

UNIVERSITY OF GRONINGEN

SOFTWARE ARCHITECTURE

GROUP 3

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## Smart Flood Monitoring

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## Revision History

<b>Version</b>	<b>Author</b>	<b>Date</b>	<b>Description</b>
0.1	all	06-09-15	Setting up the working environment and the initial document structure. Draft versions of the first four chapters created, which are (respectively) Context, Architectural business information, Requirements and Analysis.
0.1.2	Menninga, ...	10-09-15	First version of functional requirements
0.1.3	Joris & Eedema	13-09-15	Changed the context and enhanced the business information
0.2	Brandsma Guntur	13-09-15 13-09-15	Updated the requirements part Updated the stakeholder of requirements part
0.2.1	Menninga Brandsma Klinkenberg & Eedema	17-09-15 17-09-15 17-09-15	Updated the functional requirements Updated architectural vision and use-cases Updated technical requirements, some formatting, started work on the first two decisions
0.2.2	Menninga	19-09-15	Added and updated functional requirements
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	Putra	19-09-15	Processed feedback, revised the stakeholder, and added decision on database selection.
0.3	Menninga Brandsma	23-09-15 24-09-15	Improved functional requirements after feedback Revised architectural vision, extended and improved use-cases
	Menninga	24-09-15	Changed layout of the risk assessment section
	Fakambi	24-09-15	Improvements to the non-functional requirements
	Eedema	24-09-15	Improvements to the business part
	Menninga	24-09-15	Changed layout of the risk assessment section
	Putra	24-09-15	Improved stakeholder with new quality attributes. Added key-drivers after stakeholder.
	Menninga	26-09-15	Complemented and improved non-functional requirement section Removed some obsolete functional requirements Improved risk assessment section
	Putra	26-09-15	Business rationale, chapter 5,6,7.
	Brandsma	27-09-15	Improved some figures. Improved chapter 4. Reviewing.

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# 1 System Context

We are the architecture team of the company RugSAG3. Our team is specialized in making smart systems for environmental monitoring.

All around the world, natural disasters cause a lot of trouble. These disasters can result in catastrophic events that cause deaths and require a huge amount of money to repair the damages caused. People lack the knowledge on when the disaster is about to happen, how to properly prepare and how to properly act during such a disaster.

Climate change and extreme weather phenomena cause these disasters to get worse over time. Every year the amount of these disasters increases and they become increasingly more severe. This causes the damage of the natural disasters to increase, which means that there is a great need for a system that can reduce this damage and helps the people during natural disasters like these. The system that we develop aims to do this. The goal of our first product is to:

1. save lives,
2. reduce damage costs,
3. reduce the social consequences.

To achieve the aforementioned goals, the system will provide predictions with regard to upcoming floods.

The first release of this system that we, as the architecting team of RugSAG3 design, will only support floods as a natural disaster. The system will provide warnings and guidance to the necessary people before and during a flood. By using various kinds of sensors, like vehicles and control units, this system monitors certain areas. If something suspicious happens, the system will check and verify the information in order to not give false flood warnings. When a flood indeed occurs (or will occur), the system provides warnings and guidance to the necessary people during and, if possible, before a flood.

When this flood monitoring system works as planned and shows that it can indeed reduce the damage of floods, RugSAG3 will extend the systems functionality by adding support for the monitoring of other kinds of natural disasters and situations that desire a monitoring system.

Over time, the system will reduce social, financial and human losses of natural disasters, starting with floods. This will revolutionize the way we think about natural disasters. Though the market around environmental monitoring is very competitive, this system aims at being a core part of future monitoring systems by being as dynamic and flexible as possible. Thereby allowing new features to be added easily, allowing the system to grow over time, including new upcoming user needs.

## 2 Architectural business information

The following section describes the different aspects of the business environment of the Smart Flood Monitor. First we will explain our vision and why there is place for us at the market.

After this the product and its stakeholders will be explained. This chapter is completed with a more detailed look at the business model and some models about the market and the financial prospect.

### 2.1 Business opportunity

There are many natural disasters happening each year all over the world. Each year these disasters take lives, destroys a lot of properties, and cause social disturbance. Looking for example at the Indian ocean's tsunami in 2004, it looks that the damage could have been significantly reduced if the necessary people were warned[?, ?].

In the future more floods are expected because of global warming[?]. The rise of the sea level is a consequence of global warming. Another consequence is the increase of extreme weather events, for instance heavy rainfall. It is expected that natural disasters will cause 300 billion in losses annually in the upcoming decade[?]. This justifies to invest a high amount of money to minor the losses of a flood. Not only the losses in terms of money, but more importantly lives, and also social impact.

The increasing threat of the floods is the basis for our vision. RugSAG3 has the following vision: No people in the world will be harmed by floods. We want to find solutions so floods does not take lives, cause social consequences, and damage properties.

The mission of RugSAG3 is to design a flood warning system in order to save lives and reduce costs. A next generation reliable flood monitoring and warning system will help lower the catastrophic impact of floods. The system will predict imminent floods and send out people in order to reduce the impact of a flood. In the future the system should be able to monitor other kinds of disasters and send out warnings.

The Netherlands is a country that is situated for large parts(26%) under the sea level[?]. Using dikes and other solutions they protect their country against the water. The increasing sea level causes extreme danger in the Netherlands. It is important that they can monitor how dangerous imminent floods are and take action if things are looