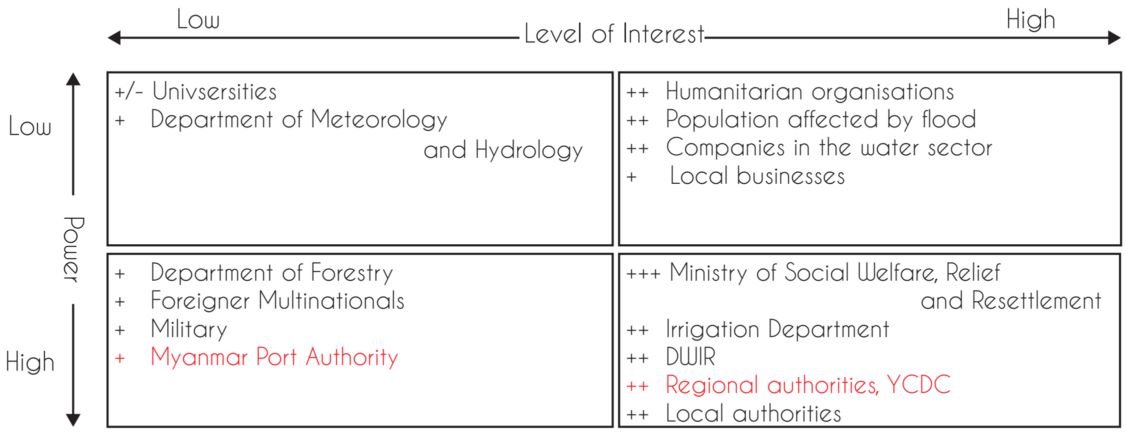


Figure 11.14: Power interest matrix

11.6 Flood risk analysis

This section contains the flood risk analysis of Dala. The general approach for a flood risk analysis is described in section 2.5.6. Normally the analysis starts with a flood hazard analysis, which would describe the hydraulic conditions. However the hydraulic conditions are already carefully elaborated in section 11.1.5. As a consequence the analysis begins directly with step two: flood scenarios.

11.6.1 Flood scenarios

For developing the flood scenarios of Dala the following important hydraulic characteristics can be be taken into account for flooding/inundation:

- Local rainfall
- High water due to upstream heavy rainfall
- High water due to tide
- High water due to storm surge
- Future factors like sea-level rise and land subsidence

A flood scenario can contain combinations of these hydraulic conditions. If this occurs the values of probability of these events should be multiplied according to probabilistic calculation rules. As not all of these hydraulic data are present for this case three flood scenarios have been developed.

The important note that was made in section 4.6.2 is also valid for this case, namely that the flood maps which are constructed in section 11.6.2 make use of the same kind of data as in the case of Nyaungdon. These flood maps can only produce water levels of multitudes of 1 metre. This means one can only construct water levels of 1 metre, 2 metres, 3 metres and so on with respect to the

reference water level (MSL). Also in this case rounding errors have been introduced because of this constriction.
The three flood scenarios that have been developed are described below, the calculations of the water level values can be found in appendix C.1.2:

- **Scenario 1**
  A water level of 7 metres as a result of spring tide. The probability that a spring tide occurs on a specific day is $\frac{1}{14}$.

- **Scenario 2**
  A water level of 9 metres as a result of a regular high water level (HWL) and a storm surge due to a severe storm (cyclone). The probability is adopted on the basis of two probabilities. Firstly, the probability that high water occurs is on a specific day is 1. Secondly, the probability that a strong storm occurs is $\frac{1}{25}$ years, see section 11.1.5. In this scenario these two events occur simultaneous, so the probability is $\frac{1}{25}$ years.

- **Scenario 3**
  A water level of 10 metres as result of a spring tide and a storm surge due to a severe storm. The probability of a spring tide is $\frac{1}{14}$ days. Furthermore the probability that a strong storm occurs is $\frac{1}{25}$ years, see section 11.1.5. As a consequence the probability that scenario 3 occurs in a specific year is $\frac{1}{350}$.

An overview of these flood scenarios is given in table 11.7.

	Water level rise due to				probability	
	regular high water	**spring tide**	**severe storm**	**h(m)**	**1/day**	**1/year**
Scenario 1		X		7	$7,1 \cdot 10^{-2}$	1
Scenario 2	X		X	9	$1,1 \cdot 10^{-4}$	$4,0 \cdot 10^{-2}$
Scenario 3		X	X	10	$7,8 \cdot 10^{-6}$	$2,9 \cdot 10^{-3}$

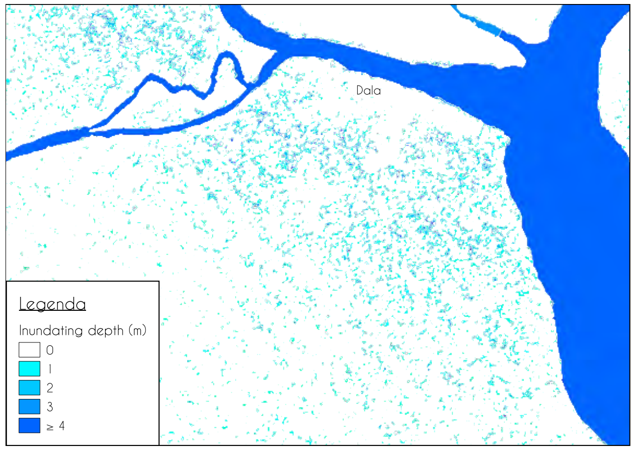
Table 11.7: Overview of flood scenarios in Dala

11.6.2 Flood damage assessment

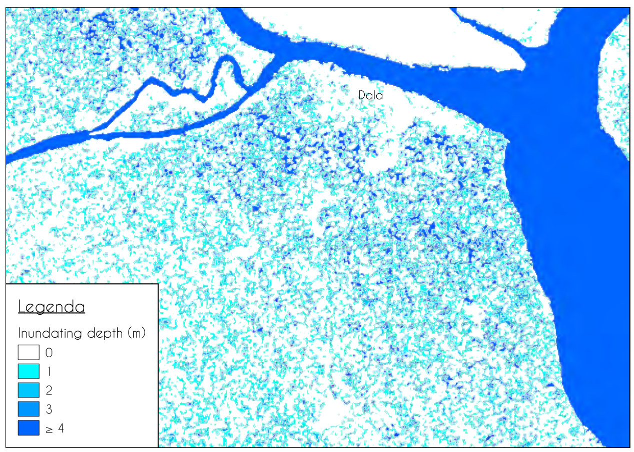
The goal of this section is to visualise the damage in the region of Dala caused by inundation. This is done by the following three steps, which are clarified in section 2.5.6.2.

11.6.2.1 Determination of flood characteristics

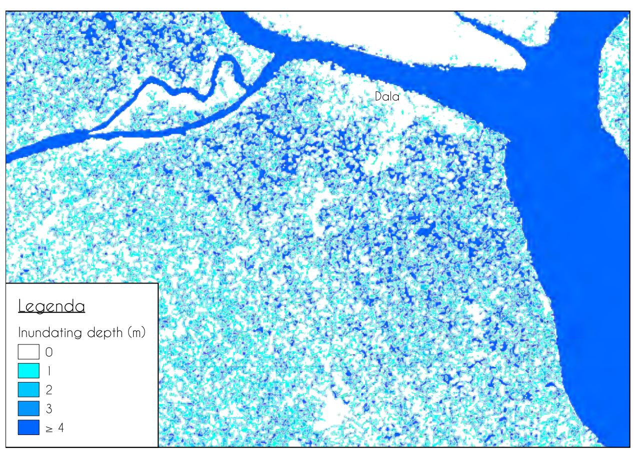
This step primarily aims to sample the inundation areas of the region of Dala. These areas are modelled in `Qgis` which makes use of digital elevation maps. `Qgis` makes use of the same of kind data as is used for the case of Nyaungdon, see section 4.6.3.1.



(a) Flood map scenario 1



(b) Flood map scenario 2



(c) Flood map scenario 3

Figure 11.15: Flood maps for the flood scenarios

These maps are sampled with the same settings and type of data as at Nyaungdon. No distinctions are made for inundation depths equal or higher than 4 metres, since 100% damage occurs in this stage. In addition the colors are pixelated which is caused by the horizontal inaccuracies. Furthermore vertical inaccuracy can be noticed at inhabited areas as well as in Nyaungdon. Despite of the smaller buildings, the ground level is still falsely measured. As a result the ground level seems to be higher than it actually is. In reality the altitudes of the inhabited areas should be lower, which is visible in the figures of section 11.4. This flood damage assessment is accomplished based on these flood maps. Despite the fact that these flood maps are not entirely realistic, these maps are used to give a better understanding about the approach of the flood damage assessment. This is in accordance with the stated criteria of section 2.2.

11.6.2.2 Assembling information on land use data and maximum damage amounts

In this section only the information on land use is assembled, since the collection of the maximum damage amounts for each damage category has already been elaborated in section 2.5.6.2, in which it is assumed that maximum damage amounts are similar throughout the whole country. Before constructing the land use map three classifications are made: water, buildings and vegetation. It is difficult to classify the infrastructure, so for this simplified assessment the infrastructure is disregarded. Furthermore bare soil is not noticed and therefore not taken into account. The land use map is constructed in `Qgis` by using `landsat` images of Dala. The final land use map of Dala is shown in figure 11.16.

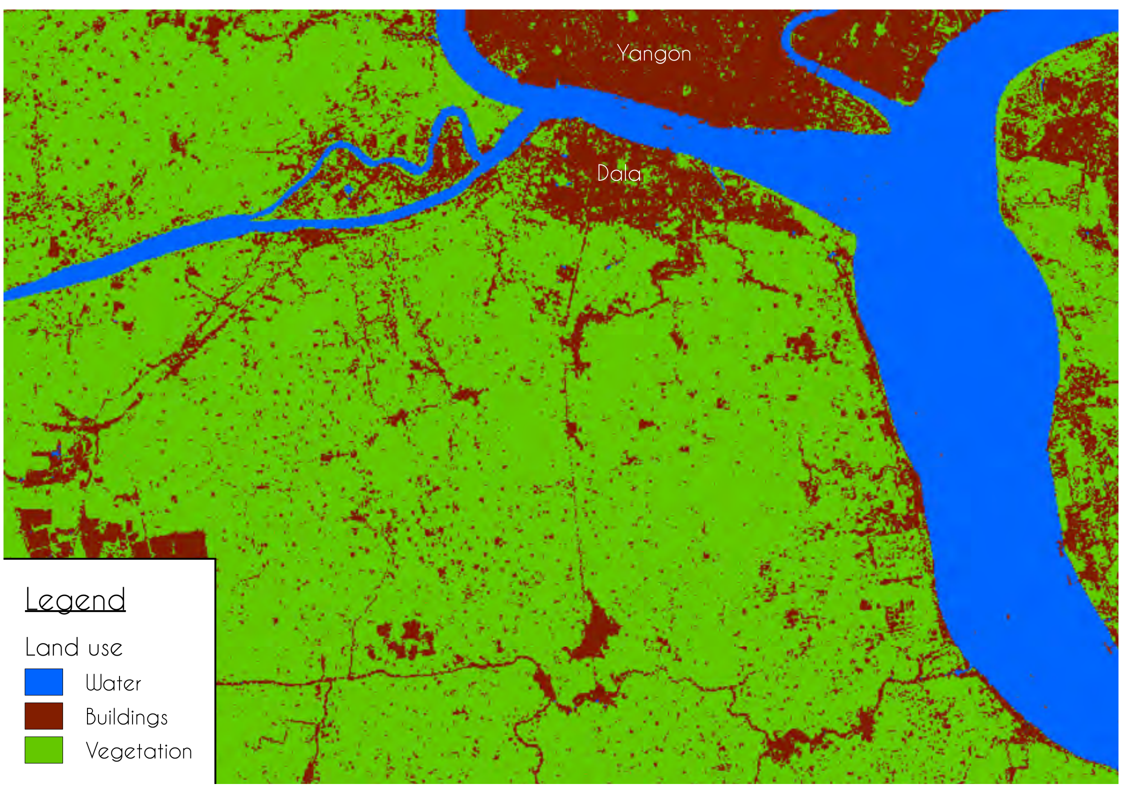


Figure 11.16: Land use of Dala

This figure gives a global representation of the land use in Dala. There are two features of the landscape of Dala area observed. Firstly, the land use in Dala consists mainly of vegetation. Secondly, Dala is not densely built on at this moment. Moreover some errors can be noticed. For instance, buildings in the river are detected which could be caused by ships in the river which are measured as buildings.

11.6.2.3 Application of stage-damage function

In this section the flood map and the land use map are integrated and combined with the stage-damage function to give an insight in the damages of the research area. Section 2.5.6.2 describes the general approach for this step which is reproduced in this section for Dala. Therefore also in this case the research area is firstly divided in three logical areas, based on their land use and inundation depths. These are depicted in figures 11.17 and 11.18 in which:

- Area 1: the urban area outlined in yellow
- Area 2: the east faced rural area outlined in blue
- Area 3: the west faced rural area outlined in red

Figure 11.17: A flood map divided into 3 areas

Figure 11.18: The land use divided into 3 areas

Secondly, the three surface areas are calculated by using `Google` maps. Thirdly, the areal percentages of land use and the areal percentages of inundation depths are determined. Finally, these percentages and surface areas are combined in the `Excel`-sheet with the stage-damage function, which is elaborated in section 2.5.6.2. This calculation is done for every flood scenario. This results in the areal flood damage and total flood damage for every flood scenario, see table 11.8. Furthermore, the water level of each flood scenario is plotted against the areal damages and total damages to give an insight in the gradient of damage, see figure 11.19.

	Water level	Damage of total area	Damage of area 1		Damage of area 2		Damage of area 3	
	h(m)	€	€	€/m^2	€	€/m^2	€	€/m^2
MSL	3	0	0	0	0	0	0	0
Flood scenario 1	7	15,170,909	11,670,432	0.90	2,125,598	0.06	1,374,879	0.05
Flood scenario 2	9	38,596,151	29,429,785	2.28	5,014,230	0.15	4,152,135	0.15
Flood scenario 3	10	58,657,250	45,717,649	3.53	7,385,089	0.23	5,554,512	0.20

Table 11.8: Results of the damage assessment for Dala

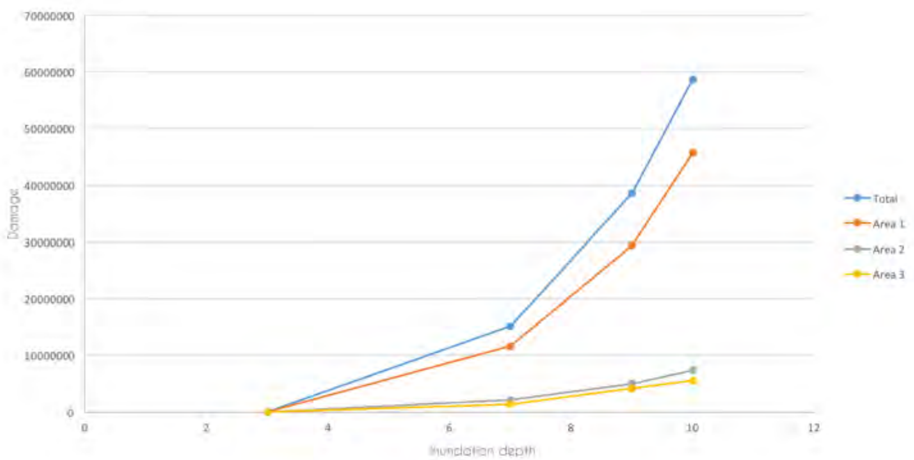


Figure 11.19: Damage plotted against water level for each scenario

In figure 11.19 is clearly visible that the damages of area 1 is of high importance for the total damage. As a result the curve of the total damage follows the curve of area 1.

Extra flooding of area 1

In section 4.6.3.1 it is noticed that the ground levels are falsely measured in inhabited areas due to the vertical inaccuracy of the SRTM-data. To observe observation how these errors will effect the total damage extra inundation is manually added in area 1 for flood scenario 2 and flood scenario 3, since during these flood scenarios the water will flow over the heightened road. The results of these calculations are exhibited in table 11.9, in which the changed values are given in orange. Figure 11.20 shows the distribution of damages for the case of extra flooding.

	Water level	Damage of total area	Damage of area 1		Damage of area 2		Damage of area 3	
	h(m)	€	€	€/m^2	€	€/m^2	€	€/m^2
MSL	3	0	0	0	0	0	0	0
Flood scenario 1	7	15,170,909	11,670,432	0.90	2,125,598	0.06	1,374,879	0.05
Flood scenario 2	9	44,938,776	35,772,411	2.77	5,014,230	0.15	4,152,135	0.15
Flood scenario 2	10	66,471,365	53,531,764	4.14	7,385,089	0.23	5,554,512	0.20

Table 11.9: Results of the damage assessment

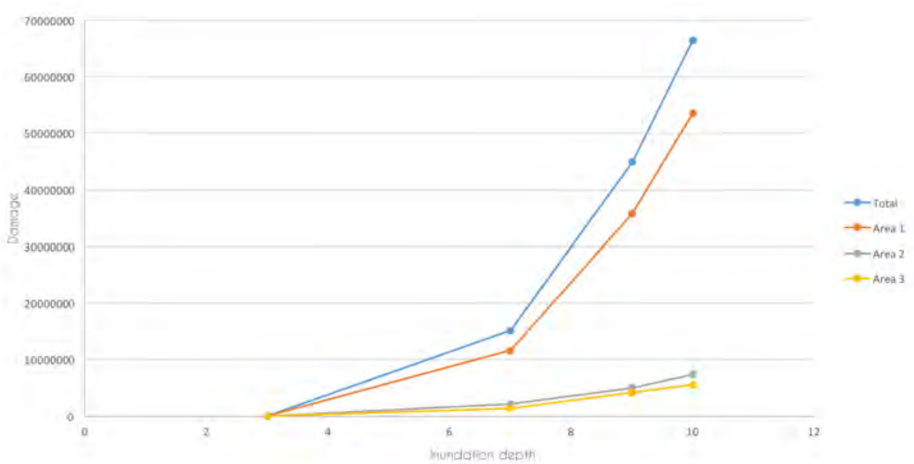


Figure 11.20: Damage plotted against water level for each scenario with extra flooding

From table 11.9 can be noticed that the total amount of damage has mildly increased for flood scenario 2 and flood scenario 3. Furthermore, in figure 11.20 it is also noticed that the gradient of the plotted line becomes mildly larger after passing the water level of 7 metres and 9 metres. Therefore, it can be concluded that more flooding in area 1 will effect the total damage in a mildly negative way.

11.6.3 Flood risk analysis

The `Excel`-sheet has also provided the FN-curve for the case of Dala and can be seen in figure 11.21 and figure 11.22.

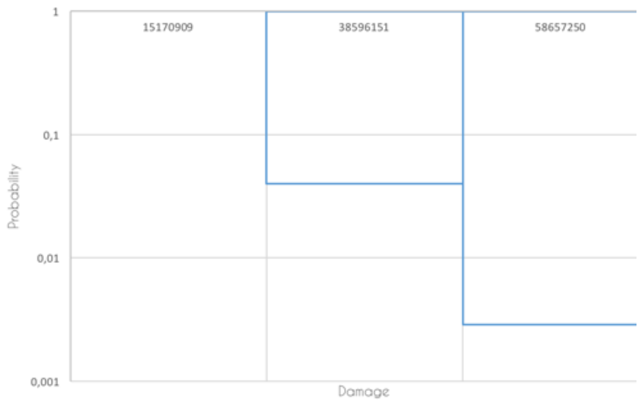


Figure 11.21: FN curve Dala (main situation)

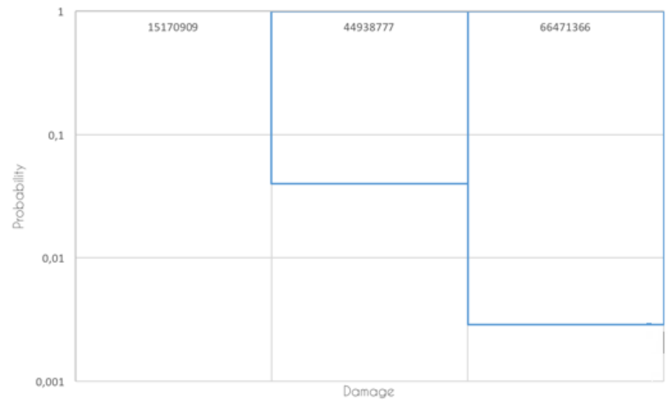


Figure 11.22: FN curve Dala with extra flooding

The following table includes the data corresponding with the figures above.

	Flood scenario	**Damages (€)**	**Probability (-)**
Main situation	Flood scenario 1	15,170,909	1
	Flood scenario 2	38,596,151	0.04
	Flood scenario 3	58,657,250	$2.86 \cdot 10^{-3}$
Extra flooding regarded	Flood scenario 1	15,170,909	1
	Flood scenario 2	44,938,777	0.04
	Flood scenario 3	66,471,366	$2.86 \cdot 10^{-3}$

For this case the total risk of a region is equal to the surface area below the FN-curve. The total risk for these two situations is:

	Total risk (€/year)
Main situation	16,165,236
Extra flooding regarded	16,423,145

Table 11.10: Total risk

It is interesting to see how much a certain area contributes to the total risk of the entire area. Table 11.11 shows how much each area adds to this total risk in percentages of the total risk:

	Area	Per. of total (%)
Main situation	Area 1	0.77
	Area 2	0.14
	Area 3	0.09
Extra flooding regarded	Area 1	0.77
	Area 2	0.14
	Area 3	0.09

Table 11.11: Area contribution to total risk

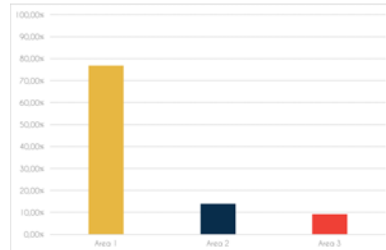


Figure 11.23: Visualisation of table 11.11

11.6.4 Applying multi-layer measures

As the framework describes there are layers in the multi-layer approach with measures that could influence the risk. The same as for case 1 holds for the case of Dala. Prevention measures lower the probability of flooding and spatial solution measures might influence the amount damage. Furthermore it might be of interest to see how the risk and damage increase when the population of Dala increases. Therefore the following adaptations have been simulated in the `Excel`-sheet:

	Description
Adaptation 1	Population of Dala is doubled
Adaptation 2	More buildings in area 2 and 3, less in area 1 & area 2 and 3 have the same types of buildings as area 1
Adaptation 3	Reducing probability of flood scenario 1

Table 11.12: Adaptations

For these adaptations the following values have been found:

	Main situation	Extra flooding	Adap. 1	Adap 2.	Adap. 3
Damage (€)					
Flod. Scen. 1	15,170,909	15,170,909	30,128,033	16,945,382	16,945,382
Flod. Scen. 2	38,596,151	44,938,777	76,637,055	43,516,453	43,516,453
Flod. Scen. 3	58,657,250	66,471,366	116,498,780	64,571,913	64,571,913
Total	112,424,310	126,581,052	223,263,868	125,033,748	125,033,748
Risk (€/year)	16,165,236	16,423,145	32,102,285	18,068,383	5,359,347

Table 11.13: Values of risk and damage

Obviously the risk and damage have been doubled when the population has been doubled. Due to the simplicity of the `Excel`-sheet the population growth is spread equally over all the areas. If the growth was not spread equally, the risk and damage can be expected to differ from this doubled value. For example the growth could occur in one specific area, an area that might contribute more to the total risk than the other areas.

Adaptation 2 can be seen as a spatial solution, where buildings are located further from the river and where the area is less densely populated. This did not decrease the damages and this can be explained by the low lying land of Dala. This spatial solution, the relocation of buildings, should come with elevation of the area in order to decrease the damages.

Adaptation 3 reduces the probability of flooding in flood scenario 1. One can for example think of the rise of a dike. This adaptation decreases the risk largely, mainly because the current flooding probability is very high.

It can be concluded that prevention of flooding will contribute largely to the risk reduction of Dala. Spatial solutions might also contribute to reduction of damage and thus to the reduction of the risk. It must be said that this can only work in combination with prevention measures or with spatial solutions that include elevation of the buildings.

11.7 Evacuation process analysis

In this section it is tried to analyse the current evacuation process of Dala. This section is however less detailed than the evacuation process analysis of Nyaungdon. The main reason was a lack of data about the evacuation process in Dala. The most important source for data was an interview with a employer Nyein Aya from the Yangon City Department Centre (YCDC). Other sources, as the internet were hardly accessible in the English language and almost non-existent on the subject of evacuation. The second reason for the lack of details in this analysis is that the necessity for optimizing the current evacuation situation is low. In the current situation the population of Dala accepts the floods and there is hardly any material or immaterial damage as the houses are constructed on stilts and flooding hardly occurs. However when the city will rapidly grow, the businesses probably won't accept the floods because it will cause a lot of material and immaterial damage.

11.7.1 Current evacuation process analysis

In this subsection the current situation is analysed with the help of the four elements. These elements are chosen as they are described in the report of Kolen (2016). The time line for this analysis is skipped, as more data is required to do the analysis.

11.7.1.1 Element 1: Threat and impact

Element 1 contains insight in the threat and impact of a possible disaster. This is already done in the section 11.6. In this element an impact scenario analyses can be performed. In this analysis it is decided to not specify the threat and impact element even more.

11.7.1.2 Element 2: Decision making by authorities

The measurement is done by the DMH of Yangon. If the water level of Yangon exceeds a certain level or a cyclone is predicted, that is headed towards this certain area, an early warning is given to the population of Dala. The early warnings are not only broadcast on TV but also on the radio programmes, social media, newspapers and journals. These early warnings are presumably done by the DMH of Yangon.

The main responsible body for disaster preparedness is the General Administration Department (GAD), according to Nyein Aye. This department acts as the civil service for the state and region governments and provides the administration for the country's districts and townships (Chit Saw & Arnold, 2014). One of the departments general goal is disaster preparedness, but they do this is cooperation with the Ministry of Social Welfare, Relief and Resettlement. To specify which responsibilities the General Administration Department has in Dala and how they communicate to other important actors is not precisely known.

11.7.1.3 Element 3: Environment and traffic infrastructure

In this section the main focus is analysing the environment. It is chosen not to do an estimation of the vehicle traffic movement as the population of Dala have hardly any cars and because the specific location of the temporary houses/shelters are unclear.

The analyse of the environment is based at data of the total Dala area (or Dala township) instead of the Dala urban centre. One of its reasons is the lack of data, the other reason is that the environment can have a larger scope than the investigation area. The Dala area has 28 monasteries (YCDC, n.d.), were they are located is unclear. According to Nyein Aye most of the population will evacuate to one of these monasteries. So it is recommended that these monasteries are well accessible. The township of Dala has around 30 schools in the township varying from primary schools (24), middle schools (4) and high schools (2). The policy of the National Disaster Committee is that these schools will close the moment that a flood is predicted. Special need is required to schools near the waterfront. In the west of the Dala city, one of basis education primary school is located 300 meter of the waterfront. A good communication to this particular school is required when flood disasters are predicted.

Other important buildings that needs to be checked are jails and hospitals. As far as is known, Dala has only a state-owned hospital located around 500 meter of the waterfront. Because it is that close to the waterfront, it is recommended that this hospital has its own evacuation procedure. It should plan upfront what would happen to the patients and how they should be transported. Also here a good communication between authorities is required.

11.7.1.4 Element 4: Citizens response

It is chosen not to make an evacuation model or to conduct an extensive survey on how the citizens respond to flooding. This has been decided because there has not been much experience with evacuation in order to give good insight about the evacuation process. However a little insight is given by interviewing experts Nyein Aye of the City Development Department Centre (YCDC). She interviewed the community and the monks in Dala at 17 October 2016 about the evacuations. As stated before, the population does not evacuate when a flood is caused by higher monsoon rain. However this was a different case when the Cyclone Nargis in 2008 hit Dala, that also caused a catastrophic destruction into the whole country. She explains that in the past no special cyclone shelters have been built for the population of Dala. However when the cyclone stroke the population evacuated into the monasteries in their neighbourhood. Nyein Aya explains that the people flee to these monasteries because they feel safer than other places. How the people travel to the temporary houses/shelters is unclear.

11.7.2 Define bottlenecks

Too little is known to give an insight in the bottlenecks. It is recommended to interview multiple experts to get a more detailed overview.

11.7.3 Conclusion evacuation Dala

Because of the lack of data it was hard to get an insight in the current situation of Dala. One of its reasons could be that there is no evacuation plan at all in Dala, however this can not be concluded. What can be recommended is that *if* there is not a evacuation plan, that at least the minimum (standard) evacuation package is chosen as one of the alternatives of Dala. The minimum package contains a guideline of steps in what to do if a disaster occurs and responsibilities to organise an evacuation are appointed. A more detailed explanation of this package can be found in the section development of alternatives.

11.8 Future scenario analysis

As explained in section 2.5.8 the future scenario analysis follows six steps and these have been treated for the case of Dala below.

11.8.1 Step 1 - Determine key question

The main problem definition of this report is "What is a good method to make several regions in Myanmar flood proof?". This definition can be adapted for the future scenario analysis to formulate the key question for the case of Dala. The key question for this case is:

What future scenarios might unfold for Dala that could influence flood safety?

11.8.2 Step 2 - Determine the contextual factors

The Mekong Delta Plan has been a relevant reference project when coming up with possible contextual factors that could be relevant for the case of Dala, although its content differs. The Mekong Delta Plan has looked at possible future outcomes for an entire delta and not so much for a specific area within a delta. Still its ideas have been investigated for this future scenario analysis as Vietnam and Myanmar share some similarities.

A relevant factor for future scenarios for Dala and Yangon could be the population growth. As a bridge will connect Yangon to Dala the city of Yangon might expand towards Dala. The bridge might also bring significant economic developments to the area. As has been done in the Mekong Delta Plan one could also look at the development of agriculture, industry and services. Climate related aspects like climate change, land subsidence, groundwater extraction, rainfall and sea-level rise are also variables that could be taken into account.

Several trends for the future of Yangon have been studied for the purpose of creating a strategic urban development plan (JICA & YCDC, 2013). JICA and YCDC (2013) have assumed that

Yangon will develop similar to Bangkok between 1975 till 2000. Bangkok experienced a political revolution in 1973, which lead to rapid changes in the country between 1973 and 2000. For several trends they have described different scenarios. Several of these trends, with multiple scenarios or without, have been discussed below.

11.8.2.1 Population growth

The JICA and YCDC (2013) estimated that Yangon would experience a similar growth as Bangkok has had in the past, with an population growth rate of 2.6 %.

	Present	Projection					
	2011	2018	2020	2025	2030	2035	2040
Greater Yangon	5,572,242	6,669,012	7,020,309	7,981,656	9,074,649	10,317,314	11,730,146

Table 11.14: Amount of people living in Greater Yangon as estimated by JICA and YCDC (2013)

As the projection of 2018 is only 2.5 years away, something can be said about these estimates. In 2014 Yangon area had 7,360,703 inhabitants according to Department of Population (2015) and this is already more than expected for 2018. This would mean that Yangon is growing more rapidly than expected.

11.8.2.2 Economic developments

Economic developments can consist of different things. Different types of companies could settle in Dala, ranging from industrial companies to service companies or even local shops. One could also look at the economic growth of a country or of specific locations. For this case it is more relevant to look at economic growth of specific locations.

JICA et al. (2015) have made some estimations on the development of labor forces in Greater Yangon. This is based on the population growth of Greater Yangon. Some shifts between the industrial categories are expected.

Township Group	Labor Force in 2011 by Industrial Category				Labor Force in 2040 by Industrial Category			
	Total	Primary	Secundary	Tertiary	Total	Primary	Secundary	Tertiary
CBD	119,573	0	8,400	111,173	140,465	0	8,932	131.533
Inner Urban Ring	653,564	789	17,359	635,416	784,877	1,338	22,674	760,865
Outer Ring	270,473	5,714	1,677	263,082	349,480	6,261	2,977	340,242
Northern Suburbs	375,366	1,011	18,043	356,312	852,131	3,743	80,044	768,344
Older Suburbs	587,241	538	41,770	544,933	498,923	418	31,639	466,866
South of CBD	85,932	386	2,556	82,990	293,951	1,213	8,512	284,226
New Suburbs	597,025	36,437	93,605	466,983	1,759,314	117,858	329,348	1,312,109
Periphery Area	156,385	9,544	24,519	122,322	1,772,439	108,174	277,892	1,386,373
Total	2,845,557	54,419	207,928	2,583,209	6,451,581	239,005	762,018	5,450,558
Structural Ratio	100.0%	2.9%	7.3%	90.8%	100%	3.7%	11.8%	84.5%

Table 11.15: Labor Forces

Considering economic growth, JICA and YCDC (2013) have not so much estimated if it would happen, but only when. They expect the gross domestic product (GDP) per capita will reach the same GDP/capita as Thailand reached around 2011. This might happen around 2040 in the low case, 2035 in the middle case and 2030 in the high case, see table 11.16.

City/Country	Year	GDP/capita
Yangon/Myanmar	2011	1,465
Low Case	2040	9,500
Middle Case	2035	9,500
High Case	2030	9,500
Thailand	2011	9,500

Table 11.16: Three estimations for GDP/capita in Yangon/Myanmar (JICA & YCDC, 2013)

11.8.2.3 Summary contextual factors

A summary of the contextual factors for the case of Dala and Yangon can be found in table 11.17.

Population growth
Economic growth
Development of agriculture
Development of industry
Development of services
Climate change
Land subsidence
Groundwater extraction
Change in rainfall
Sea level rise
Residential increase

Table 11.17: Contextual factors Dala and Yangon

11.8.3 Step 3 - Cluster the contextual factors into driving forces

Now the contextual factors can be clustered into driving forces. Contextual factors can be clustered only if several contextual factors are of the same category. The driving forces are marked bold in table 11.18.

Population growth
Residential increase
Economic growth
Development of industries
Development of primary industries
Development of secondary industries
Development of tertiary industries
Environmental changes
Climate change
Change in rainfall
Sea level rise
Local human induced effects
Groundwater extraction
Land subsidence

Table 11.18: Driving forces Dala and Yangon

11.8.4 Step 4 - Classify the driving forces according to their impact and uncertainty

As stated before, the future scenario analysis of Dala is different from future scenarios of an entire county. This is an area specific future scenario analysis and some driving forces are less uncertain or have a higher impact on Dala than it would have on a country.

		Uncertainty	
		Low	High
Impact	Low		
	High	Economic growth Local human induced effects	Development of industries Population growth Environmental changes

Table 11.19: Impact and uncertainty of driving forces

The development of industries in Dala has a high impact on the area of Dala and has a high uncertainty. Its impact is high as it has direct impact on the value of the area, besides the use of the waterfront can differ. Its uncertainty is high because currently there are no specific plans for the development of industries in the area of Dala. The population growth in Dala has a high impact and uncertainty. The population growth of Yangon is quite certain, but the question remains if Dala becomes a densely populated township as well.

Environmental change could have a huge impact and is definitely not certain. Environmental change is an uncertainty many regions have to cope with in Myanmar. For this case it is assumed that the driving forces ‘development of industries’ and ‘population growth’ have a more urgent combination of uncertainty and impact than the driving force ‘environmental changes’. Therefore these first two will be used on the two axis of the scenario matrix.

The economic growth of Yangon has a high impact, but does not seem to be that uncertain. It is difficult to grade the economic growth of Dala, but when subdividing the driving forces into table 11.19 it has been assumed that the economic growth is coupled with the development of industries and population growth. Economic growth in an area is depended on the development of the industries and population growth. In this way economic growth is less uncertain than these two driving forces. The same holds for the local human induced effects. Large scale subsidence due to groundwater extraction and the construction of buildings depends largely on the development of industries and population growth in Dala.

11.8.5 Step 5 - Design a scenario matrix

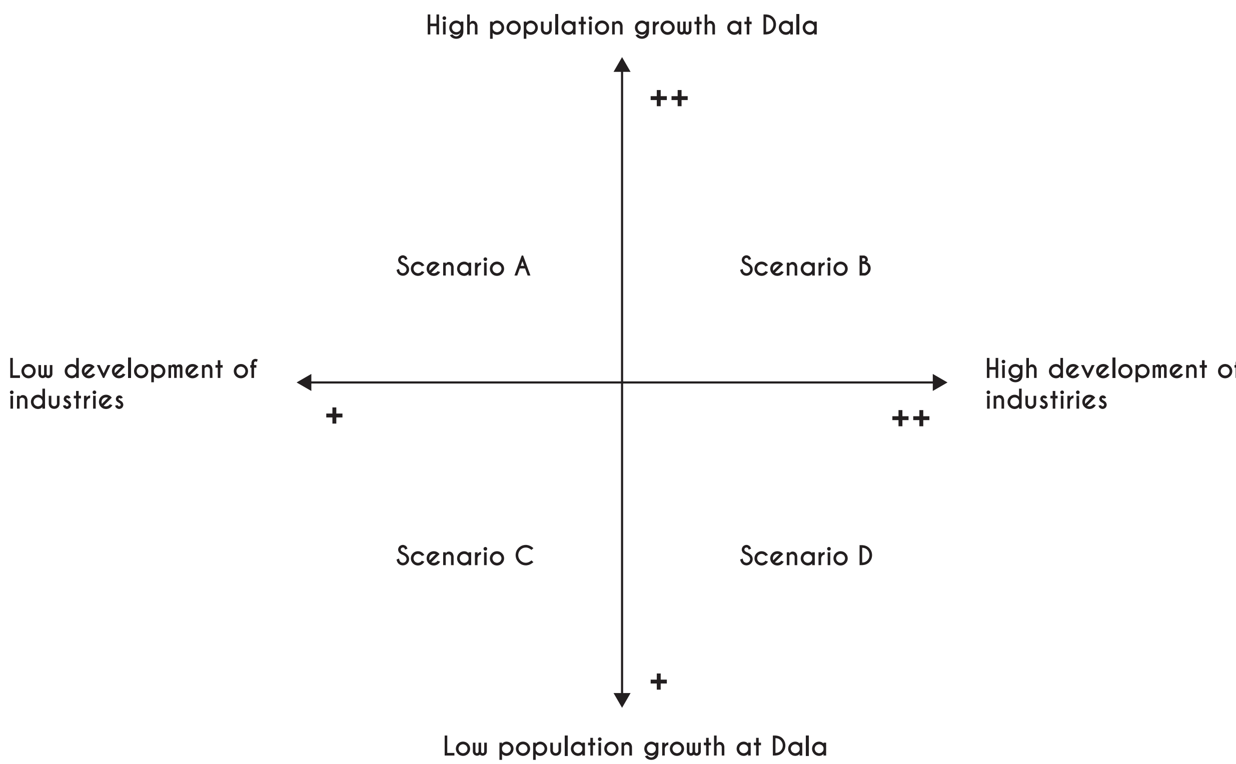


Figure 11.24: Scenario matrix Dala

Figure 11.24 shows the scenario matrix for the case of Dala. Population growth has been shown on the y-axis and the development of industries on the x-axis.

11.8.6 Step 6 - Detail the scenarios

The four scenarios for Dala have been discussed below.

11.8.6.1 Scenario A

Low development of industries & High population growth

This scenario consists of low development of industries and high local population growth. This means that the area of Dala will mainly become a residential area. The waterfront will not have specific industrial purposes and the population density will be rather high. Not a lot of businesses will settle in Dala.

11.8.6.2 Scenario B

High development of industries & High population growth

Scenario B consists of both high population growth and high industrial growth. The waterfront will have both industrial purposes as well us public purposes. Furthermore one could expect businesses to settle in Dala. A high population density will be present.

11.8.6.3 Scenario C

Low development of industries & Low population growth

This scenario looks the most like the current situation in Dala. Not many people will move to Dala and the area will be not become popular for businesses. The waterfront will not have public or industrial purposes.

11.8.6.4 Scenario D

High development of industries & Low population growth

Scenario D is a scenario where Dala will mainly be dominated by the development of businesses. The population density will be low and the Dala area consists of many types of industries. The waterfront will have industrial purposes only.

12 | Phase 2: Developing alternatives

In this chapter different alternatives are developed in order to find a solution to floods in Dala. The alternatives are developed in three categories, as has been done before in section 2.3.1. The alternatives are based on the existing measures and applied on this case. The alternatives are grouped in the three categories namely layer prevention, spatial solutions and crisis management. An overview of this approach and the chosen measures is depicted in figure 12.1.

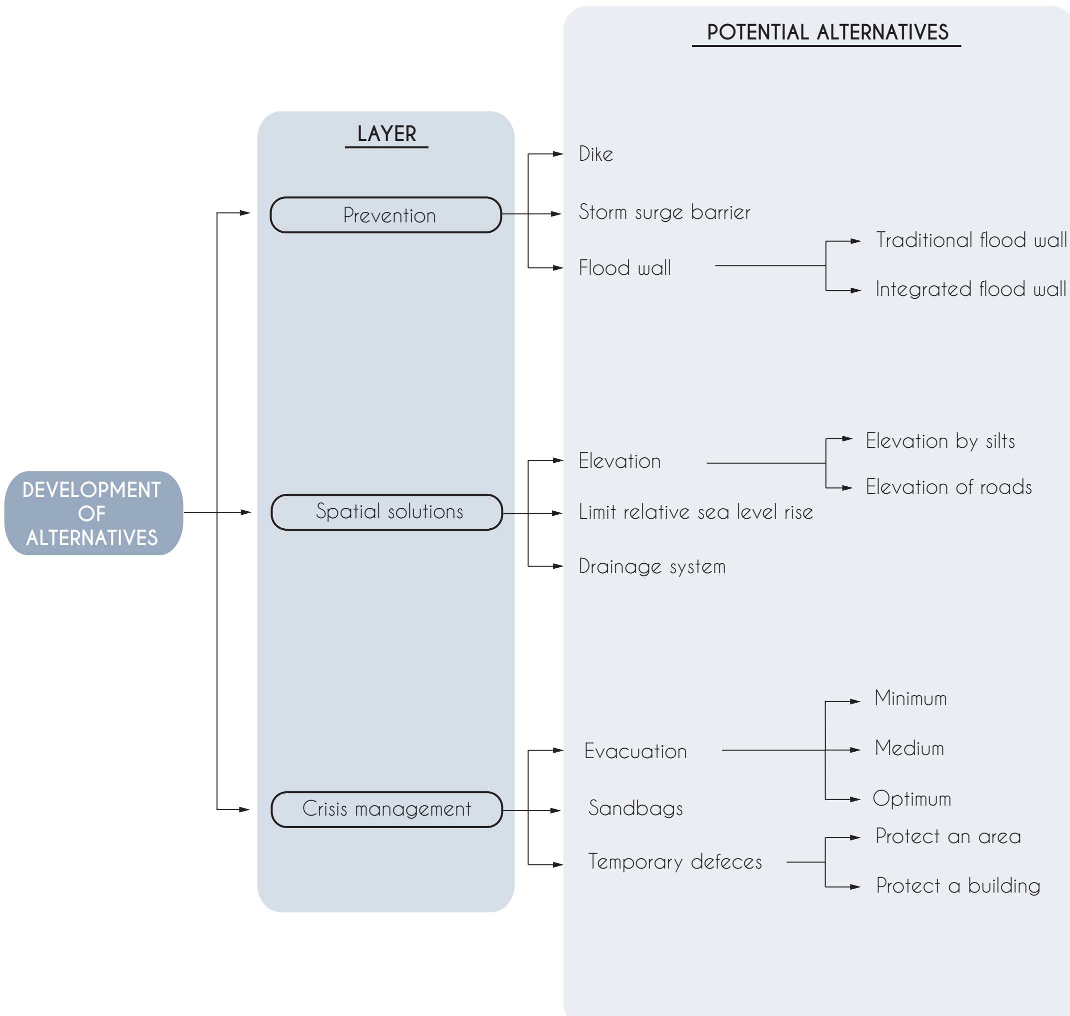


Figure 12.1: Overview development of alternatives

12.1 Layer 1: Prevention

12.1.1 Dike

One of the solutions to prevent Dala from flooding is a dike around Dala. Dala is surrounded by water at three sides (north, east and west). Due to storm surges the water level in the river will rise, this causes problems. The dike is necessary at all the river sides. It might be wise to construct a dike that could protect the whole densely populated area of Dala. This means that the west side of this dike should have a length of about 2.5 km. The north side should be totally covered, this means a dike length of about 6.5 km. The east side is not in direct danger because Dala township is not directly located at this waterline, but in case of a storm surge it can be expected that the water will reach the buildings. To prevent flooding from this side a dike with a length of about 2 km should be sufficient. In the case that Dala will expand this dike can be extended.

Flood scenario 2 (see section C.1.2.1) shows that a water level of 9 metres will be reached once every 25 years. The crest level of the dike should therefore be able to retain a water level of at least 9 metres. At the moment Dala is regularly flooded in some areas during spring tide. The water level at spring tide is 7 metres and therefore it is estimated that the altitude of heightened road at the river side is about 7 metres high. So a dike should be about 2 metres above this current ground level of the road. In the future the dike can potentially be elevated if a higher safety level is required.

It is important to keep the dike profile intact to keep it strong. The dike should be uniform over the entire length and should not be interrupted by buildings or any other hard structure. Therefore it is important to make a building free zone around the dike. If future dike expansions are taken into account, the free space around the dike should be large enough in order to heighten the dike even more without the the necessity of removing buildings that might have been constructed in that zone. Another threat to the dike profile is erosion as this also affects the strength of the dike. It is crucial to take measures against erosion to prevent the disastrous consequences of erosion. If no significant impacts are expected a grass cover of the dike should be a sufficient protection. In critical parts more extensive measures should be taken, such as bank protection.

12.1.2 Storm surge barrier

To prevent Dala from the most severe floods a storm surge barrier can be constructed in the Yangon river south east of Dala. Severe storm surges occur once every 25 years, the water level will be 9 metres during such a storm (see section C.1.2.1). So the storm surge barrier should be able to retain a water level of 9 metres to protect from storms with an occurrence of once every 25 years. To achieve a higher protection level, the ability to protect against severe storms that occur once of for example every 350 years could be needed. This means the storm surge barrier should be able to retain a water level of 10 metres.

For the location of the storm surge barrier the width of the river and the available space to construct it are important. It is preferable to choose a location that prevents a large area from damage. This would imply a location close to the sea but the river is very wide at the mouth and therefore less suitable for the storm surge barrier. The smallest width is preferable for the barrier because this makes it cheaper and easier to construct. The smallest width at the Yangon river is in a bend more or less half way up to Yangon. The problem at that location is the presence of the Yangon Main Port. So the construction of the barrier at that location is not possible because there is not enough space. The consideration with respect to the width and the predicted damage provides a location more downstream of the Yangon Main Port as the best location for the storm surge barrier.

The fact that the Yangon River is important for the transportation of passengers and cargo (see section 11.3) should not be forgotten. The navigability of the Yangon River is very important for the ports around Yangon. So the storm surge barrier should not block the shipping industry. To prevent disturbances in the shipping, a movable structure would be ideal. Navigability in normal circumstances will be possible and only a blockage during storms prevents shipping through the barrier. It must be noted that dikes at the ocean side of the barrier should have sufficient height, as these parts are not protected by the barrier.

12.1.3 Flood wall

To protect Dala a flood wall is a possible solution. This is a vertical concrete wall located at the water line and high enough to retain the water level during storm surges. This means the flood wall in Dala has to be a least 9 metres to protect Dala from floods that occur once every 25 years (see flood scenario 2 in section C.1.2.1). The surface level at the water line is estimated at 7 metres so the flood wall has to reach 2 metres above the ground level of the heightened road. Dala needs protection at the east, north and west side therefore the the flood wall should cover these sides like a dike should do.

A flood wall can be implemented in two different ways. The first way is to make a big vertical wall with low laying land behind, this is called a traditional flood wall. The second way is to place soil besides the wall to make a slope from the top of the wall towards land. This soil body can be used for different functions like a boulevard or a recreational area. The second option integrates the flood wall more in its surroundings due to the coverage with soil and is therefore called an integrated flood wall.

12.2 Layer 2: Spatial solutions

12.2.1 Elevation

Since Dala is already a very low lying area and it is expected that the ground level will go down due to consolidation of the soil and water extraction, it is wise to elevate certain parts of the township in advance. A spatial solution that has already been party implemented in Dala is the elevation of roads and houses. This is an effective measure to protect properties during a flood and a good way to make sure that transport by road is still possible. Both will be elaborated below.

12.2.1.1 Elevation by stilts

Houses are very vulnerable to floods when constructed on ground level because of the undesired topography of Dala as explained in section 11.1.1. Therefore most of the people living in Dala have already constructed their houses on stilts as has been explained in section 11.4. Not all houses have been constructed on stilts though, especially not the concrete houses. The reason why these are not elevated is unknown, but if new houses of concrete would be constructed with an elevation in the future these would be more resilient to floods.

12.2.1.2 Elevation of (main)roads

The elevation of roads is another measure that has been applied throughout Dala already. Most of the roads in Dala are heightened which will make it easy to continue that way of constructing roads in the future. People are accustomed with the construction methods of constructing roads with an elevation. Since the township Dala is expected to grow rapidly is it wise to make sure attention is given to the drainage system next to these heightened roads.

12.2.2 Limit/prevent relative sea level rise

A less acknowledged factor, but often also very important, is relative sea level rise due to groundwater extraction and consolidation. It is one of the biggest anticipated problems in Dala. It is a phenomena seen all over the world in developing countries with rapid city growth. The main reason for this problem is that people start pumping up water for themselves to have access to clean water. To prevent, or at least to limit, the effect of relative sea level rise there should be a major focus on a well functioning water network. In this way everyone should have access to clean water without the necessity to extract their own water. Also the urbanisation rate causes land subsidence which is hard to control. Something that could be done too, at least limit the effect of land subsidence during city development, is mapping the subsoil to get insight in the subsoil. If there are large muddy areas and areas that consist of a sandy subsoil, the areas with sand should be used for the larger buildings and larger urbanised parts. By choosing the right areas for the right buildings the effect of relative sea level rise could be limited for the case of Dala township.

12.2.3 Drainage system

A major problem for Yangon and every large city in Myanmar is the drainage of water during rainfall. Large amounts of water have to be transported through drainage systems that have to be maintained with care. In Yangon the drainage channels have recently been protected with large concrete blocks to prevent blockage of the channels due to garbage and leaves. Still Yangon struggles to control the extreme amount of water that has to be discharged. If Dala starts to develop with fast pace, it should made sure that enough attention has been given to a well functioning drainage system, especially because of the disadvantageous topography of Dala. Yangon is located on a hill, so water naturally flows into the river. For Dala this is not the case, so the need of a well functioning drainage system is high. The channels need to be covered in order to prevent garbage and other materials to fall in. They also have to be cleaned on a regular basis since garbage could always make its way in and still block the system.

12.3 Layer 3: Crisis Management

12.3.1 Evacuation

Three different options are considered concerning the possible evacuation-related measures. These options have been elaborated below. The taken measures have been divided in three or four different elements, which have been elaborated in section 2.5.7.

Option 1: minimum

1. An early warning system should be present.

2. An evacuation committee should be formed including a clear division of tasks for all the members. Besides this, a To-Do list has to be made by the nationwide committee, containing all the steps to be taken in case of an evacuation. The chairman of the township should be responsible for the communication to the chairmen of the surrounding villages and all other parties as the fire department and the health care sector.

Option 2: medium

1. An early warning system should be present.

2. An evacuation committee should be formed including a clear division of tasks for all the members. The committee should have regular meetings to discuss the approach for an evacuation. Besides a To-Do list has to be made by the nationwide committee, containing all the steps to be taken in case of an evacuation. The chairman of the township should be responsible for the communication to the chairmen of the surrounding villages and all other parties as the fire department and the health care sector. In addition clear communication on the evacuation approach towards the population is required.

3. Shelters should be defined in advance. Additionally, a general traffic management plan should be set up in advance. Next to this a more detailed evacuation plan should be made for special buildings like the hospital and the prison.

4. The fire department, health care parties, NGO's and local authorities should be prepared in advance due to the fact that they are provided with information on what to do in case of an evacuation.

Option 3: optimum

1. Besides the early warning system, several scenarios should be elaborated in an analysis.

2. The local evacuation committee should have regular meetings with all the members and crisis-managers to discuss the approach for an evacuation. The division of tasks and several plans should be made for the different scenarios. Occasionally evacuation drills should be performed to prepare the members. The communication towards the inhabitants of the township should always be transparent.

3. Shelters have to be defined in advance and should be stocked with supplies like food and water. Additionally, a traffic management plan should be set up in advance and its reliability should be verified by several traffic models. A detailed evacuation plan should be made for special buildings like the hospital.

4. The fire department, health care parties, NGO's and local authorities are prepared in advance due to the fact that they are provided with information on what to do in case of an evacuation. Moreover, inhabitants should be informed to prevent panic and release the amount of stress in case of an evacuation.

12.3.2 Sandbags

Sandbags are already present in Dala in a limited amount. Most people use them to create a stair towards the heightened roads from their houses. In this way people can enter their houses without getting wet feet. Sandbags are not used to defend the area from flooding. Besides, to construct a dike out of sandbags of approximately 10 km would consume way too much time. By the time a flood wave in the river is measured it is no longer possible to construct a dike out of sandbags on time before it will reach Dala.

For Dala it also holds that people could use green soil bags. These can be placed on the dike to improve it in a sustainable way. Although this seems like a useless effort since there is no dike to place these bags on.

12.3.3 Temporary flood defences

Like in case 1: Nyaungdon the area could be protected with temporary water defences or only individual buildings could be protected by means of these barriers. As has been explained in section 2.3.1, there are multiple types of temporary water defences like inflatable barriers, membrane barriers and modular barriers. Next to these three types of barriers there are the sandbags, which has been elaborated independently of the temporary defences. The temporary barriers have been explained in more detail below.

12.3.3.1 Protecting an area

If the whole area of Dala township should be protected by temporary defences with a barrier length of approximately 10 km should be stored. Depending on the chosen type of barrier a certain location with sufficient storing capacity is needed.

12.3.3.2 Protecting individual buildings

In the process of the development of alternatives one should always consider to protect only the most valuable or most strategic important locations. Although large areas of Dala will be flooded a lot of money could be saved by protecting these locations. Next to that, these buildings can be used as shelters for evacuated inhabitants. A cost-benefit analysis should determine such a decision. Also the differences between the possible temporary defences should be considered to use the right barrier for the right problem, since not all barriers perform the same under different circumstances.

13 | Phase 3: Assessment

13.1 Method

Firstly it must be mentioned that the cost-benefit analysis has not been treated for this case study, as there is not sufficient information available in order to complete even a simplified cost-benefit analysis.

To compare the possible alternatives they have to be evaluated on the basis of a multi-criteria analysis. This analysis is divided in four parts: rating the alternatives, determining weight factors, ranking the alternatives and creating packages. The criteria that are used in this analysis are already developed in the general framework. Therefore the step of determining the criteria is left out in this analysis, so this analysis starts with rating the alternatives.

13.2 Rating alternatives

It is important that all the different alternatives are being rated from effective to not effective or from good to bad. All different scales could be normalised into one universal scale, as scale of 1 to 5 has been used. For this case no different kind of scales have been used to evaluate different alternatives. This makes it way more easy to normalise the final score. In case more information was known it might have resulted in different scales that could be used for this step in the multi-criteria analysis. Colours are used to visualise the normalised score. The results can be seen in the table below.

Measures / Criteria	Weight	Null solution: current measures	Dike	Storm surge barrier	Flood wall traditional	Flood wall integrated	Elevation by stilts	Elevation of roads	Limit/ prevent RSLR	Drainage system	Evacuation optimum	Evacuation medium	Evacuation minimum	Sandbags	Temporary defences (area)	Temporary defences (building)
Material damage	1.331	1	5	4	5	5	3	1	2	2	1	1	1	4	4	5
Immaterial damage	3.377	1	5	4	5	5	4	3	2	2	5	4	3	4	4	2
Probability	2.216	2	5	4	4	5	2	2	3	2	2	2	2	3	4	3
Initial costs	1.338	5	2	1	3	2	3	2	2	3	4	4	5	4	2	2
Operational costs	0.881	5	5	3	5	5	5	5	5	5	2	3	4	3	4	4
Maintenance costs	1.003	5	4	2	4	4	5	5	3	3	5	5	5	5	3	3
Implementation time	0.536	5	1	1	1	1	3	2	4	3	3	4	5	4	4	4
Available space	0.723	5	4	4	4	4	5	4	3	4	5	5	5	5	5	5
Aesthetics acceptance	0.197	4	3	4	1	4	5	4	5	5	5	5	5	4	4	4
Disturbance for local residents	0.474	5	3	4	3	3	4	4	5	5	5	5	5	5	5	5
Preservation of biodiversity	0.159	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
Hindrance for ships	0.288	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
Accessibility by roads	0.477	3	3	3	3	3	3	5	3	3	4	4	3	3	3	3

Table 13.1: Overview rating the alternatives

For Dala it is clearly noticeable that the preservation of biodiversity and hindrance for ships are not considered to be affected by any of the alternatives. This means that all the alternatives will get the same score if only these two criteria are concerned. Larger differences can be noticed in the top part of the table. If an alternative is rated by a number '1' (red) it means that, concerning this criterion, it scores worse in relation to an alternative that is rated with the number '5' (green). For instance the criterion 'initial costs' scores the best for the null solution because this is this alternative nothing will be done. So this is the cheapest solution. A storm surge barrier though will cost a lot of money due to investments resulting in the least favourable rating. A more detailed explanation is given in appendix C.2.

Overall a flood wall has a more favourable rating in compared to for instance a drainage system or an evacuation plan. This does not mean that a flood wall is always the best solution, which will be shown in section 13.4. A very important item in determining the final ranking is the weight factor which will be elaborated below.

13.3 Weight factors

This factor, shown in table 13.1 in the gray column, mainly determines whether a certain criteria is important or not. These weight factors have been determined by using a method which is explained in the general framework in section 2.7.1.4. This has been done for all different scenarios described in the future scenario analysis. An overview of the different scenarios is given below.

- scenario A: high population growth (++) low development of industries (+)
- scenario B: high population growth (++) high development of industries (++)
- scenario C: low population growth (+) low development of industries (+)
- scenario D: low population growth (+) high development of industries (++)

By looking at all different scenarios one could assume that certain criteria become more important when population grows rapid or not. The same holds for an increasing industrial development or decreasing industrial development. These weights given for all different criteria have been determined and for one of the scenarios this method is shown in appendix C.2. In table 13.2 an overview is given for all four different scenarios. Especially the first six criteria seem to be of importance for all scenarios, but simultaneously they also vary the most over these scenarios. Therefore these criteria largely determine the outcome of this multi-criteria analysis.

Although the criteria have not been changed, they all have been modified for each different future scenario for the Dala case. This means that a variety might be expected in the final ranking of the alternatives. For now one could notice that especially the immaterial damage is the most important factor for all but one scenario. The scenario in which it is not important is the scenario in which no residential area is expected and only an increase in industrial area is assumed. In this case the material damage will outweigh the immaterial damage which, strikingly, results in large differences in combination with the growing importance of the three combined costs.

	scenario A	scenario B	scenario C	scenario D
Material damage	1.33	2.56	0.66	2.87
Immaterial damage	3.38	2.97	1.49	1.14
Probability	2.22	1.86	1.72	2.15
Initial costs	1.34	0.91	2.32	1.74
Operational costs	0.88	0.76	1.83	0.94
Maintenance costs	1.00	0.90	2.06	1.17
Implementation time	0.54	0.66	0.82	0.99
Available space	0.72	0.76	0.58	0.64
Aesthetics acceptance	0.20	0.19	0.11	0.14
Disturbance for local residents	0.47	0.50	0.54	0.44
Preservation of biodiversity	0.16	0.14	0.18	0.12
Hindrance for ships	0.29	0.25	0.24	0.24
Accessibility by roads	0.48	0.54	0.47	0.42

Table 13.2: Overview of weight factors Dala

13.4 Ranking alternatives

The determined weight factor and the rate of the alternatives are combined to find the final rank of all the alternatives. This is done by multiplying the weight factor with each score given to a certain alternative. After adding al these outcomes per alternative, each has come to a certain score determining the final rank. Only the end result for each future scenario is shown here, a detailed explanation is given in appendix C.2.

	scenario A	scenario B	scenario C	scenario D
Null solution: current measures	13	15	4	9
Dike	2	2	6	2
Storm surge barrier	10	8	15	11
Flood wall traditional	3	3	3	3
Flood wall integrated	1	1	5	1
Elevation by stilts	7	6	7	7
Elevation of roads	12	12	11	15
Limit/prevent RSLR	14	13	14	13
Drainage system	15	14	13	14
Evacuation optimum	6	9	9	12
Evacuation medium	8	10	8	10
Evacuation minimum	9	11	2	8
Sandbags	4	4	1	4
Temporary defences (area)	5	5	10	5
Temporary defences (building)	11	7	12	6

Table 13.3: Overview ranking alternatives Dala

In table 13.3 an overview is given of the final ranking of all alternative for all different scenarios. The alternatives that score relatively the best or are the most interesting are marked by a grey colour. The other alternatives are left blank. As earlier stated, the flood wall is a solution that ends up high for all scenarios. However in scenario C it does not end up as the best solution, evacuation turns out to be the best solution for this specific case. Although it does not seem to score the best in table 13.1 in which the alternatives are rated, it still turns out to be the best solution in combination with a drastic change in the weight factor for that specific scenario.

This is just one example out of the multiple that can be seen in the tables shown in this chapter. For each different scenario the weight and scores given could always be adjusted, depending on who is doing so. If, for instance, someone with more insight in the situation performs the same multi-criteria analysis a total different outcome is not unlikely. Therefore it is not assumed that the outcome of this analysis results in the best solution, especially not since the future is highly uncertain. It is recommended to perform this analysis by an expert in the future to get better insight in possible solutions.

An other remarkable fact is that the alternatives that score the best are mostly of level 1: prevention measures, or level 3: crisis management measures. The level 2 measures turn out to be less favourable in comparison with the other measures. This does not mean that they should not be considered any more. They might have to be included in a wider solution plan in which multiple solutions should be combined to protect Dala. In this way a cost effective total solution could be achieved in which all three layers are present in a functioning plan. The combining of solutions will be elaborated in more detail in section 13.5 below.

13.5 Creating packages

For Dala multiple packages should be created since the different future scenarios are extremely diverse. Although the outcome of the multi-criteria analysis is not as diverse, multiple packages could be created, each fitting its own scenario best.

- *Scenario A*
  In this scenario the population has grown intensively in comparison with the industries. Dala township therefore consist mainly of residential area that has to be protected. In order to prevent the area from flooding an integrated flood wall has been chosen. This measure had the best overall score in the first layer, prevention, in most of the scenarios. As described in section 11.6.4 a reduction in the flood probability drastically decreases the risk, reducing the costs per year. Therefore measures that reduce this risk should definitely be included in the package. Besides the first layer in the multi-layer safety approach there should be measures from other layers that will be applied in Dala as well.

  For the second layer, spatial solutions, a combination of houses constructed on stilts and a well developed drainage system have been chosen for this scenario. Since the residential area might only consist of relatively cheap houses like the current houses that are constructed out of bamboo, they could easily be constructed on stilts. This reduces the material damage in the case that a flood still occurs. The drainage system should be improved in order to make sure that water due to heavy rainfall could be transported out of the township, otherwise causing inaccessibility to certain parts of Dala.

For the third and final layer, crisis management, a medium evacuation plan is advised to be incorporated into the total package. Lots of people will be living in this area in this scenario. It is therefore wise to prepare an evacuation plan in case other measures fail to defend the area. A medium evacuation plan should be sufficient. Although sandbags end up high in the final ranking they are not included in the package itself but could still always be used in case of emergency. The main focus for crisis management should be on evacuation measures since sandbags need a lot of time to be placed for which the amount of time is not always available.

- *Scenario B*
  In this scenario both the population and the industries have increased drastically, causing a densely populated area with lots of industry related activities. For this scenario the population density is higher compared to scenario A based on the increase of industrial area. For the fist layer the same prevention method is chosen, the integrated flood wall.

  For the second layer though houses on stilts are not included in the package. Due to the higher density, apartment buildings are expected which are not easily constructed with an elevation. The same holds for the industries, they are also not constructed with an elevation. Therefore more attention should be given to the urban planning of the township itself with the main focus on the drainage system. In a high populated area this should be the main focus for the spatial planning layer in the multi-layer approach. If blockage of such systems occurs they could cause serious hindrance for traffic through Dala.

  For the third layer an optimum evacuation plan is added to the package. The reason that the optimum variant is chosen instead of the medium evacuation that has been chosen in scenario A is also related to the higher density. It will be harder to evacuate the area if an area is densely populated. Therefore it is wise to invest in a optimum evacuation plan. For the sandbags the same consideration has been made like in scenario A. They score relatively well, but evacuation is probably more effective especially if time is limited.

- *Scenario C*
  This scenario contains the least development of al four scenarios. There is probably less money available to protect Dala in this case since there are not that many changes compared to the current situation. Therefore the cheaper variant of the flood wall is chosen for this scenario. It is not properly integrated in its surrounding resulting in a less aesthetic attractive prevention measure.

  For the second layer, spatial solutions, houses constructed on stilts should be implemented. In the current state most houses are already constructed on stilts and if the area is barely developing, this measures should work good enough.

  In the third layer, crisis management, a minimum evacuation plan is advised. Since not much money might be available in order to construct the flood wall with the desired level, chances of flooding could be higher compared with the other scenarios. Therefore an evacuation plan should be implemented. The simplest variant should be sufficient for Dala in this scenario and is also the cheapest option. Sandbags are also advised to be implemented in this scenario since the flood wall might not be constructed sufficiently to prevent flooding against extreme high water levels. Therefore sandbags might compensate for that.

- *Scenario D*
  This final scenario is mainly determined by the increase of industrial development. For this

scenario the prevention will also be done by an integrated flood wall like has been done in the first two scenarios.

For the second layer in the multi-layer safety approach, an integrated drainage system combined with well developed urban planning should be sufficient to make sure water can be transported out of the area. Although urban planning is not one of the alternatives proposed, is is very important that once an area will drastically change attention is given to the urban planning combined with solutions for spatial planning. Once these solutions are added into the urban planning it will not cause trouble afterwards, in the case these kind of solutions are being implemented in later stages.

Since the area will develop into a industrial zone instead of a residential zone it will consist mostly of industrial buildings. Therefore a different solution is proposed for the third layer in this scenario. Temporary defences will be applied on small scales. Not Dala as a whole will be protected from water by these barriers, only certain areas or buildings will be. Important buildings or factories that have a strategic location for protection will be protected. It is also possible that certain factories invest in temporary defences themselves, to protect them from flooding. Next to the temporary defences, a minimum evacuation package is used to evacuate the area in case the temporary defences fail to work properly.

To summarize the chosen packages an overview is given in the table below.

	Scenario A	**Scenario B**	**Scenario C**	**Scenario D**
Layer 1	Integrated flood wall	- Integrated flood wall	Traditional flood wall	- Integrated flood wall
Layer2	Drainage system Houses on stilts	Drainage system	Houses on stilts	Drainage system
Layer 3	Evacuation medium	Evacuation optimum	Evacuation minimum Sandbags	Evacuation minimum

Table 13.4: Overview of suggested solutions per scenario

14 | Phase 4: Implementation

In this chapter an advise is given on the implementation of the alternatives in Dala. Dala has four different scenarios depending on population growth and development of industries. This resulted in four packages who are analysed below. After the analysis a strategy is made to implement the alternatives as a no-regret solution.

14.1 Analysing the packages

To be clear about the solution packages made in chapter 13, they are repeated in the table below.

	Scenario A	**Scenario B**	**Scenario C**	**Scenario D**
Layer 1	Integrated flood wall	Integrated flood wall	Traditional flood wall	Integrated flood wall
Layer 2	Drainage system Houses on stilts	Drainage system	Houses on stilts	Drainage system
Layer 3	Evacuation medium	Evacuation optimum	Evacuation minimum Sandbags	Evacuation minimum

Table 14.1: Overview of suggested solution packages per scenario

In every scenario it is advised to build a flood wall. In scenario A, B and D an integrated flood wall and in scenario C a traditional flood wall. So the alternatives for layer 1 are quite similar. In Layer 2, spatial solutions, drainage systems and houses on stilts are includes in the packages. Scenario A has both, scenario B and D have a drainage system and scenario C has houses on stilts. Furthermore every package includes an evacuation plan. Scenario C and D, including low population growth, have a minimum plan. Scenario A and B have more extended evacuation plans. Only scenario C has an extra measure in layer 3 namely sandbags.

14.2 Future adaptation strategy

The goal is to develop a strategy for the future protection of Dala in such a way that measures are taken fitting the future scenarios that are still likely to occur. In the start phase of the project all four scenarios should be included but after some time maybe one or more of the scenarios can be written off.

Due to the rapid changes expected in Dala it is important to have a look at the development of the area often. It is recommended to include a decision moment every two years at least. Sometimes a shorter time period in between decision moments is needed, like in the case of drastic changes. One of these changes could be the construction of the bridge between Yangon and Dala. This will influence the development towards one of the scenarios and therefore the strategy adaptation. At every decision moment it is important to consider the actors. The key players should always be involved. Attention should also be given to the subjects and the context setters. See figure 11.14 for an overview of all the actors.

Since a flood wall is included in all four packages this measure can be implemented from the beginning. If after some time it is clear scenario C is not going to match the future the flood wall can be integrated. In the beginning the flood wall will protect current Dala township and can be extended later if Dala township will stretch out.

Another measure that can already be taken from the beginning is an evacuation plan. A minimum evacuation plan is necessary for every scenario so this can be implemented. Potentially this plan can be extended to a medium plan if scenario A and B are most likely to occur or even extended to an optimum plan if scenario B will turn out to match the future.

15 | Conclusion Dala

In the introduction of this case study it has been described that Dala is likely to become an area where flooding will be a big problem. Consequently, the following research question has been formulated:

What are suitable measures to make Dala flood proof?

To conclude, Dala can be made flood proof for all four scenarios. For each scenario a package has been developed. Some similarities can be found within these four packages, but also large differences are found due to the influences of future developments on Dala. The advised measure in layer 1 is always a flood wall, whatever future scenario unfolds. In layer 2 is described that a good drainage system is of high importance, possibly in combination with building houses on stilts. Solutions in layer 3 range from optimum to minimum evacuation measures, depending on the type of developments in Dala, sometimes in combination with temporary defences. A detailed adaptive strategy for the implementation will be necessary in order to steer the development of the type of solution. This is important due to the rapid changes in this area. Having decision moments every two years would be wise.

This conclusion follows from the conclusions of the four phases of which the framework consists. The main conclusions of the each phase has been given below.

Phase 1: Analysis

Since the problem owner is the government, key players with a high level of interest and power in the decision making process will be: the Ministry of Social Welfare, Relief and Resettlement, the Irrigation Department, DWIR, regional authorities (YCDC) and local authorities. For Dala it is of importance to keep several other organisations and ministries satisfied and especially the Myanmar Port Authority should be regarded as a 'sleeping dog'.

The flood risk analysis has shown that the prevention measures are very important to reduce the risk of Dala. The area of Dala floods easily as there are only a few current measures and an increase of the population will increase the risk largely.

Little information about current evacuations is present. Some information has been retrieved about the evacuation during Nargis, but it is still very limited. It is advised that, if there really is no evacuation plan present, there should be at least a minimum evacuation plan.

The future scenario analysis is of high importance for the case of Dala, as it is expected that Dala might grow rapidly. The two critical uncertainties that have been found are the development of industries and the population growth. The ranges between the four developed scenarios are quite wide.

Phase 2: Development of alternatives

Within the three layers of the multi-layer safety approach several alternatives have been developed to make Dala more flood proof.

Phase 3: Assessment

As a result of a multi-criteria analysis, four packages of measures have been chosen, one for each future scenario. These packages are shown in the table below.

	Scenario A	**Scenario B**	**Scenario C**	**Scenario D**
Layer 1	Integrated flood wall	Integrated flood wall	Traditional flood wall	Integrated flood wall
Layer 2	Drainage system Houses on stilts	Drainage system	Houses on stilts	Drainage system
Layer 3	Evacuation medium	Evacuation optimum	Evacuation minimum Sandbags	Evacuation minimum

Table 15.1: Overview of suggested solution packages per scenario

Phase 4: Implementation

Because of the variations within the four packages a good adaptive strategy should be implemented. Decision moments should be included at least every 2 years. Some measures could already be taken, like implementing a flood wall and a minimum evacuation plan can already be implemented.

16 | Recommendations Dala

For the case of Dala some case specific recommendations have been done below. These recommendations have been treated with their corresponding section and some general remarks have been made.

16.1 General

Dala is located at a very complex location, where two rivers come together and where tide also plays a major role. The influence of river fluctuations have not been regarded in this case. This is partly because of the lack of data about upstream river water level influences. Tide dominates daily water level fluctuations and this makes it hard to find data about the river influences. For this case study it was assumed that the storm surge levels have a larger impact regarding floods. For further research on Dala it might be of interest to have a look at the water levels near Dala when heavy rainfall occurs upstream.

An interesting study that could be done for Dala is setting up a `Delft-3D` model of port of Yangon. With such a model one can impose different situations, such as storms at the ocean or high river discharges, and one can see how high the water levels will be in the port of Yangon. Furthermore this might also give an insight on the sediment transport rates and what really happens at the river bend near Dala. This is of high importance for the navigability of the port.

16.2 Phase 1: Analysis

Hydrology

The measurements at Monkey Point and Elephant Point give good insight about the tidal water levels in the Yangon Port. Still the data needs to be improved in order to do better and more accurate calculations and the key lies in the time of the measurements. Tides should be measured for a longer period, such that a definite (or seasonal depended) mean sea level (MSL) can be determined. Furthermore longer measurements also give good indications about spring tides.

Flood risk analysis

Similarly as for the case of Nyaungdon it is advised to have more accurate data, such that an extreme value analysis can be undertaken with more realistic results.

Dike breaches might also be of interest in the case of rapid growth in Dala. The area has a bathtub shape and it might be interesting to see where the water flows to and how much damage occurs in case a dike breaches at different locations.

It is recommended to play with many more adaptations in the `Excel`-sheet. It is possible to change the amount of houses and their values and then it can be seen how the total risk increases for Dala. One can also play with the probabilities of the flood scenarios; how much is the total risk reduced when increasing the probabilities? What probabilities are preferable and does this correspond to realistic height of the dikes?

Evacuation process analysis

As stated in the evacuation process analysis, there was little information available on evacuations for this report. In order to know more about the evacuation process and if there is any evacuation plan more data should be found. This is difficult as it is unknown if there is any plan and for this report there has not been a decisive answer to this question.

16.3 Phase 3: Assessment

As described chapter 13 the cost-benefit analysis has been neglected for the case of Dala. Since some expensive alternatives have been suggested as solutions for the flooding problems in Dala it is recommended to still do this cost-benefit analysis. Only then one can say for sure if the solution is also a realistic solution.

16.4 Phase 4: Implementation

Besides the adaptive strategy, which has been implemented for the case of Dala, it could be very interesting to see how the solutions that have been found in phase 3 would be spatially implemented in Dala. In order to do this properly one does need a lot of information. Just to start, one has to know everything about the soil conditions near the waterfront. Furthermore the hydraulic data should be elaborated in order to design a proper flood wall. Regarding the spatial solution one needs to know more about the willingness of people to elevate their houses. If a drainage system is suggested as a solution one has to know how this could work properly and how this can be adapted in the design of the town. Regarding the evacuations it might be of interest to see how one can prevent the creation of bottlenecks in the system.

Overall it can be concluded that for the implementation phase many more data is needed. It will take a lot of time before such a detailed implementation can be realised.

17 | Data

In this report it is frequently mentioned that data is inaccurate or occasionally lacking. It is very important for the reproduction of this framework or for further research that data would be more exact and reliable. Therefore this chapter is specially added and gives an overview of:

- Used data
- More (accurate) available data
- Lacking data

This overview is based on the list of available data in Myanmar written by Hasman (2014). His thesis also includes data for water management related subjects. If that kind of data is required it is wise to take a look at his list of retrieved data. The overview of our retrieved data is shown in table 17.1 in which the data is described by following six aspects:

Source The data can be obtained by the responsible departments, branches or organisations. The names of the department, branches or organisations could be so long that abbreviations are used. These abbreviation are fully written out below:

- DMH - Department of Meteorology and Hydrology
- ID - Irrigation Department
- AD - Agricultural Department
- HB – Hydrology Branch
- YCDC - Yangon City Development Committee
- JICA - Japan International Cooperation Agency
- MIMU - Myanmar Information Management Unit
- USGS - United States Geological Survey
- NTT - NTT Data Corporation
- *other* - It is noticed that the data is present, but it is not clearly identified which organisation, branch or department is the author.

Quality The quality defined as the reliability and accuracy of the data. It also includes the legibility of the data, since some of the data is only available in the Burmese language. Moreover if the accuracy of the data is known, then this value is displayed within brackets.

Quantity The quantity of the data refers to the amount of available data. To do extended and/or further researches more data of some type is needed because then the reliability and accuracy will increase. For instance, to determine the probabilities of occurrence a larger amount of data is preferable.

Accessibility The accessibility is defined as how easily data can be obtained.

Impact The impact refers to how the specific data will affect the final result of the report. So by using this data the result will become more accurate and reliable.

Costs The costs are defined as the price of purchased required data. Furthermore *free* is displayed if the data is unpriced and *unknown* will be display if the price is unknown.

The aspects quality, quantity, accessibility and impact are valued with minus and plus signs. Where ++ is very good, 0 is neutral and - - is very bad.

Data type	**Source**	**Quality**	**Quantity**	**Accessibility**	**Impact**	**Cost**
			Used data			
Water level river (Nyaugdon)	ID	+	0	- -	++	free
Water level river (Nyaugdon)	DMH	+	+	0	+	7 €/(p.l.p.y)*
Tidal water level river (Dala)	JICA, YCDC	+	-	+	+	free
Storm surge level (Dala)	JICA, YCDC	+	-	+	++	free
Digital elevation maps (`SRTM`)	USGS	- (30m)	++	++	++	free
Satellite images (`landsat`)	USGS	+	+	++	++	free
Evacuation proces (Nyaundon)	ID	0	-	- -	+	free
Humanitarian organisation (regional)	MIMU	+	+	++	0	free
			More (accurate) available data			
Water level river (Irrawaddy)	DMH	+	+	0	++	7 €/(p.l.p.y)*
Water discharge (Irrawaddy)	DMH	+	0	0	+	7 €/(p.l.p.y)*
Sediment discharge (Irrawaddy)	DMH	+	0	0	0	7 €/(p.l.p.y)*
Actual rainfall	DMH, ID	+	+	0	+	7 €/(p.l.p.y)*
Expected rainfall	DMH, HD other	0	0	0	+	7 €/(p.l.p.y)*
Digital elevation maps (`AW3D`^{TM})	NTT	+ (5m)	++	0 0	+	1.7 €/km^2 **
Digital elevation maps (`AW3D`^{TM})	NTT	++ (0.5m-2m)	0	0	++	43.3 €/km^2 **
Soil characteristics	AD, other	0	-	0	+	unknown
Impact maps	MIMU	-	0	++	-	free

Table 17.1: Overview of used data and more (accurate) available data

*p.l.p.y means per location per year

*This data can only be obtained on request and if the purchase contains a substantial surface.

Lacking data

For a complete evacuation process analysis a transport model should be constructed which should be used for plan studies. However to build such a transport model more (extensive) data is required of the infrastructure and traffic demand. Unfortunately this data is currently not present in Myanmar. In addition, table 17.1 shows that data is not present for soil characteristics. As a result the risk analysis is simplified, making it difficult to implement the alternatives.

18 | Evaluation of framework

In this section an evaluation of the framework is done. With the help of each criterion, the framework is evaluated. As is stated before in section 2.3 it is difficult to quantify these criteria, therefore these criteria have been evaluated in words.

- **Elementary**
  The framework itself is rather elementary. There is tried to limit the use of jargon. Still some parts of the analysis can be seen as difficult or too detailed. An example is the flood risk analysis, which is at first sight rather difficult. Understanding this flood risk requires some preliminary knowledge. However if the analysis was even more simplified, the results would been affected.

- **Transparency**
  The transparency of this framework can be considered to be rather high. All the steps that should be taken in the framework have been written down and can be reproduced. Still there are some limitations, but this is caused by the limited accessibility of certain documents. Furthermore some analyses might need a certain program that have limited transparency.

- **Objectivity**
  For the greater part of this framework one can follow the steps from an objective point of view. However, there are some parts where this does not apply. In the flood risk analysis a stage damage function, see figure 2.10, was created for Myanmar, but this has not been done objectively. The interpretations of potential damage in Myanmar should be done by local experts.

  Furthermore the evacuation analysis also has a subjective aspect, namely that one has to conclude if the current evacuation plan is sufficient enough or not. Local representatives might have other standards regarding evacuations.

  The most subjective analysis is the multi-criteria analysis, especially the determination of the weight factors. Grading how important certain aspects are, is the main part of the analysis. This objectivity could be increased, if for example the grading of the criteria is based on the opinion of local experts. In order to enable adaptations for follow-up studies to these gradings the multi-criteria analysis has been done in an `Excel`-sheet and this ensures that the framework itself is objective.

- **Flexibility**
  As this framework has only been applied for two cases studies, it is difficult to evaluate this criterion. All that can be said for the two cases studies is that the framework has been sufficiently flexible. The question remains if the framework can also be easily be adapted for different types of areas, like for example coastal regions.

- **Use of existing methods**
  In almost every analysis, existing methods have been used. Not every time the methods are

explained but if this was the case, it is clearly indicated.

The multi-layer safety approach is rather new, but it is implemented and used in the Netherlands. The "Room for the River" project is a good example where this method has been put to use. Using this method in a country like Myanmar does require a different perspective. Measures that are common in the Netherlands might not be realistic for Myanmar and also in Myanmar measures are present that barely occur in the Netherlands, like constructing on stilts.

The method for Evacuation analysis has been created for Myanmar. The method for this research is adapted by combining multiple methods with each other, and adding common sense. Apparently an evacuation process analysis was not yet existing or was not accessible for this research.

It can not be avoided that some methods have to be adapted in such a way that it fits for study cases of Myanmar. It is of importance that these adaptations do not influence the main function of the method that is used. For this framework the main ideas of the methods have always been taken along and it can be said that for this framework this criterion is largely satisfied.

- **Based on research**
  This framework fits the criterion that it should be based on research, with the exception for the assumed data. Many of the analyses are based on data found from research. The problem is that much of this data is still lacking in Myanmar and this means assumptions have to be made when following this framework. If one has a location with little to no data it can not be assured that this framework gives a solution based on good research.

What can be concluded by analysing these criteria, is that the approach of the framework is sufficient. What needs to be noted is that this framework is only tested at two cases, so an other cases can affect the score of each of the criteria.

19 | Conclusion

In this report the question that has to be answered is:

What is a good method to make several regions in Myanmar flood proof?

The objective, to answer this question, is to make a general framework, that when run through, one can find a suitable measure to make a particular area in Myanmar flood proof. It can be concluded from the two test cases that the framework works; when the framework is run through, it provides a measure or a package of measures for a particular scenario against floods. Whether these measures are the most suitable to make an area flood proof should be checked in more extended follow-up studies. The package for Nyaungdon includes optimisation of dikes, sandbags and a medium evacuation plan. For Dala the packages consist of a flood wall, spatial solutions and different kind of evacuation plans. However whether this framework is a 'good' method is hard to conclude, as that can only be tested if it is compared to other methods.

What can also be concluded is that the research goals are largely achieved. The framework is reproducible and an overview is given from where data can be retrieved. The framework has only been tested on two areas and this is not enough to conclude if this framework is applicable for several regions in Myanmar. Therefore more extensive research has to be conducted on multiple different locations. Besides, the criteria for the framework that are stated in the beginning of the report are met. From chapter 18 it can be concluded that the framework is elementary, transparent, objective, flexible, based on existing methods and based on research.
To conclude, the framework that is created, is a guideline which can be seen as a method to find a solution to make an area in Myanmar flood proof for several scenarios.

20 | Recommendations

These recommendations are related to the framework. The recommendations regarding the cases have been discussed within the cases themselves.

In general it is recommended to continue the feedback loop that is implemented within the structure of the framework. As this framework has only been tested with two different case studies it can be said that this framework has not yet been tested intensively. The framework should be put to test with more and especially different case studies. Case studies that would be of interest could be coastal regions, because some aspects of these regions have not been tested in the framework. Furthermore evacuation plans in lower delta regions might be an interesting subject.

Some recommendations can be done regarding the assessment phase. As stated before, the cost-benefit analysis has not been elaborated extensively in the framework. In the case studies they have even been neglected, due to a lack of data. It is recommended to elaborate this analysis for the assessment, as this might give a better insight on possible solutions in relation with the results from the multi-criteria analysis. The results of the mult-criteria analysis might seem good, but if it is not financially realistic it should of course not be chosen as the final solution. Furthermore the criteria of the multi-criteria analysis should ideally be assessed by experts on the subject of Myanmar.

The implementation phase can be elaborated far more in detail. The big restraint on the implementation phase in this framework has been the lack of data and time for the case studies. This part of the framework could be expanded when more data becomes available and when more cases studies are undertaken. This is again a reason why the feedback loop should be continued. In the end it would be preferable if the implementation phase can act as the coupling element between the framework and further research on the realisation of the solution that has been found.
As a final notion it could be questioned if this method is suitable to be used by the civilian government. It is therefore recommended to elaborate this framework in more detail before the government can make use of it. Out of experience it can be stated that the government likes concrete developed ideas which have not been generated by this framework. Besides, it is recommended that a team, composed of people from all the different departments within the ministry, should elaborate the framework themselves since the responsibility of floods is separated over all these different departments. By doing so the framework could be adjusted such that it will be improved for the applicability in Myanmar.

A | General Framework

A.1 Framework proposal

A.1.1 Framework citeria

The criteria of the framework have been determined by using an objective tree. This is an analysis method used to define a high-level and abstract objective in terms of more specific lower-level objectives. The objective tree is depicted in figure A.1. The resulting criteria are listed and clarified in this section.

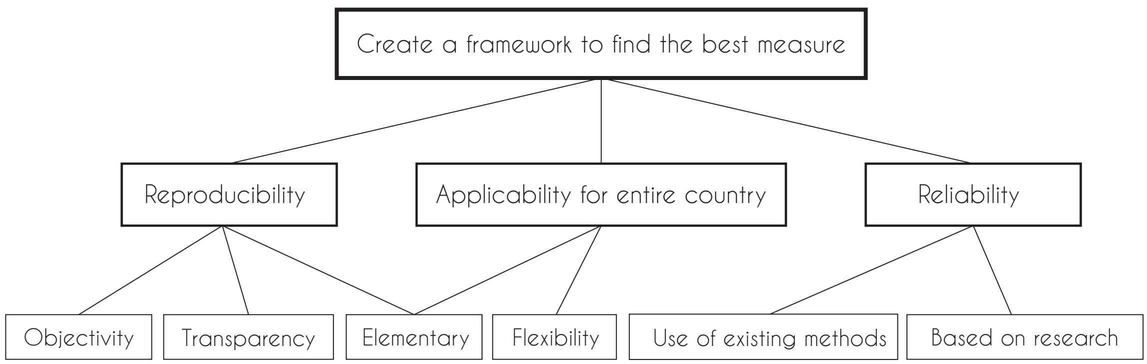


Figure A.1: Objectives tree framework

The second level-objectives are defined as follows:

- **Reproducibility**
  The framework should be constructed in such a way that it is easy to reproduce by other students and engineers in the future. All involved parties when it comes to decision making about floods should be able to run through the framework and obtain the desired outcome.
- **Applicability for the entire country**
  As described in the framework goal, the framework should be applicable to the entire country of Myanmar. This is hard to accomplish due to the variability of flood-related problems. It is something though that has to be strived for in order to cover as many areas as possible.
- **Reliability**
  The framework should have the ability to perform properly and have a reliable outcome.

The lowest-level objectives of the framework form the criteria of the framework. Their definitions are as follows:

- **Elementary**
  The framework should be as simple as possible, including only the essential parts to function properly and excluding superfluous details.

- **Transparency**
  The framework should operate in such a way that it is easy for others to see what actions have been performed. All steps have to be explained in detail without withholding information.

- **Objectivity**
  To obtain a reliable outcome, all the phases of the framework should be conducted objective. Individual biases, interpretations, feelings and imaginings should always be excluded.

- **Flexibility**
  To ensure the applicability of the framework to different cases it should be flexible, hence adjustable. Ideally it could cover all flood related problems in Myanmar.

- **Use of existing methods**
  To increase the reliability of the framework existing methods should be used wherever possible. These methods have been used frequently and their efficacy has been proven. Examples of these methods are an objective tree or a multi-criteria analysis.

- **Based on research**
  In order to be reliable the framework should be based on scientific data as much as possible.

A.1.2 Actor analysis

An actor is a social entity, person or organization, able to act on or exert influence on a decision (Enserink et al., 2010). Or in other words: actors are those who have a certain interest in the system or have the ability to influence the system both directly and indirectly (Enserink et al., 2010). This analysis is useful to understand which actors are critical for the Governance and always should be involved in every decision step.

To make an actor analysis of the situation in Myanmar is really complex (MCRB, 2015). The mean reason is the large and complex history of Myanmar and the consequences it still has in the current political situation, see section refsec:historymyanmarintroduction. The military has dominated in the past 50 years in Myanmar. How much influence the military in the governance still has is hard to define. The ethnic diversity has resulted in many perspectives on the role of the government (MCRB, 2015). This makes it hard to determine which (political) actors are playing a part concerning preventing floods.

This actor analysis is split up in 3 different parts. In section A.1.2.1 an overview is given with all the actors involved concerning flooding. In section A.1.2.2 a formal chart is exhibited including the formal task, authorities and relations of actors in-between. In section A.1.2.3 all the actors are classified concerning based on the level of support/interest and power.

A.1.2.1 Overview of all the actors involved

In table A.1 an overview of the problem formulation is given of each actor concerning flooding in Myanmar. The table supports a systematic comparison of the problem formulation and helps to identify similarities and differences between actors (Enserink et al., 2010). For each actor their interest, desired situation, expected situation, the causes and possible solutions are described.

	Interest	Desired situation/objectives	Expected or existing situation	Causes	Possible solutions / sources
Military in Myanmar	Retain power.	Protect the 'Myanmar' people from floods.	Flood keeps damaging the people of Myanmar and their belongings.	Lack of flood protection.	Have influence on the decision for effective flood protection.
Irrigation Department	Responsible for Irrigation.	Responsible for well function river banks (including dikes, dams).	The river banks are not sufficient enough to prevent floods.	Lack of technology (Steijn et al., 2015).	Seek for cooperation with other governments.
Department of Water resources and Improvement of River systems (DWIR)	Providing/ maintaining flood protection measures (Department of Water resources and Improvement of River systems, 2014), navigational guidance (Modins, 2002) and water quality.	Good flood protection measures, keep the rivers navigable and good water quality in Myanmar.	The current flood protection measures are not sufficient and new measures can have an influence on navigability	Lack of flood protection and for example a dam (as a new measure) can prevent boats from sailing.	Has influence on decisions concerning flood protection and navigability.
Department of Meteorology and Hydrology (DMH)	Proving information to reduce disaster risk (Wright, 2008).	Have a sufficient warning and weather forecast system.	The hydraulic data is now not sufficient enough.	Lack of capacity and equipment (Hammond, 2015b).	Cooperate with departments of other countries to find ways to gather data.
Department of forestry	Responsible for forestry and logging sectors (Kroon & Rip, 2015).	To keep the amount of forest/mangroves at a certain level (also prevent floods).	The amount of forest will decrease and therefore the natural flood protection will decrease as well.	By illegal cutting down forest	Increase the supervision and awareness of the danger of cutting down trees.
Ministry of social Welfare, Relief and Resettlement	Responsible for overseeing disaster management	To prepare the population what to do when disasters happen.	The behaviour of the people during floods is not the best or safest one.	Because of a lack of knowledge.	Help to train the people.
Regional authorities (region, state or self administered area)	To guarantee the welfare of the region (Ocha, 2016).	To have as little as possible damage to the population material/ immaterial.	Flood will damage the region and let the population suffer	There is no permanent flood protection.	Providing food, water, cash, construction materials when damage occurred.
Local authorities (Union Territory, Zone, Division)	To guarantee the welfare of the town.	To have as little damage to the population material/ immaterial.	Floods will damage the town.	There is not a sufficient flood protection.	Care for emergency packages with medicines, water and food.
Population affected by flood)	To live in a safe welfare area.	Minimize material/immaterial damage from flooding.	Floods cause that materials get destroyed and people will get sick.	There is not a sufficient flood protection.	Care for emergency packages with medicines, water and food.
Local businesses in risk area (farmers)	To make a profit/living.	Get a guaranteed certain income.	The harvest will probably be damaged.	Due to flooding the harvest will drown.	Protest to collect money for the lost harvest and protest for awareness against flooding.
Universities (MMU, YTU)	Increase the knowledge in science related subject.	Increase the knowledge of flooding.	The current knowledge of hydraulic analyses is weak.	Lack of sources to gather information.	Cooperate with other universities and companies globally.
Foreigners multinationals (Heineken, Coca cola, . . .)	Make a profit in Myanmar.	Supports flood relief and rebuilding in Myanmar(Staff,2015).	Potential buyers/employers are in 'danger'.	Due to flooding.	To train and invest in people to get their business back.
companies in water sector (Boskalis,Arcadis, HKV..)	To make a profit in Myanmar.	To make Myanmar flood proof and support local economy.	Flood protection measures in Myanmar are weak and navigability not guaranteed.	The Myanmar water sector have a shortages of money/ knowledge.	To find flood protections solutions that are sufficient. To make Myanmar more stable.
Humanitarian organisations (Worldbank,NGO.)	To help the population in Myanmar.	To mitigate the damage of flooding.	Without a permanent solution mitigation is needed.	Flooding is causing damage.	To share food, water and shelter to the suffered population.

Table A.1: Problem formulation for actors concerning flooding in Myanmar

Military

In this analysis there is chosen to let the 'military' be an individual actor because of its past, its huge influence in governance and probably because of its contrary thinking concerning flood affected minorities in Myanmar. The exact influence of the military is hard to define. The military can in the current situation be seen as a political party with his members in every ministry of the Governance. As can be seen in section 1.2 the military had a huge influence over the past 50 years in Myanmar. Although the elections in 1990, it is still not a democracy, but a civilian government that is progressively gaining respect (Richmond et al., 2014). It is a civilian governance because of the huge influence the military still has. Although the party of National League of Democracy (NLD) won the elections, currently 25 percent of the parliamentary seats and a number of key government positions are reserved for members of the military (Duggan, 2016). This will give the military effectively a right to veto over any proposal, as every amendment must have at least 75 percent of votes of both houses (Duggan, 2016).

Minorities/Population affected by floods

Suu Kyi, the leader of the National League of Democracy (NLD), wants to reunite the minorities and plans peace conferences to stop the war (Straaten, 2016). Sometimes people of influence could still think contrary and maybe this will have an effect on the decision which alternative will be chosen to make Myanmar flood proof. This is hard to take along in the analysis, because it is unpredictable and unsure. Therefore, no distinction is made between the minorities and the rest of the people of Myanmar.

Ministry of Transport and Communication

The ministry of Transport and Communication plays an important role in the government concerning flooding. It leads the committees deciding on flood protection in the government and has two departments that have an power and interest in solving problems concerning floods. These departments are the department of Meteorology and Hydrology (DMH) and the department of Water resources and Improvement of River systems (DWIR). Especially the DWIRS works on flood protection measures.

Regional and local authorities

Here is a distinction is made between local and regional authorities. In reality it is a bit more complex in the Republic Union of Myanmar. Myanmar is subdivided into several regions, states and even self-administered areas with policy makers. In this analysis these are all regional authorities. The states and regions comprises some districts, these districts have their own management as well and are therefore self-regulated on most local level. These are the local authorities.

The districts can be further divided into townships in the urban areas and village tracts in rural areas. Village tracts consist of groupings of villages. (Hilden et al., 2016). The townships and villages are not self-regulated and therefore not an individual actor in this analysis.

A.1.2.2 Formal chart

In the diagram below the most important relations between actors are shown. There is chosen not only to describe the formal relations, but also the informal ones. A dashed rectangle means the actors belong in the same shared group. A single-headed arrow indicates a hierarchical relationship, a two sided arrow indicates a representation of a relationship (Enserink et al., 2010). The most striking relations or shared groups between actors will be explained in the text below.

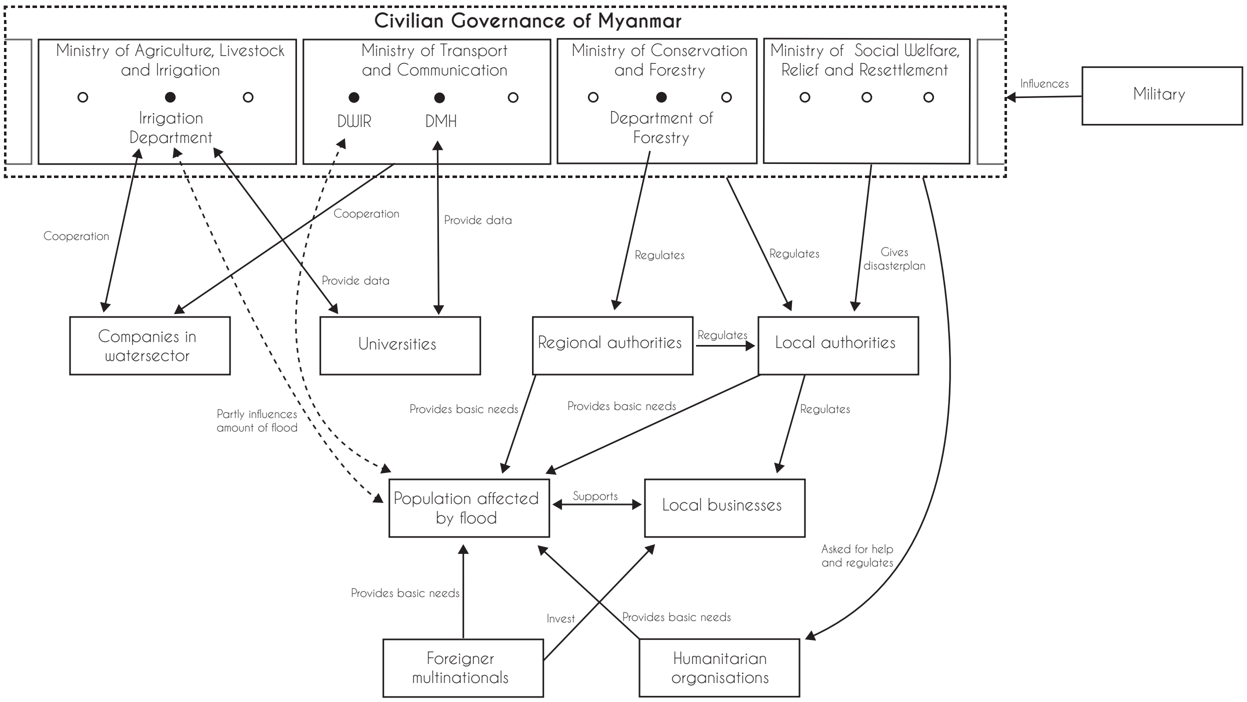


Figure A.2: Formal Chart

Maybe the most striking relationship are the dashed arrows from the Irrigation Department (ID) and the Department of Water resources and Improvement of River systems (DWIR) towards the population affected by flood. These departments can in some situations have an influence on the amount damages caused by floods. T his influecne can affect the population as well positive and negative. Positive because they are responsible for flood protection like the height of dikes and dams (ID) and are responsible for protection measures on river banks (DWIR) next to that they can reduce flood impact by regulated overflow of dams (ID). This is negatively as well because the over flown areas will suffer from this. For example, in 2015 the ministry was forced to release water from a number of dams and reservoirs to prevent overflowing. The wave of water resulted in a flash flood that as a consequence flooded some parts of small township (Hammond, 2015b).

Another shared group that needs explanation is the civilian government. There is chosen to make an special box with an arrow for the military because as described above. It still has a lot of (striking) influences. The civilian government consist of different ministries with their own tasks and responsibilities. In this figure only the ministries are shown that have an influence on flooding in Myanmar. The ministries are subdivided into several departments. These departments have more specific tasks and specific responsibilities. Also here, only the departments that are important concerning flooding are shown. Although all these governmental organs represent one governance, the responsibilities between departments and ministries are unclear, not well tuned. It is known that even different departments of different ministries are responsible for the same job, examples of inefficiency are the following; the department of Metrology and Hydrology is measuring the rainfall in Myanmar, but so does the department of Irrigation (Commandeur, 2016). They each belong to a different ministry. Another example is that several ministries criticize one another; the department of Metrology and Hydrology is responsible for weather and warning forecast but gets criticized of it working methods by the Ministry of Social Welfare, Relief and Resettlement (Hammond, 2015b). The Ministry of Social Welfare has to make a better and more sustainable disaster plan based on these weather and warning forecast data.

Another actor that stand out is 'Population affected by flood'. Although many actors are providing help to it, this has been different in the past. According to van Meel et al. (2014) people on the village level are not used to expect service delivery from the government. In 2008 there was also a lot of criticism from humanitarian organisations that they were not able and allowed to help after the disasters from flooding. It changed however and in 2014 the government asked the organisations for help.

A.1.2.3 Power and interest of actors

A tool to visualize interdependencies is to make use of a power/interest matrix (Bryson, 2004). Such a matrix provides a quick overview on the total actor environment and indicates how actors should be treated. Every actor will be categorized in one of the four possible groups based on power and interest. Whereas the plusses and minuses are used to indicate if an actor supports or opposes the main interest and objects of the governance of Myanmar concerning floods (Enserink et al., 2010). For now the plusses and minuses are given without concerning alternatives. The alternatives may change the amount of support/opposes on the interest and objects. The power will be determined by the amount of important resources an actor has and whether they are replaceable or not. The amount of interest will be determined by whether a decision concerning flooding influences the behaviour of the actor.

The four groups in the power/interest matrix are classified as crowd, subjects, context setters and key players (Enserink et al., 2010). One by one we will explain them below:

- Crowd: the actors who have minimal effect on the casus.
- Subjects: the actors who are highly interested but have a lack of power. The best way is to keep them informed.
- Context setters: the actors who normally don't have interest, but when involved, have high power. These actors should be kept satisfied. Their status of critical actor, due to the important resources, might give them the power for veto decisions. The one thing that should be prevented is that these 'sleeping dogs' will turn into 'barking/biting dogs'. This unwanted transition can be prevented through education and awareness raising activities (Enserink et al., 2010).
- Key players: the actors who have high level of power because they have important resources and are dedicated because of the high level of interest.

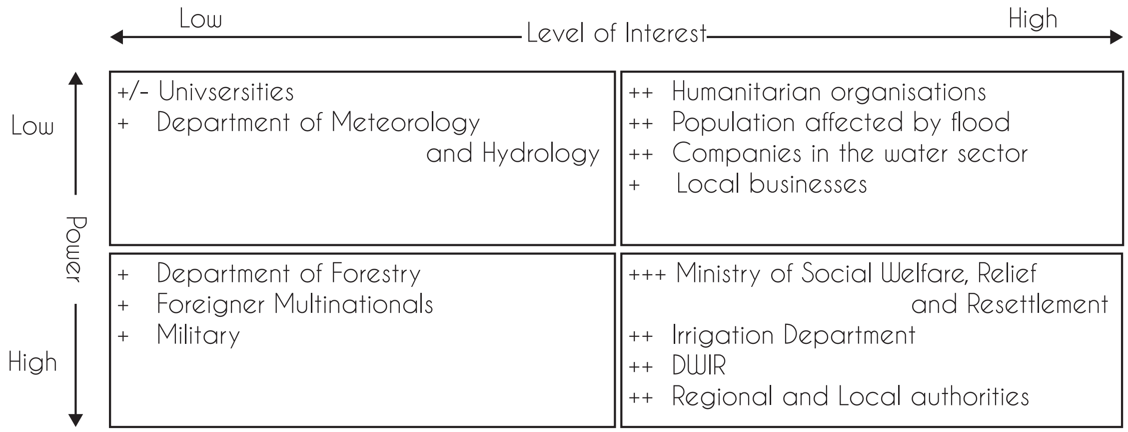


Figure A.3: Power interest matrix

Crowd

The Department of Meteorology and Hydrology is part of the crowd because it has no direct interest in floods and its power level is low. This department collects a lot of data that can be used for prediction purposes but it is not the only institute with data and is therefore replaceable.

Universities are researching floods and their causes. It is the task of an University to do independent research therefore it is supposed to be not supporting or opposing the main interest and objectives of the governance of Myanmar.

Subjects

Humanitarian organisations are highly supporting the flood resilience side of the flood related problems because their goal is to help the population as much as possible if needed. However their interests might be different compared to other involved parties since humanitarian organisations do not make a consideration between different aspects, they just help people in need. These organisations are powerful, but not in a direct way. They can put a lot of pressure on the government but they do not have power in decision making.

Local businesses are supporting the main interest and objectives of the government because they want to survive and want a good economy, so they do not want to be destroyed by severe floods. The local businesses will not always support the government because their first priority is with themselves and not the country as a whole. One of the possible local businesses that can be found a lot in Myanmar are the farmers, these farmers experience advantages of floods as well, besides all the negative effects, due to the drop of fertile soil on land.

Companies in the water sector have a lot of knowledge about water hydraulics, river bathymetry and the recorded floodings. Therefore they can have an influence on the protection and mitigation of floods but not directly because they do not have the power in decision making. The companies can give advice to the government on how to apply certain measures and they can work out plans in detail for the government. This can be done in corporation with, for example, the Dutch government.

Context setters

Context setters can be 'sleeping dogs' as stated above but they don't always are. In this case the department of forestry is not one of the sleeping dogs. This department is working actively on the prevention of the illegal logging. Hereby this department has a huge influence on flooding, the more trees are chopped down, the less water will be absorbed into the soil and therefore will flow directly into the rivers more rapidly. Minimizing the amount of chopped down trees will have a positive influence on the amount and impact of flooding. The reason that the department of forestry is counteracting the illegal logging is not only because of floods more downstream, there are more reasons like nature conservation and ecological diversity. The floods itself are not of interest of this department.

Foreign Multinationals and the military can be seen as 'sleeping dogs'. The multinationals and military will not interfere a lot in the flood problem, because they agree with the protection of the local people. Although if they are affected themselves, they will use their power to implement certain measures. This can have a lot of influence on the government and the local people.

A.1.3 Flood risk analysis

A.1.3.1 Economic damage assessment

The original stage damage function can be seen in the figure below.

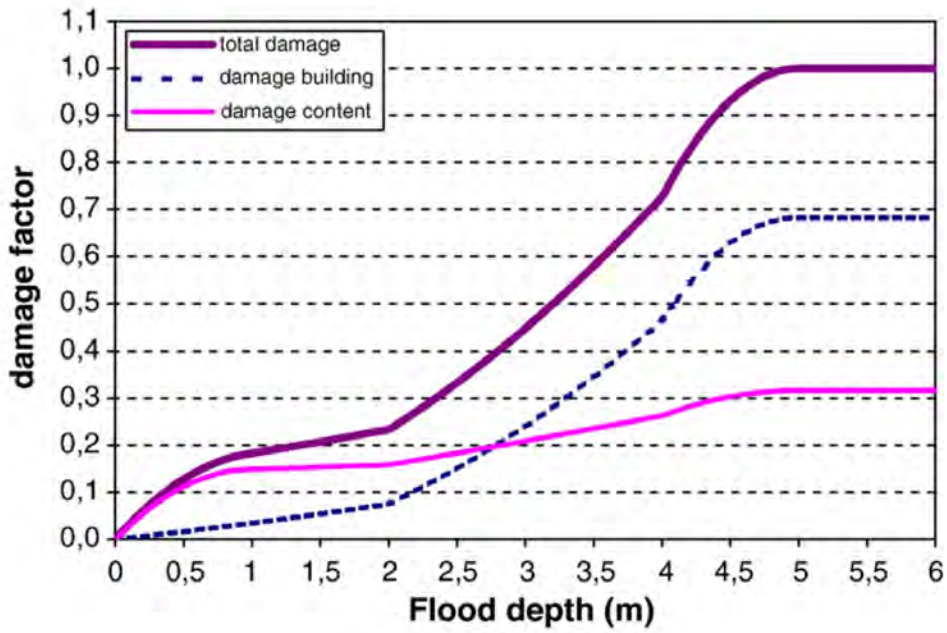


Figure A.4: Relation between flood depth and damage factor for houses, distinguishing between damage to building and house content (Jonkman et al., 2007)

A.1.3.2 Vegetation (rice)

For simplification of calculating with the vegetation it is assumed that vegetation will only consist of rice, which is one of the primary agricultural export product of Myanmar. Additionally a small calculation is made to give an insight in the monetary value of rice paddies in m^2:

Required
a) The current export price: $400 - 460 per tonne metric (Linn Aung, 2016).
b) Production of rice paddy: 4 ton per hectare(10,000m^2) (de Padau, 1998)

Calculation
The price of rice is assumed to be $450 per tonne metric equal to €400 per tonne metric. Multiplying by 4, which refers to the production of a rice paddy, and dividing by 10.000 results in a price of €0.16 m^2. With the assumption that the farmer received 60% of the total export price the monetary value of the rice paddy is €0.01 m^2

A.1.3.3 Fishery

Information about the monetary value (m^2) of fishery is difficult to obtain. Therefore is assumed that it will be 5 times the vegetation value which results in € 0.05 m^2. For a more reliable and accurate value further investigation is recommended.

A.1.4 Assessment criteria

The alternatives generated in the second phase of the framework have to be evaluated based on criteria. These criteria have been determined by using an objective tree, as described in sectio 2.7. This tree is shown in figure A.5. The main objective, efficient improvement for a flood prone area, can be found in the upper layer of the tree. From this, the lower layers can be derived with a set criteria and their desired direction as an outcome, which are marked red in the figure. These criteria are elaborated in this section.

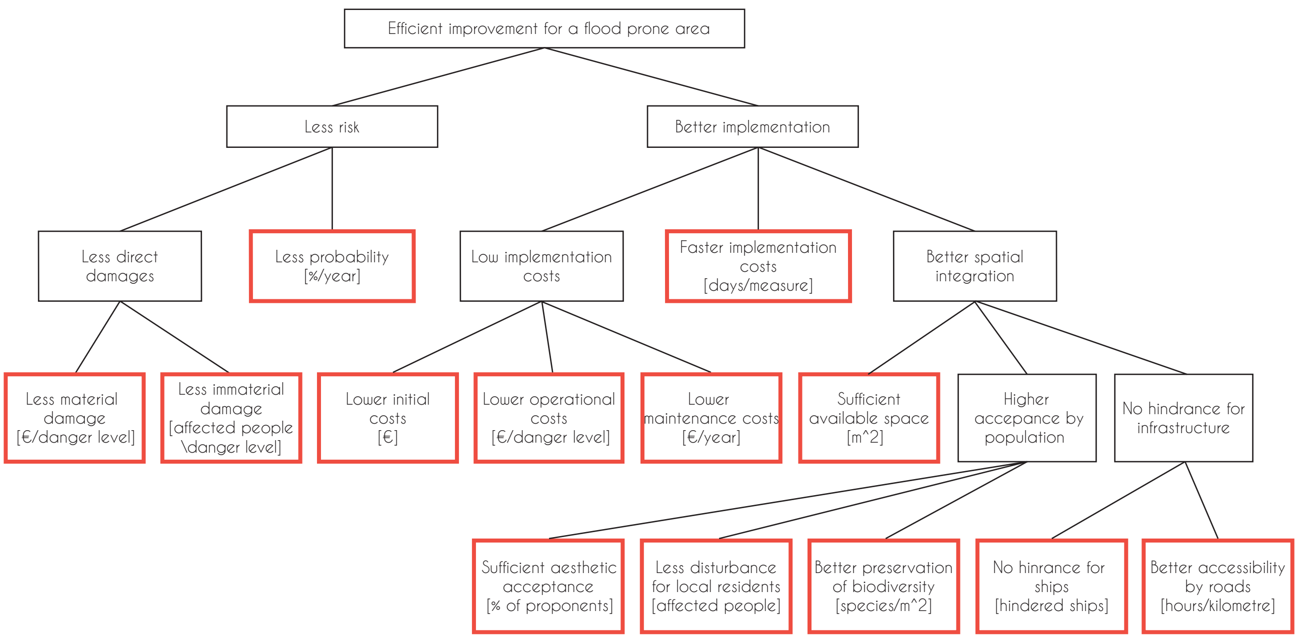


Figure A.5: Objective tree

A.1.4.1 Criteria

Material damage [Euro/danger level]
Material damage is defined as the damage that can be expressed in a monetary value. The damage to buildings and agriculture is material damage caused by floods. The damage is expressed in euro per danger level. The danger level is the water level at which a flood originally would occur.

Immaterial damage [affected people/danger level]
Immaterial damage is defined as the damage that can not be expressed in a monetary value. During a flood people can be affected, the affected people in this criterion are restricted by causalities.

Probability of flood occurrence [%/year]
The probability of flood is determined as to what extent a measure prevents a flood. The prevention measures found in layer one are especially designed to reduce the probability.

Implementation time [days/measure]

The time it takes to implement a measure is another criterion. This time can be important for the time scale on which the flood resistance or resilience is ready for operation. The unit scale is days per measure. Some measures have to be implemented once, which are mostly measures from layer 1 and layer 2. Others have to be implemented more often because they are only applied in case of flood. This are mostly the alternatives of layer 3: crisis management.

Initial costs [Euro]
The initial costs are the costs that are made in the initial phase. This are costs to start up the measure. Examples are the costs to build a dike or the costs of buying a temporary defence.

Operational costs [Euro/danger level]
The operational costs are the costs that arise in case of danger level. The crisis management alternatives score high on this criterion because action is needed every time a danger level occurs.

Maintenance costs [Euro/year]
Costs made during the lifetime of a measure to ensure its functionality.

Aesthetics acceptance [% of proponents]
A often underestimated criterion is the aesthetic acceptance of a measure. Although it might seem of negligible importance since it does not improve the flood safety, one should not underestimate its impact. A measure with a bad acceptance is very likely to have many dissidents. These can be inhabitants with low impact power, but these could also be urban developers who have great impact when it comes to decision making about the measures.

Disturbance to livelihood [affected people]
Preferably the livelihood of the habitants and workers in an area should not be affected by a measure. Examples that have the biggest chance to be disturbed by a measure in Myanmar are buildings within the boundaries of the dike profile, fishermen and farmers living outside the dike ring and other buildings located at the wrong side of the dike.

Preservation of biodiversity [number of species/m^2]
Biodiversity boosts a ecosystem productivity where each species, regardless of their size, all play an important role. A large number of plant species can result in a greater variety of crops and healthy ecosystems have a greater potential in recovering from disasters. In order to increase the acceptance of a measure, its important to take this criterion into account. A measure that does not effect the biodiversity at all will obtain a neutral score. Subsequently, negative scores will be given to measures that damage the present biodiversity.

Available space [m^2]
There should be enough space available in the design area to implement the measure. The amount of space needed varies significantly depending on the measure.

Hindrance for ships [hindered ships]
Preferably, the implemented measure should not hinder navigation. This is especially of importance in often navigated large rivers as the Ayeyarwady.

Access by roads [hours/kilometre]
Infrastructure is important for the accessibility of people and goods.

B | Case 1

B.1 Phase 1: Analysis

B.1.1 Hydrology

Year	Maximum Water Level [ft]	Maximum Water Level [m]
1985	24.5	7.47
1986	24.8	7.56
1987	23.6	7.19
1988	24.8	7.56
1989	25.3	7.71
1990	24.7	7.53
1991	25.1	7.65
1992	22	6.70
1993	25.5	7.77
1994	20.8	6.34
1995	25.3	7.71
1996	24.6	7.50
1997	26.3	8.02
1998	24.9	7.59
1999	24.6	7.50
2000	23	7.01
2001	22.2	6.77
2002	25.2	7.68
2003	23.3	7.10
2004	26.1	7.96
2005	23.3	7.10
2006	22.9	6.98
2007	24.5	6.47
2008	23	7.01
2009	22.1	6.74
2010	22.7	6.92
2011	23.8	7.25
2012	22.9	6.98
2013	24	7.32
2014	23	7.01
2015	25.8	7.86

Table B.1: Yearly maxima water levels Nyaungdon

B.1.2 Flood risk analysis

B.1.2.1 Flood hazard analysis

Bin	Freq	Cum	P	Q	G
7.0 to 7.1 m	3	3	0.130434783	0.869565217	-0.711420172
7.1 to 7.2 m	3	6	0.260869565	0.739130435	-0.295452862
7.2 to 7.3 m	1	7	0.304347826	0.695652174	-0.173603722
7.3 to 7.4 m	1	8	0.347826087	0.652173913	-0.054538065
7.4 to 7.5 m	1	9	0.391304348	0.608695652	0.06371791
7.5 to 7.6 m	6	15	0.652173913	0.347826087	0.849931959
7.6 to 7.7 m	2	17	0.739130435	0.260869565	1.196398655
7.7 to 7.8 m	3	20	0.869565217	0.130434783	1.967814715
7.8 to 7.9 m	1	21	0.913043478	0.086956522	2.39720595
7.9 to 8.0 m	1	22	0.956521739	0.043478261	3.113350665
8.0 to 8.1 m	1	23	1	0	-

Table B.2: Gumbel calculations

Water level (m)	**Probability P**	**1 in X year**
7.5	2.2523132E-01	4.4
7.6	1.5368786E-01	6.5
7.7	1.0275093E-01	9.7
7.8	6.7773238E-02	14.8
7.9	4.4307931E-02	22.6
8.9	2.8800455E-02	34.7
8.1	1.8650632E-02	53.6
8.2	1.2048650E-02	83.0
8.3	7.7715231E-03	128.7
8.4	5.0076914E-03	199.7
8.5	3.2246899E-03	310.1
8.6	2.0756660E-03	481.8
8.7	1.3357050E-03	748.7
8.8	8.5938696E-04	1163.6
8.9	5.5286458E-04	1808.8
9.0	3.5564588E-04	2811.8
9.1	2.2876883E-04	4371.2
9.2	1.4715096E-04	6795.7
9.3	9.4650103E-05	10565.2
9.4	6.0879879E-05	16425.8
9.5	3.9158230E-05	25537.4
9.6	2.5186634E-05	39703.6
9.7	1.6200030E-05	61728.3
9.8	1.0419828E-05	95970.9
9.9	6.7020050E-06	149209.1
10.0	4.3107074E-06	231980.5

Table B.3: Water level with corresponding probabilities

One in X year	**Water level (m)**
5	7.531803935
10	7.706606814
20	7.871726441
40	8.032645979
80	8.191598942
160	8.349599255
320	8.507130593
640	8.664429245
1280	8.821611998
2560	8.978736914
5120	9.135832938
10240	9.292914523
20480	9.449988891
40960	9.60705965
81920	9.764128605
163840	9.921196658
327680	10.07826426

Table B.4: Probabilities with corresponding water levels

B.1.3 Evacuation analysis

In this section the set up of a survey is described. The survey is a stated preference survey to analyse stated choice behaviour. Stated behaviour is analysing behaviour in a 'What if' situation. In this section the evacuation behaviour of the population of Nyaungdon is analysed. To read this appendix knowledge about statistics is required. However the level of analysing the survey is not sufficient to call it scientific. To make a correct scientific report more time should be spared. Such a research would take up at least entire month. Also it is chosen to do the analysis in `Excel` in stead of SPSS. `Excel` is a more transparent method but as a consequence it misses complexity.

B.1.3.1 Introduction

From a research of Kolen (2016) it is stated that there are rational reasons for Dutch citizens to evacuate or not. Some of the reasons mentioned are the traffic conditions, work obligations and desire to take care of elderly. It is interesting to investigate if these reasons are applicable for Burmese people as well. Also the behaviour concerning evacuation has been investigated in order to find several bottlenecks that can be improved by government. Which transport mode will the population choose and where will they go?

The scientific goal of this analysis is to get insight in the behaviour of the people in Nyaungdon concerning evacuation. This will provide relevant information to adjust the policy concerning disaster plans. Therefore an answer is found on the following questions:

- To what extent have the inhabitants experienced an evacuation?
- Which form of evacuation would be chosen?

- Which means of transport would be used to evacuate?
- Which reasons are most important when deciding on to evacuate or not?

This appendix is divided into several section in order to find the answer to the mentioned questions. In section B.1.3.2 a literature study has been performed on the behaviour of people during evacuations. In section B.1.3.3 an explanation is given concerning the data collection of the survey. In section B.1.3.4 the findings of the research are given and in section B.1.3.8 the conclusion is discussed.

B.1.3.2 Literature study

A lot of research has been done concerning the phsycho-behavioural research on evacuation. Out of the report of Leach and Campling (1982) can be concluded that the behavioural response of people is remarkably consistent across different types of disastrous conditions. They found a structural behaviroual part that can be divided in a number of phases. The phases range from pre-impact, when an emergency is becoming probable, to post-impact, when emergency has passed (Leach & Campling, 1982). The phases are:

- Threat: population is inactive and in denial.
- Warning: the population did not change their behaviour and is still in denial and inactive.
- Impact: different behaviours are shown varying from calmness, stunned and uncontrolled behaviour.
- Recoil rescue: the population shows dependency and emotional expression.

Phase three is striking as it contains behaviour varying from calmness to uncontrolled behaviour. However it goes hand in hand with other literature studies. Helsloot and Ruitenberg (2004) stated that people do not panic during the entire evacuation and act rational. This is in contrast with the findings of Pel (2014) who stated that people do change in behaviour during the movement part of the evacuation. According to Pel driving behaviour changes due to stress, emotion and driving task attention loss. What can be investigated in a survey is the behaviour the inhabitants performed in the past. Kolen (2016) describes seven reasons explaining why people do *not* evacuate. The seven reasons are traffic conditions, work obligations, the desire to protect their house and belongings, the desire to take care of pets, the desire to take care of elderly, the (dis)belief of the forecast and the access to transportation. Every reason has been tested by the survey to what extent the people in Nyaungdon think it is important. Besides, the survey is complemented with a four other factors. According (Pel, Bliemer, & Hoogendoorn, 2011) two other reasons are of importance as well: the order from the authorities to evacuate and secondly whether the neighbours are evacuating or not. Other factors that are added are the amount of help that is provided during evacuation and the height of the water level.

B.1.3.3 Explanation of data collection

In this section the survey set-up and the data collection is discussed. In the survey set-up the method is explained and the factors are operationalised. In the section of data collection the sample of the population is discussed.

Survey set-up

For this research the data has been collected in a short time span. This is known as a snapshot. The survey seemed an appropriate method to investigate the behaviour of the population of Nyaungdon. The survey is conducted in a written form and is handed out to the population of Nyaungdon. It is chosen to conduct the survey anonymously. The survey is divided into three parts. The first part asks general information of the respondents, part two focusses on the respondents that have already experienced an evacuation and part three considers the evacuation in Nyaungdon. In the table below it is shown how the factors can be operationalized. The total survey that is handed out on 14 September can be seen in the last section on evacuations of this appendix. Note: This is a translated survey since the original survey is in Burmese. There are four different classifications for the scale of measure: nominal (dichotomy), ordinal, interval and ratio. The scale of measure discusses the nature of information.

Factor	Operationalization	Possible answers	Scale of measure
General factor	Gender	Male/Female	dichotomous
	Age	Birth year	ratio
	Living situation	Living with children or elderly, four possibilities	ordinal
	Household members	Household members, four possibilities	interval
Evacuation experience	Flood experience	Yes/No	dichotomous
	Evacuation experience	Yes/No	dichotomous
	Living Nyaungdon	Yes/No	dichotomous
	Cause flood	Monsoon, rain, both, I dont know, four possibilities	ordinal
	Panic	Yes/No	dichotomous
	Receive help	Yes/No	dichotomous
Evacuation in Nyaungdon	Know what to do	Yes/No	dichotomous
	Aware of danger	Yes/No	dichotomous
	Disaster training	Yes/No	dichotomous
	Evacuation location	Higher floor, shelter, family, monasteries, higher ground	ordinal
	Knowledge other town	Yes/No	dichotomous
	Mode	Walking, bike, motor, car, truck, bus, taxi	ordinal
Motivations to evacuate	Work obligation	Five point scale	interval
	Traffic condition	Five point scale	interval
	Care of pets	Five point scale	interval
	Care of elderly /children	Five point scale	interval
	Belief forecast	Five point scale	interval
	Access to transportation	Five point scale	interval
	Help provided	Five point scale	interval
	Advice authorities	Five point scale	interval
	Height water level	Five point scale	interval

Table B.5: Operationalization of factors

The variable *birth year* is in ratio as it maximizes the measurement level. It is chosen not to ask for the age as elderly sometimes have forgotten this. A lot of factors are asked at a dichotomous scale to make it simple to fill in for the respondent. The dichotomous questions are questions where only two answers have been provided and have the objective to find the target group who has experienced the evacuation. In the table it can be seen that the motivations to evacuate are operationalised at a five point scale. With this scale the respondent can state if it is an important factor or not, ranging from from 'huge important factor' to 'not important'. Not for every motivation it is chosen to give a direction to the variables. For example with the factor 'taken care of elderly/children' it can be rather positive as negative. Although Kolen (2016) states that this motivation is a reason to *not* evacuate, which would mean this would have a negative direction, 'taken care of elderly/children' can be interpreted to choose to protect them and evacuate, so that it would be a positive direction. With the other factors, directions can be given as 'the water level' and the 'order of authorities'. It is clear that they have a positive direction. When the water level is too high or when the order is given, people see this as a reason to evacuate.

Data Collection

The target group of the survey is the population of Nyaungdon above the age of 16. This target group is chosen as it is conscious to see the effects of floods and can it prepare itself for evacuation. The population is too large to ask every citizen in Nyaungdon about his expected behaviour during an evacuation, so it is chosen to work with the sample of 74 respondents. The objective was to spread the survey under as much as possible people. The font of Burmese language does not work on western computers, therefore is chosen not to spread the survey on social media. Next to that spreading it on social media would make the probability too high that people not living close to Nyaungdon would complete the survey. The data is collected on Wednesday 14 September 2016. The time scale was between 10 a.m until 5 p.m. It took the respondents about 10 minutes to complete the survey.

B.1.3.4 Data preparation

In this section the data from the survey is prepared. There are four steps that have been executed. The first one is looking for the missing values: these are blank spaces where a respondent did not fill in any answer. The missing values should be excluded from the investigation. Furthermore the questions should be analysed again to check if they are interpreted correctly. If there are too many missing values the corresponding questions should be deleted.

Interpretation of questions

Here the interpretation of the questions is analysed. When a closer look is taken at the data, one can see that three questions have been left blank for ten percent of the respondents. The most common reason for not filling in answers is that the respondent did not understand the question. Although this question is in general the explanation, the three questions shall be discussed in detail to analyse on other reasons. One of the questions was 'How important in the decision to evacuate, is the motivation that your neighbours are leaving'. It can be declared that 'the neighbours leaving' is more a revealed shown behaviour than that people are conscious to take this fact along in the evacuation or not. Also it could be that the respondent did not have a close neighbour. Twelve percent of the respondents did not fill in 'Do you know what to do when you have to evacuate?' . Here the explanation can be here that the respondents wanted to choose a middle way. An answer to say that they know 'sort of' what to do. Eleven percent of respondents did not fill in the question 'Where do you evacuate to'. One of the reasons can be that they do not know where to go to.

What is striking in the dataset is that respondents filled in questions that they were not suppose to answer. If the answer on question 6 was: 'No', the respondent had to skip 3 questions and go to number question number 11. Unfortunately approximately twenty percent did not understand this and completed all the questions. In the data set these answers are left out.

B.1.3.5 Representative

To check if this survey is representatvei it is checked if the findings can be generated to the entire population of Nyaungdon. In more detail, in this section it is checked if the group of respondents consists of the same composition as the population of Nyaungdon. In a scientific report every correlation found should be checked on its significance. This can be done with the Pearson Correlation (R-value) and the Residual sum of squares (R^2). However this analysis has been excluded to make it more simple. When handing out the survey a huge problem came forward, namely: more than the half of the respondents asked to fill in the survey was *illiterate*. This was not expected as in literature can be found that 96 percent finishes primary school in Myanmar (Administration Committee Nyaungdon Township, 2016). However this can be explained as 96 percent of the youth is going to school. This automatically has led to the fact that some of the surveys were orally conducted. This is time consuming therefore a way has been figured out to let the respondents fill in the surveys by themselves. Signifying that more educated people have probably filled in the survey, making it less representative for Nyaungdon. Another consequence is that groups of non-illeterate people must be found in Nyaungdon to complete the survey. A solution was found by letting the teachers of primary schools, the rich families and employers of the city development complete the survey. As a consequence more women than man completed the survey, around 75 percent of the respondents is women. This can be explained due the fact that around 87 percent of the teachers in Myanmar is female (Worldatlas, 2016). This is also not representative as the male/female ratio is in general around 50 percent.

Normal distribution

A check has been done to see if a variable has a normal distribution. This is required to do a statistical analysis. To test a normal distribution assumption the Kolmogoroc Smirov test is recommended with $\alpha = 0.05. However there is a rule of thumb to simplify this test and that is that every group per variable is greater tha$
$t-test should be done. This however is excluded from this analysis as data of the population is lacking. It is recommended$

B.1.3.6 Research findings

In this section the method how to implement a statistical analysis in `Excel` is explained followed by an analysis of the most striking results.

Using `Excel`

First the data have been filled in manually because the survey was not collected online. Answers at dichotomous questions on gender as men/women should be filled in with 0 and 1 in `Excel`. It is chosen to complement the data with ones and zeros because it makes it suitable to analyse it further in `SPSS`. Although `Excel` is not a perfect analysing tool for statistical analysis, it has some useful statistical analysis packages. One should go to options in `Excel` and click on the analysis tool pack and analysis tool pack VBA. After this one should analyse and click on 'descriptive statistics'. This will give following outcomes:

- Average: the average is of importance at a ratio level and dichotomous level. At a dichotomy scale the average is the percentage of group 1.

- Standard error: is the average mistake if an answer of the respondent is taken and would compare it with the average. How greater the amount of respondents how smaller the standard error.
- Median: the middle of the distribution if the are ranged from high to low.
- Modus: the most frequent answer. This is interesting in almost every measure scale.
- Standard deviation: The average deviation of the average score of a question.
- Kurtosis: gives an idea wherever or not extreme scores are in the dataset.
- Flexure: gives the distribution of positive and negative values. This is not that interesting for this analysis.
- Range: The difference of the lowest(minimum) and highest (maximum) score.
- Missing values: The number of blank spaces.

Important percentages

In the table below the most important findings are found expressed in percentages. It is tried to clarify some of the findings but again these findings are not statistically significant.

Percentage	**Important findings**
75%	are women
67%	had a flood experience
31%	had a evacuation experience
50%	of the evacuation experienced respondents believed the cause was the monsoon
78%	of the evacuation experienced respondents felt panic
49%	of the evacuation experienced respondents did not receive help during evacuation
63%	were living in Nyaungdon
84%	knows what to do during evacuation
81%	is not aware that they live in a dangerous area
91%	did not receive a disaster training
67%	knows the township where to evacuate to
68%	chooses the car as mode to evacuate
Average score	**Motivations to evacuate**
2.46	traffic conditions
2.81	work obligations
2.69	desire to protect your house
2.50	desire to protect pets/animals
3.77	desire to take care of elderly
3.07	(dis)belief of the forecast
3.41	access to transportation
3.22	the matter of help that will be provided during evacuation
2.42	the fact that neighbours leave their houses
3.25	the advice of the authorities to evacuate
3.47	height of the water level

Table B.6: Findings of the survey

What is striking is the percentage of evacuation experience respondent. It was expected that the percentage would be higher taken into account the floods of 4 years ago. What is also is that 80 percent felt panic during the evacuation. It is probably not because the population did not know what to do, as 84 percent claims they do know, but maybe it is because they did not receive enough help (49 percent claims not to received help). What also can be noticed is that 68 percent would take the car as a mode choice to evacuate if they had the choose. This can create a bottleneck as there is no traffic management arranged during evacuation. Also with the question: 'Did you experience flood' other causes of evacuation are thereby excluded. Only one evacuation experienced respondents answered: 'No' I did not have a flood experience. Other interesting percentages are the 91 percent that not received disaster training and 81 percent that is not aware that they live in a 'dangerous area that can be flooded'. Also when local citizens are interviewed they believe in the strength of the dike. After analysing the motivations to evacuate, it can be concluded that every aspect scored a sufficient/important role whether to evacuate or not. All aspects score above 2.4 on average. The relative highest rank is scored by taking care of elderly/children (3.8). Taken into account that with a five point scale including 0 (no importance) to 4 (huge importance), it almost scores the maximum. Other high motivations are the water level (3.5) and the access to a transportation (3.4). The relative lowest scores are for the fact that the neighbours are leaving (2.4), taken care of animals or pets (2.5) and work obligations (2.5) .

Correlation

An other analysis that `Excel` provided is the correlation. A correlation expresses the direction and strength of a linear relationship between two variables. Correlations can only be tested if the variable has an interval measure of scales. A moderate correlation is between 0.5-0.7 and a strong correlation is between 0.7-0.85. A moderate, positive correlation can be found (0.6) between the importance of 'the height of the water level' and the 'order to evacuate by authorities'. This makes sense as the authorities will base their information to evacuate on the water level. Other correlations have scored lower than 0.5, so are not discussed in this section.

Where to evacuate to?

In `Excel` there is also the possibility to make histograms. A histogram gives a visual overview of amounts. It is chosen to discuss the location where to evacuate to in a separate section. According Twint (Irrigation department) Nyaungdon provides 32 shelters to evacuate in the province Nyaungdon, but it is interesting if the population are planning to go there.

Evacuation choice	**Frequency**	**Percentage**
A higher floor of your house	14	0.19
Shelters/ Relief camps	18	0.24
Family/friends	20	0.27
Monasteries	5	0.07
Higher grounds	7	0.09
Other	2	0.03
Missing	8	0.11

Table B.7: Evacuation location

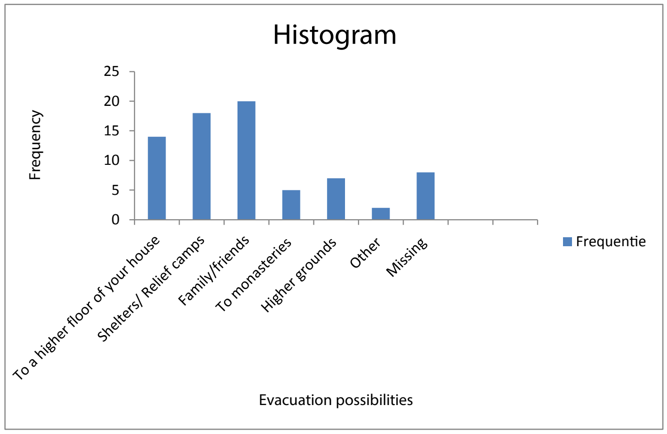


Figure B.1: Histogram evacuation location

What can be noted is that three location choices are the most popular ones. One, a vertical evacuation, the possibility to move to a higher floor of your house and two horizontal evacuation options. One is going to shelters and relieve camps located in/at schools and monasteries and the other option is to go to friends and families.

B.1.3.7 Difference in motivations

In table B.6 the average scores for the motivation to evacuate or not, have been shown. To see if the differences between motivations are significant, a student t-test for paired samples have been done. This t-test has been done because the scale is both ordinal (or continue) and they are dependent variables. The paired sample T-test is chosen as the samples are taken from the same group of respondents. In `Excel` this analyses can be executed. The 0-hypotheses assumes there is no relation between the averages of the importance of motivation. The alternative hypotheses assumes that the 'taken care of elderly' would score higher than the factor 'neighbours leaving'. The test can be one-sided as a direction is appointed.

	Variable 1: Neighbours leaving	**Variable 2: Care of elderly/children**
Average	2.424	3.771
Variance	0.833	0.179
Observation	66.000	70.000
Paired variation	0.496	
Estimated average of samples	0.000	
Freedom degrees	134.000	
T- statistic data	-11.149	
P(T<=t) one sided	0.000	
Critic value of T-test: one sided	1.656	
P(T<=t) two sided	0.000	
Critic value of T-test: two sided	1.978	

Table B.8: T-test paired samples

The choice of either a one or two sided T-test is dependent on the expectation of differences between the samples and if you have good reasons to expect that difference. There are differences in average score 2.4 versus 3.7, so it is chosen to have a one sided T-test. If the p-value is below 0.05, the differences are significant. Looking at the table with a p=0, makes the differences significant. So it can be concluded that the population in Nyaungdon thinks that 'taken care of elderly/children' is more important to decide to evacuate or not than the fact that neighbours are leaving. Hereby not taken into account that the sample is not representative.

B.1.3.8 Conclusion

It can be concluded that the survey provided insight in the behaviour of the people in Nyaungdon. The survey was however not representative, because of the percentage of women is 75 and the amount of illiterates in Nyaungdon. Furthermore the number of respondents that experienced evacuation was around 23, which is not enough to generalize the findings to the entire population. However the behaviour of these respondents have given interesting insights. Around 80 percent of the evacuation experienced respondents felt panic during their evacuation and the half of the respondents that have experienced evacuations received help. Around 60 percent have used their car to evacuate. The most popular evacuation location of 30 percent was visiting friends and family outside Nyaungdon.
Three evacuation possibilities are the most popular: moving up one floor, going to monasteries and going to friends and families. Around 68 percent of all of the respondents would choose the car as a mode to evacuate. The motivations differentiate as 'taken care of elderly/children' is seen as most important to take along.

B.1.3.9 Recommendation

As is stated in the introduction a more extensive survey to analyse the behaviour of Nyaungdon is recommended. It should also be more appropriate if the data was collected on multiple days at multiple time frames. This would solve the lack of representability. It is also recommended to ask the level of education in a future analysis. In order to solve the problem of illiteracy the surveys could be conducted orally, but this has the consequence that it would be too time consuming. Another interview techniques that is recommended to be executed in the future is interview with an expert.

Enquete Nyaungdon

PART I: GENERAL INFORMATION

1. What is your gender?
    a. Male
    b. Female
2. What is your birth year?
    a. [ ]
3. What is your living situation?
    a. Living with children
    b. Living with elderly
    c. Living without children and elderly
    d. Living with children and elderly
4. How many members does your household count (including you)?
    a. Less than 2 members
    b. 3-5 members
    c. 5-7 members
    d. 7 and more

PART II: EVACUATION EXPERIENCE

The following questions will be about evacuation. Evacuation is the principle of moving people, animals and property to a relative safer location.

5. Did you ever experienced a flood in your life?
    a. Yes
    b. No

6. Did you ever had to evacuate in your life?
    a. Yes
    b. No

If your answer of 5 was b: 'No' , than go to PART III.
If you had experienced multiple evacuations, pick the most recent one.

7. Were you during this evacuation living in Nyaungdon?
    a. Yes
    b. No
8. If you had to evacuate what was the cause of the flood?
    a. Monsoon rain
    b. Cycloon/typhoon
    c. Both
    d. I do not know the cause of the flood
9. Did you felt panic during the evacuation?
    a. Yes
    b. No
10. Did you receive any help during the evacuation?
    a. Yes
    b. No

PART III: EVACUATION IN NYAUNGDONE

The following questions are about evacuations in Nyaungdon. Try to answer the questions what you have done in the past. If you answered in question 5b: No. Try to answer the questions what you will do in the future.

11. Do you know what to do when you have to evacuate?
    a. Yes
    b. No
12. Are you aware that this area is a danger area and that can be flooded?
    a. Yes
    b. No
13. Did you ever had an evacuation or disaster training?
    a. Yes
    b. No
14. Where did or will you evacuate to?
    a. To a higher floor of your house.
    b. Shelters/ Relief camps
    c. Family/friends outside Nyaungdon
    d. To monasteries outside Nyaungdon
    e. Higher grounds
    f. Other…..
15. If you are evacuating outside Nyaugdon, to which city/township did or will you go?
    [ ]
16. Which transport mode did or will you use to evacuate?
    a. Walking
    b. Bicycle
    c. Motor
    d. Car
    e. Trucks
    f. Bus (Public transport)
    g. Taxi
17. Determine how the following aspects play a role in your choice to evacuate or not. Cross for each aspect one of the five boxen.

	Plays no role	Plays a little role	Plays a sufficient role	Plays an important role	Plays an huge role
Work obligations					
Traffic conditions					
The desire to protect your house and belongings					
The desire to take care of pets/ animals					
The desire to take care of the elderly/children					
The belief or disbelief of the forecast					
Access to transportation					
The matter of help that will be provided during evacuation					
The fact that neighbors leave their houses					
The advice of the authorities to evacuate					
Height of the water level.					

Figure B.2: Survey translated in English

B.2 Phase 3: Assessment

In this chapter the multi-criteria analysis is described in more detail. Since each scenario consist of 4 tables, it is chosen to show and explain only one of the scenario's in more detail. For further information it is recommended to have a look at the `Excel` sheet. In this analysis it is chosen to elaborate on scenario A. Scenario A has a population decrease and an economic increase.

B.2.1 Rating alternatives

The rating of alternatives is the same for every scenario in Nyaungdon. In this section a closer look is taken on the particular values and colours of the alternatives. It can be concluded that the prevention measures, located in layer 1, score good on reducing the material damage, immaterial damage and probability. These prevention measures are heightening dikes, optimising dikes, Room for the River and a dam. The temporary defences(area) and sandbags score good as well as they reduce the damage when a disaster strikes. After taking a closer look on the scores of immaterial damage, it can be noticed other measures score good as well. Every evacuation package has a favourable outcome. This is logical since the main goal of an evacuation is to reduce the number of fatalities and casualties.

The next group of criteria that is discussed in more detail consists of the costs. The initial costs of the dam and the Room for the River measure are high and have therefore the colour red and the value 1. The null solution and the evacuation minimum score on initial costs the colour green (value 5). It takes no initial costs to implement these alternatives as the minimum evacuation is already included in the null solution and the null solution includes no new measures. The operational costs are expressed in $€/dangerlevel$. All the alternatives score good on this criterion except the evacuation packages and sandbags, as it takes a lot of time, effort and money to organise and implement these measures. The measures that are only taken when danger level occurs have high operational costs. A second kind of costs are the maintenance costs described in $€/year$. Maintenance costs can be seen as beforehand known annual costs. The most striking score is the score for Room for the River, colour red (value 1). With this alternative the river needs to be controlled in a certain direction every once in a while. The costs for controlling are high because the river needs to be dredged and dikes need to be built.

The other measures are hard to classify, therefore they are discussed separately. Available space is the land-space a measure requires. In Nyaungdon this indicator has a relative low importance because none of the measures requires a lot of land-space. Scores between green (value 5) and blue (value 3) are given. At other research areas this indicator can be seen as relative important, it depends. The aesthetic acceptance scores low on building a dam. Preservation of biodiversity and hindrance of ships are criteria on which the measure dam has the worst score. Other indicators like accessibility by roads score good (green, value 4) on the following alternatives: advice on urban planning and the evacuation packages medium and optimum. In table B.9 all the results are shown.

B.2.2 Weight factors

The weight factors are different for every scenario, so it is chosen to describe only scenario A. Two tables are needed to come to the calculated weight factors. These two tables are table B.10 and

table B.11. These tables can also be found in the `Excel` sheet. For simplification the table B.10 is programmed in a way that only part of the `Excel` sheet have to be filled in. The weight factors will automatically be calculated after filling in the necessary numbers. The boxes in table B.10 that need to be filled in are all the boxes *above* the diagonal value 1. The boxes *below* the diagonal 1 are automatically filled in.
The grey coloured indicators are marked because they change in each scenario. In case of economic growth the costs seem relatively less important. In case of population growth the immaterial damage, disturbance and aesthetics acceptance are seen as relatively more important.

One indicator is taken as an example: the material damage. If the material damage is compared to itself the value is 1 since the level of importance is equal. If material damage is compared to the immaterial damage it will score 5, this means immaterial damage is more important than material damage. This is because reducing fatalities is seen as the relatively most important objective for the authorities during a disaster. By comparing reducing material damage with reducing the probability, the material damage is seen as more important and therefore scores 2. Furthermore the material damage is seen as relatively more important than the other indicators. The initial costs score higher than the operational and maintenance costs because initial costs are considered as more important. The other indicators score between 6 and 9, meaning that material damage is seen as extremely more important than these indicators. In table B.10 all values of the weight factor for scenario A can be seen.

In table B.11 the values are divided by the sum of the specific columns. This is done to normalise the values. The total weight factors can be seen in yellow.

B.2.3 Ranking alternatives

The weight factors are multiplied by the scores of table B.9. The results can be seen in table B.12. The total scores can be calculated by summing up the columns. The total scores of each measure can be ranked from 1 to 14. The lowest rank is given to the null solution. It is therefore recommended to implement one of the alternatives. The results can be seen in table B.12.

Criteria \ Measures	Weight	Null solution: current measures	Heighten dikes	Optimise dikes	Dam	Room for the river	Drainage system	Relocate schools & hospital	Advise on urban planning	Remove fishermen & create harbour	Evacuation optimum	Evacuation medium	Evacuation minimum	Sandbags	Temporary defences (area)	Temporary defences (building)
Material damage	2,348	1	5	5	4	4	2	3	3	2	1	1	1	4	4	5
Immaterial damage	3,289	1	5	5	4	4	2	2	3	2	5	4	3	4	4	2
Probability	2,346	2	5	5	4	4	2	2	2	2	2	2	2	3	4	3
Initial costs	1,089	5	2	2	1	1	2	2	5	2	4	4	5	4	2	2
Operational costs	0,855	5	5	5	5	5	5	5	5	5	2	3	4	3	4	4
Maintenance costs	0,734	4	4	3	4	1	3	5	5	5	5	5	5	5	3	3
Implementation time	0,528	5	2	2	1	1	3	2	5	2	3	4	5	4	4	4
Available space	0,527	5	2	4	4	3	4	4	5	3	5	5	5	5	5	5
Esthetics acceptance	0,250	5	3	4	2	4	5	5	5	4	5	5	5	4	4	4
Disturbance for local residents	0,301	5	2	5	4	1	5	4	5	1	5	5	5	5	5	5
Preservation of biodiversity	0,223	4	4	4	1	5	4	4	4	4	4	4	4	4	4	4
Hindrance for ships	0,244	5	5	5	2	4	5	5	5	5	5	5	5	5	5	5
Accessibility by roads	0,266	3	3	3	3	3	3	3	4	3	4	4	3	3	3	3

Table B.9: Scorecard Nyaungdon scenario A

Criteria \ Criteria	Material damage	Immaterial damage	Probability	Initial costs	Operational costs	Maintenance cost	Implementation time	Available space	Aesthetics acceptance	Disturbance for local residents	Preservation of biodiversity	Hindrance for ships	Accessibility by roads
Material damage	1	1/5	2	3	5	5	7	6	9	8	9	7	8
Immaterial damage	5	1	3	4	5	5	7	8	9	8	9	7	8
Probability	1/2	1/3	1	6	5	5	6	6	9	8	9	7	8
Initial cost	1/3	1/4	1/6	1	3	3	4	3	4	4	4	4	3
Operational cost	1/5	1/5	1/5	1/3	1	2	2	4	3	3	5	4	4
Maintenance cost	1/5	1/5	1/5	1/3	1/2	1	2	3	3	4	5	4	2
Implementation time	1/7	1/7	1/6	1/4	1/2	1/2	1	1/2	3	3	4	3	3
Available space	1/6	1/8	1/6	1/3	1/4	1/3	2	1	4	2	3	3	2
Aesthetics acceptance	1/9	1/9	1/9	1/4	1/3	1/3	1/3	1/4	1	1/2	2	2	1/2
Disturbance for local residents	1/8	1/8	1/8	1/4	1/3	1/4	1/3	1/2	2	1	1/2	2	2
Preservation of biodiversity	1/9	1/9	1/9	1/4	1/5	1/5	1/4	1/3	1/2	2	1	1/2	1
Hindrance for ships	1/7	1/7	1/7	1/4	1/4	1/4	1/3	1/3	1/2	1/2	2	1	1
Accessibility by roads	1/8	1/8	1/8	1/3	1/4	1/2	1/3	1/2	2	1/2	1	1	1
Total	8.16	3.07	7.52	16.58	21.62	23.37	32.58	33.42	50.00	44.50	54.50	45.50	43.50

Table B.10: Weight factors 1

Criteria	Material damage	Immaterial damage	Probability	Initial costs	Operational costs	Maintenance cost	Implementa tion time	Available space	Aesthetics acceptance	Disturbance for local residents	Preservation of biodiversity	Hindrance for ships	Accessibility by roads	Total
Material damage	0,123	0,064	0,266	0,181	0,231	0,214	0,215	0,191	0,180	0,180	0,165	0,154	0,184	2,348
Immaterial damage	0,613	0,322	0,399	0,241	0,231	0,214	0,215	0,191	0,180	0,180	0,165	0,154	0,184	3,289
Probability	0,061	0,107	0,133	0,362	0,231	0,214	0,184	0,191	0,180	0,180	0,165	0,154	0,184	2,346
Initial cost	0,041	0,080	0,022	0,060	0,139	0,128	0,123	0,095	0,080	0,090	0,073	0,088	0,069	1,089
Operational cost	0,025	0,064	0,027	0,020	0,046	0,086	0,061	0,127	0,060	0,067	0,092	0,088	0,092	0,855
Maintenance cost	0,025	0,064	0,027	0,020	0,023	0,043	0,061	0,095	0,060	0,090	0,092	0,088	0,046	0,734
Implementation time	0,018	0,046	0,022	0,015	0,023	0,021	0,031	0,016	0,060	0,067	0,073	0,066	0,069	0,528
Available space	0,020	0,054	0,022	0,020	0,012	0,014	0,061	0,032	0,080	0,045	0,055	0,066	0,046	0,527
Aesthetics acceptance	0,014	0,036	0,015	0,015	0,015	0,014	0,010	0,008	0,020	0,011	0,037	0,044	0,011	0,250
Disturbance for local residents	0,015	0,040	0,017	0,015	0,015	0,011	0,010	0,016	0,040	0,022	0,009	0,044	0,046	0,301
Preservation of biodiversity	0,014	0,036	0,015	0,015	0,009	0,009	0,008	0,011	0,010	0,045	0,018	0,011	0,023	0,223
Hindrance for ships	0,018	0,046	0,019	0,015	0,012	0,011	0,010	0,011	0,010	0,011	0,037	0,022	0,023	0,244
Accessibility by roads	0,015	0,040	0,017	0,020	0,012	0,021	0,010	0,016	0,040	0,011	0,018	0,022	0,023	0,266
Total	1	1	1	1	1	1	1	1	1	1	1	1	1	

Table B.11: Weight factors 2

Criteria / Criteria	Null solution: current measures	Heighten dikes	Optimise dikes	Dam	Room for the river	Drainage system	Relocate schools & hospital	Advise on urban planning	Remove fishermen & create harbour	Evacuation optimum	Evacuation medium	Evacuation minimum	Sandbags	Temporary defences (area)	Temporary defences (building)
Material damage	2,35	11,74	11,74	9,39	9,39	4,70	7,04	7,04	4,70	2,35	2,35	2,35	9,39	9,39	11,74
Immaterial damage	3,29	16,44	16,44	13,16	13,16	6,58	6,58	9,87	6,58	16,44	13,16	9,87	13,16	13,16	6,58
Probability	4,69	11,73	11,73	9,39	9,39	4,69	4,69	4,69	4,69	4,69	4,69	4,69	7,04	9,39	7,04
Initial costs	5,45	2,18	2,18	1,09	1,09	2,18	2,18	5,45	2,18	4,36	4,36	5,45	4,36	2,18	2,18
Operational costs	4,28	4,28	4,28	4,28	4,28	4,28	4,28	4,28	4,28	1,71	2,57	3,42	2,57	3,42	3,42
Maintenance costs	2,94	2,94	2,20	2,94	0,73	2,20	3,67	3,67	3,67	3,67	3,67	3,67	3,67	2,20	2,20
Implementation time	2,64	1,06	1,06	0,53	0,53	1,58	1,06	2,64	1,06	1,58	2,11	2,64	2,11	2,11	2,11
Available space	2,64	1,05	2,11	2,11	1,58	2,11	2,11	2,64	1,58	2,64	2,64	2,64	2,64	2,64	2,64
Aesthetics acceptance	1,25	0,75	1,00	0,50	1,00	1,25	1,25	1,25	1,00	1,25	1,25	1,25	1,00	1,00	1,00
Disturbance for local residents	1,51	0,60	1,51	1,20	0,30	1,51	1,20	1,51	0,30	1,51	1,51	1,51	1,51	1,51	1,51
Preservation of biodiversity	0,89	0,89	0,89	0,22	1,11	0,89	0,89	0,89	0,89	0,89	0,89	0,89	0,89	0,89	0,89
Hindrance for ships	1,22	1,22	1,22	0,49	0,97	1,22	1,22	1,22	1,22	1,22	1,22	1,22	1,22	1,22	1,22
Accessibility by roads	0,80	0,80	0,80	0,80	0,80	0,80	0,80	1,06	0,80	1,06	1,06	0,80	0,80	0,80	0,80
Total	33,93	55,67	57,15	46,08	44,33	33,98	36,96	46,20	32,94	43,37	41,46	40,38	50,34	49,89	43,32
Ranking	14	2	1	6	7	13	12	5	15	8	10	11	3	4	9

Table B.12: Ranking alternatives

C | Case 2

C.1 Phase 1: Analysis

C.1.1 Hydrology

C.1.1.1 Tidal conditions

Point observation station

Measurements of the tidal range around the port of Yangon were done at Monkey Point.

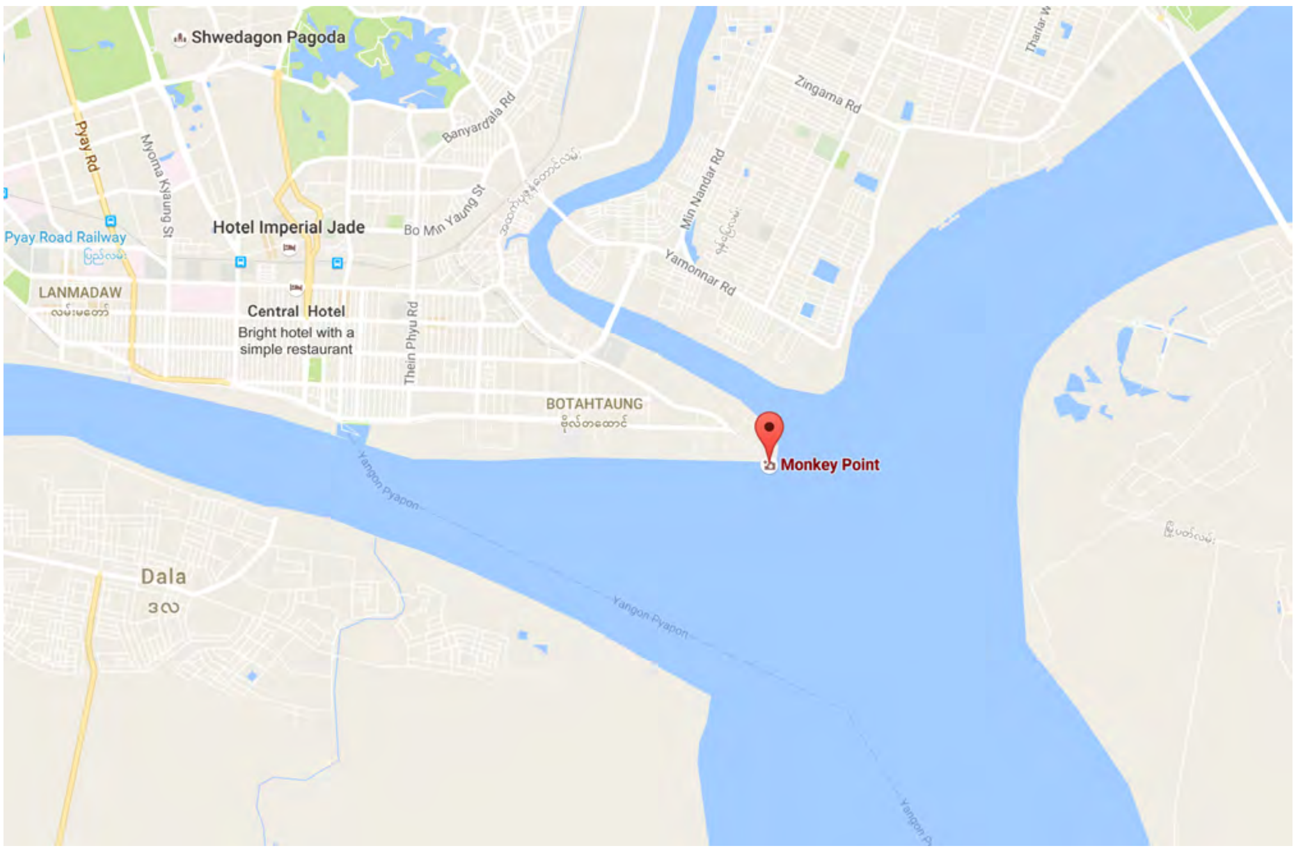


Figure C.1: Monkey Point (Google Maps, 2016)

The measurements were done between 2009 and 2011 with several interruptions, making the data less accurate (JICA et al., 2015). The data about the errors of these measurements have been noted below.

Observation Station	Average (cm)	Standard Deviation (cm)
Monkey Point	-6 (0.0)	20 (17.4)

Table C.1: Errors of tide table (JICA et al., 2015). The values within the brackets are the corrected values.

Spring water levels

In table 11.1 the spring tides and neap tides have not been noted. The following tidal levels would complement this table, but it is currently not present because of the lack of data:

- MHWS: Mean High Water Spring
- MLWS: Mean Low Water Spring
- MHWN: Mean High Water Neap
- MLWN: Mean Low Water Neap

Considering flooding the MHWS is especially interesting. In the report of JICA et al. (2015) is referred to the spring water level to be around 6.2 metres, but this corresponds to the high water level HWL. It is evident that there is no detailed view of the tidal conditions near the port of Yangon.

Some online data on the tidal range near the port of Yangon can be found. These values are not means of high and or low water springs, but are the highest and lowest HWS, HWN, LWN and LWS that could be found between 28 September and 28 October.

HWS	+7.02 m
HWN	+4.9 m
LWN	+2.75 m
LWS	+0.41 m

Table C.2: Tidal levels at Elephant Point (Meteo365, 2016)

The values from the table have been found two days after full moon and two days after last quarter moon. It is not uncommon that the effects of spring and neap tides are found later than the should have occurred in theory. This can be because of to the shapes and irregularities in depths in the oceans and bays.

C.1.1.2 Storm surges

Cyclones occur very often in the Bengal Bay. Table C.3 shows the present and near future cyclones. 'Case 1' means all cyclones and 'Case 2' stand for the strong cyclones within all of these cyclones of 'Case 2'.
Between 1979 and 2003 an amount of 57 cyclones were present within the Bengal Bay, of which 8 cyclones can be considered strong. It is expected that within the same period in the future the amount of cyclones will decrease, but that the amount of strong cyclones will increase.

		Number of cyclones in Bengal Bay	Minimum Center Pressure	Mean Center Pressure (hPa)
Present cyclones (1979 - 2003)	Case 1	57	983.1	1,002.6
	Case 2	8	980.8	991.0
Near future cyclones (2015 - 2039)	Case 1	46	962.7	1,001.22
	Case 2	13	945.8	980.9

Table C.3: Summary of Simulated Cyclones by MRI/JMA (JICA et al., 2015)

Cyclones in the Bengal Bay do not have a certain path that is followed. This deviates and is unpredictable. JICA et al. (2015) did do estimations on the the proportion of cyclones from the Bengal Bay and how many land in Myanmar.

	Total Number of Cyclones in Bay of Bengal (A)	Total Number of Cyclones Landed around Myanmar (B)	Average Number of Cyclones in Bay of Bengal per Year	Proportion (B/A)
JTWC 1945 - 2009 (65 years)	290	29	2.5	10.0%
MRI/JMA 2015 - 2039 (25 years)	46	4	1.8	8.7%

Table C.4: Number of Cyclones Formed in Bay of Bengal and Landing in Myanmar (JICA et al., 2015)

It is estimated that about 8.7% of the Bengal Bay cyclones will head to Myanmar. In order to say something about the occurrence of a cyclone similar to Nargis one can use this information. This is of importance for the flood risk analysis.

As 13 strong cyclones are expected in a period of 25 years see table C.3 and about 8.7 % of these cyclones hit Myanmar, it is reasonable to assume that in 25 years the amount of strong cyclones hitting Myanmar will be:

$$Amount\ of\ strong\ cyclones\ hitting\ Myanmar = 13 \cdot 0.087 = 1.131\,\text{cyclones}$$

Around 1 strong cyclone might hit Myanmar in 25 years. In that way it is fair to estimate that the chance of a strong cyclone hitting Myanmar is about:

$$P_{strong\,cyclone\,hitting\,Myanmar} = \frac{1}{25}$$

This is an important indication as cyclones generate a local sea level rise. This again leads to storm surges and is of importance in the Yangon Port. As described in section 11.1.5.2 JICA et al. (2015) have done some simulations with the following cases:

Case	Case Name	Pressure	Course
1	Nargis	Nargis	Nargis
2	Nargis + 1 degree	Nargis	Nargis + 1 degree
3	Nargis - 1 degree	Nargis	Nargis - 1 degree
4	Nargis future	AGCM Output	Nargis
5	Nargis futures + 1 degree (assumed strongest cyclone in the future)	AGCM Output	Nargis + 1 degree

Table C.5: Storm surge simulation in Yangon Port (JICA et al., 2015)

The cases differ in course direction of the cyclone for case 2, 3 and 5. Also future strong cyclone with different pressure levels have been simulated, namely case 4 and 5. The results of these simulations are displayed in figure 11.3.

For the flood risk analysis it is needed to to define $SSL_{\frac{1}{25}}$. This is the storm surge level that occurs once every 25 years and corresponds to the calculations above. The simulations of future cyclones gave storm surge levels in the Yangon Port of around 2.9 and 2.75 metres. For this report it has been chosen to calculate with a value somewhere in between these numbers. Thus it is assumed that $SSL_{\frac{1}{25}} = 2.8$ m.

C.1.2 Flood risk analysis

C.1.2.1 Flood scenarios

As described in section 11.6.1, some rounding errors had to be introduced in the flooding scenarios. These rounding errors for each flooding scenario have been treated below:

Flood scenario 1

High water level due to spring tide
Section 11.1.5 has described the high water level due to spring water.

$$HWS = 7.02\,m = 7.02\,m \approx 7\,m$$

$$\text{Introduced error} = 0.02\,\text{metres}$$

The probability of this water level occurring in a year is 1, as high spring water occurs about every 14 days. It is reasonable to think that if one picks a random day, that the probability of have high spring water tide (HWS) is 1 in 14:

$$P_{\text{Scenario 1}} = P_{\text{HWS}} = \frac{1}{14}\,\text{per day}$$

Flood scenario 2

High water level in combination with strong storm surge
HWL has also been described in section 11.1.5 and the strong storm surge has been described in section C.1.1.2.

$$HWL + SSL_{\text{strong storm}} = 6.2\,m + 2.8\,m = 9\,m$$

$$\text{Introduced error} = 0\,\text{metres}$$

The probability of high water level HWL is 1, as high water level occurs every single day. As described is appendix C.1.1.2 the probability of a high storm surge due to a strong storm is 1 in 25 years and if a storm surge holds longer than at least half a day, the storm surge will definitely occur in combination with HWL. Thus the probability of scenario 2 equals:

$$P_{\text{Scenario 2}} = P_{\text{SSL}} = \frac{1}{25}\text{ per year}$$

Flood scenario 3

High water level due to spring tide in combination with high storm surge (cyclone)
The water levels of flood scenario have already been described in the 2 other scenarios:

$$HWS + SSL_{\text{storm surge}} = 7\,m + 2.8\,m = 9.8\,m \approx 10\,m$$

$$\text{Introduced error} = 0.2\,\text{metres}$$

The probability of flood scenario 3 is a combination of the probabilities of the two events. It is assumed that these two events, HWS and a strong storm, are fully independent. This allows the multiplication of their probabilities (Jonkman et al., 2015)

$$\begin{aligned} P_{\text{Scenario 3}} &= P_{\text{HWS}} \cdot P_{\text{SSL}} \\ &= \frac{1}{14}\text{ per day} \cdot \frac{1}{25}\text{ per year} \\ &= \frac{1}{14} \cdot \frac{1}{25} \cdot \frac{1}{365}\text{ per day} \\ &= \frac{1}{127,750}\text{ per day} \\ &= \frac{1}{350}\text{ per year} \end{aligned}$$

C.2 Phase 3: Assessment

In this appendix the multi-criteria analysis of Dala will be elaborated in more detail. Since each scenario consists of 4 tables, it is chosen to show and explain one of the scenarios into more detail, namely scenario A. For further information it is recommended to have a look at the `Excel` -sheet used for this analysis.

C.2.1 Rating alternatives

The table that has been used for rating the alternatives does not differ for the four different scenarios, since the rating does not depend on the future scenarios. This appendix should give insight in how the table works for the case of Dala and should provide explanations for why certain ratings have been chosen. First an explanation is given about the most noticeable aspects of the table, followed by the reasoning of why certain scores have been given. A clear overview of the rated alternatives is given in table C.6.

Something that can immediately be observed is that the prevention measures such as a dike or a flood wall score extremely well on the prevention of material and immaterial damage. The downside of these alternatives are the higher costs and the larger implementation time. The evacuation measures score better on the criteria in the middle of the table in comparison with the prevention measures. Something to be noted as well is that the crisis management alternatives all together score relatively well if compared to any other measure. For most of the measures holds that there is almost always a trade-off between different criteria for a certain measure. That is the reason a table like this has been made to give a clear overview of how they are rated. Combined with the weight factor on the left, which is elaborated further on, this table can give a good estimation on which measure suits this problem the best.

It is not possible to explain every number that has been given to all the different criteria. Although a few criteria will be elaborated. The first criterion that will be explained is the material damage. Since doing nothing will definitely not provide any protection against buildings and other structures that could be damaged during a flood, this measures has the lowest score on material damage. The construction of a dike, storm surge barrier or flood wall however work really well in preventing some structures will be damaged. The elevation of houses on stilts has a neutral score since most houses are already constructed on stilts, so nothing will change that much. Although nothing changes in the null solution either, this measure does help in preventing damage of houses and other structures and therefore scores better than the null solution. Elevation of roads does not help to protect houses against flooding. The only thing that it improves is the accessibility towards Dala itself, providing better evacuation possibilities and therefore lowering the immaterial damage. Since the prevention of relative sea level rise is a process over many years, it is not a measure that has a direct impact on the criterion of material damage. It will help to prevent the land subsidence, but it is absolutely not as effective as a dike for instance. The same holds for an improved drainage system: it will not protect Dala from flooding and will therefore not have a direct impact on the criterion material damage. Nevertheless, it still helps to improve the accessibility during a flood. All the evacuation alternatives score bad on the material damage criterion since it is not a measure that aims to improve it. The only reason the evacuation would be implemented, is to save people instead of buildings, which is often considered as more important. The life of a human being is often considered to be more valuable when compared to the damage of houses and other structures. This can be seen in the column of the weight factor. The determination of these factors will be explained in the next section.

Other criteria that were important are the initial costs, maintenance costs and operational costs. For the initial costs it was important to know how much it would cost to implement a certain alternative. This criterion has been rated well if the implementation costs are low and badly in case of high implementation costs. For maintenance costs the same holds as for the initial costs. However, for the operational costs it was only important to see how much something would cost when a flood occurs. For the case of a dike or a flood wall there are no additional costs since the dike would already be there. In case of a temporary flood defence or an evacuation, there would be additional costs to set-up the defences or an evacuation plan. These additional costs are rated in the criterion for operational costs.

This way of thinking has been integrated throughout all the different criteria in relation with the different alternatives resulting in the score card in table C.6. If someone else would fill in this table different outcomes might be possible.

C.2.2 Weight factors

The weight factors are different per scenario, so it is chosen to only describe scenario A. Two tables are needed in order to find the calculated weight factors. These are table C.7 and table C.8. These tables can also be found in the `Excel`-sheet. For the ease, the table C.7 is programmed such that only part of the `Excel`-sheet can be filled in and the weight factors will automatically be calculated. The boxes of table B.10 that need to be filled in are all the boxes *above* the diagonal value 1. The `Excel`-sheet automatically fills in the boxes *below* the diagonal.

One indicator is taken as example, namely the material damage. In case the material damage is compared to itself the value is 1, as the level of importance is equal. If material damage is compared to the immaterial damage it will score 1/4, meaning that immaterial damage is relatively more important than material damage. This is because reducing fatalities is seen as the relative most important objective for the authorities during a disaster. To compare the reduction of the material damage with the reduction of the probability, the material damage is seen as more important but almost equally as important and therefore scores 2. Further on the material damage is seen as relatively more important than all the other indicators. If some criterion is seen as just a little more important, then it should be rated with a lower number, like the involved costs and the accessibility by roads. If something is less important than the criterion to be compared with it should be given a higher number, like in the case of the aesthetic acceptance and preservation of biodiversity. The number tells you how much more important or less important a certain criterion is in relation with the other. In table C.7 each value for the weight factor is seen for scenario A.

In table C.8 the values are divided by the column sums. The reason behind this principle is to normalise the values. The total weight factors can be seen in grey. These values are the values that have been used in table C.6 in combination with the rated alternatives to end up with a total score on which a ranking is based. This will be explained in the next section below.

C.2.3 Ranking alternatives

In table C.9 the weight factors are multiplied by the scores of table C.6. The results can be seen in the bottom part of the table, where all the scores have been added together. The total score for each measure can be ranked from 1 to 14. The lowest rank is given to the prevention of relative sea level rise for this specific scenario. For other scenarios this method resulted in different outcomes which have been shown in table 13.3. Often there are multiple solutions of which the final scores are very close together. It is therefore recommended to implement one of the measures together with other measures such that a solution package can be created. These packages have been described in section 13.5.

Criteria \ Measures	Weight	Null solution: current measures	Dike	Storm surge barrier	Flood wall traditional	Flood wall integrated	Elevation by stilts	Elevation of roads	Limit/ prevent RSLR	Drainage system	Evacuation optimum	Evacuation medium	Evacuation minimum	Sandbags	Temporary defences (area)	Temporary defences (building)
Material damage	1.331	1	5	4	5	5	3	1	2	2	1	1	1	4	4	5
Immaterial damage	3.377	1	5	4	5	5	4	3	2	2	5	4	3	4	4	2
Probability	2.216	2	5	4	4	5	2	2	3	2	2	2	2	3	4	3
Initial costs	1.338	5	2	1	3	2	3	2	2	3	4	4	5	4	2	2
Operational costs	0.881	5	5	3	5	5	5	5	5	5	2	3	4	3	4	4
Maintenance costs	1.003	5	4	2	4	4	5	5	3	3	5	5	5	5	3	3
Implementation time	0.536	5	1	1	1	1	3	2	4	3	3	4	5	4	4	4
Available space	0.723	5	4	4	4	4	5	4	3	4	5	5	5	5	5	5
Aesthetics acceptance	0.197	4	3	4	1	4	5	4	5	5	5	5	5	4	4	4
Disturbance for local residents	0.474	5	3	4	3	3	4	4	5	5	5	5	5	5	5	5
Preservation of biodiversity	0.159	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
Hindrance for ships	0.288	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
Accessibility by roads	0.477	3	3	3	3	3	3	5	3	3	4	4	3	3	3	3

Table C.6: Scorecard Dala scenario A

Criteria / Criteria	Material damage	Immaterial damage	Probability	Initial costs	Operational costs	Maintenance cost	Implementation time	Available space	Aesthetics acceptance	Disturbance for local residents	Preservation of biodiversity	Hindrance for ships	Accessibility by roads
Material damage	1	1/4	2	2	2	2	2	3	6	2	7	5	1
Immaterial damage	4	1	4	6	6	6	5	5	7	9	9	9	5
Probability	1/2	1/4	1	5	5	5	6	4	8	7	9	7	6
Initial cost	1/2	1/6	1/5	1	4	3	4	3	5	4	6	5	5
Operational cost	1/2	1/6	1/5	1/4	1	1	3	1/2	5	3	6	5	5
Maintenance cost	1/2	1/6	1/5	1/3	1	1	4	3	5	3	6	5	4
Implementation time	1/2	1/5	1/6	1/4	1/3	1/4	1	1/3	4	2	4	3	2
Available space	1/3	1/5	1/4	1/3	2	1/3	3	1	4	3	5	3	1
Aesthetics acceptance	1/6	1/7	1/8	1/5	1/5	1/5	1/4	1/4	1	1/4	2	1/4	1/4
Disturbance for local residents	1/2	1/9	1/7	1/4	1/3	1/3	1/2	1/3	4	1	4	5	1
Preservation of biodiversity	1/7	1/9	1/9	1/6	1/6	1/6	1/4	1/5	1/2	1/4	1	1/2	1/3
Hindrance for ships	1/5	1/9	1/7	1/5	1/5	1/5	1/3	1/3	4	1/5	2	1	1
Accessibility by roads	1	1/5	1/6	1/5	1/5	1/4	1/2	1	4	1	3	1	1
Total	9.84	3.08	8.71	16.18	22.43	19.73	29.83	21.95	57.50	35.70	64.00	49.75	32.58

Table C.7: Weight factors 1

Criteria \ Criteria	Material damage	Immaterial damage	Probability	Initial costs	Operational costs	Maintenance cost	Implementation time	Available space	Aesthetics acceptance	Disturbance for local residents	Preservation of biodiversity	Hindrance for ships	Accessibility by roads	Total
Material damage	0.102	0.081	0.230	0.124	0.089	0.101	0.067	0.137	0.104	0.056	0.109	0.101	0.031	1.331
damage	0.406	0.325	0.459	0.371	0.267	0.304	0.168	0.228	0.122	0.252	0.141	0.181	0.153	3.377
Probability	0.051	0.081	0.115	0.309	0.223	0.253	0.201	0.182	0.139	0.196	0.141	0.141	0.184	2.216
Initial cost	0.051	0.054	0.023	0.062	0.178	0.152	0.134	0.137	0.087	0.112	0.094	0.101	0.153	1.338
Operational cost	0.051	0.054	0.023	0.015	0.045	0.051	0.101	0.023	0.087	0.084	0.094	0.101	0.153	0.881
Maintenance cost	0.051	0.054	0.023	0.021	0.045	0.051	0.134	0.137	0.087	0.084	0.094	0.101	0.123	1.003
Implementation time	0.051	0.065	0.019	0.015	0.015	0.013	0.034	0.015	0.070	0.056	0.063	0.060	0.061	0.536
Available space	0.034	0.065	0.029	0.021	0.089	0.017	0.101	0.046	0.070	0.084	0.078	0.060	0.031	0.723
Aesthetics acceptance	0.017	0.046	0.014	0.012	0.009	0.010	0.008	0.011	0.017	0.007	0.031	0.005	0.008	0.197
Disturbance for local residents	0.051	0.036	0.016	0.015	0.015	0.017	0.017	0.015	0.070	0.028	0.063	0.101	0.031	0.474
Preservation of biodiversity	0.015	0.036	0.013	0.010	0.007	0.008	0.008	0.009	0.009	0.007	0.016	0.010	0.010	0.159
Hindrance for ships	0.020	0.036	0.016	0.012	0.009	0.010	0.011	0.015	0.070	0.006	0.031	0.020	0.031	0.288
Accessibility by roads	0.102	0.065	0.019	0.012	0.009	0.013	0.017	0.046	0.070	0.028	0.047	0.020	0.031	0.477
Total	1	1	1	1	1	1	1	1	1	1	1	1	1	

Table C.8: Weight factors 2

Criteria	Null solution: current measures	Dike	Storm surge barrier	Flood wall traditional	Flood wall integrated	Elevation by stilts	Elevation of roads	Limit/ prevent RSLR	Drainage system	Evacuation optimum	Evacuation medium	Evacuation minimum	Sandbags	Temporary defences (area)
Material damage	1.33	6.66	5.33	6.66	6.66	3.99	1.33	2.66	2.66	1.33	1.33	1.33	5.33	5.33
Immaterial damage	3.38	16.89	13.51	16.89	16.89	13.51	10.13	6.75	6.75	16.89	13.51	10.13	13.51	13.51
Probability	4.43	11.08	8.86	8.86	11.08	4.43	4.43	6.65	4.43	4.43	4.43	4.43	6.65	8.86
Initial costs	6.69	2.68	1.34	4.01	2.68	4.01	2.68	2.68	4.01	5.35	5.35	6.69	5.35	2.68
Operational costs	4.40	4.40	2.64	4.40	4.40	4.40	4.40	4.40	4.40	1.76	2.64	3.52	2.64	3.52
Maintenance costs	5.01	4.01	2.01	4.01	4.01	5.01	5.01	3.01	3.01	5.01	5.01	5.01	5.01	3.01
Implementati on time	2.68	0.54	0.54	0.54	0.54	1.61	1.07	2.15	1.61	1.61	2.15	2.68	2.15	2.15
Available space	3.62	2.89	2.89	2.89	2.89	3.62	2.89	2.17	2.89	3.62	3.62	3.62	3.62	3.62
Aesthetics acceptance	0.79	0.59	0.79	0.20	0.79	0.99	0.79	0.99	0.99	0.99	0.99	0.99	0.79	0.79
for local residents	2.37	1.42	1.89	1.42	1.42	1.89	1.89	2.37	2.37	2.37	2.37	2.37	2.37	2.37
Preservation of biodiversity	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48
Hindrance for ships	0.86	0.86	0.86	0.86	0.86	0.86	0.86	0.86	0.86	0.86	0.86	0.86	0.86	0.86
Accessibility by roads	1.43	1.43	1.43	1.43	1.43	1.43	2.39	1.43	1.43	1.91	1.91	1.43	1.43	1.43
Total	37.47	53.93	42.57	52.65	54.12	46.24	38.36	36.59	35.90	46.60	44.64	43.54	50.18	48.60
Ranking	**13**	**2**	**10**	**3**	**1**	**7**	**12**	**14**	**15**	**6**	**8**	**9**	**4**	**5**

Table C.9: Ranking alternatives

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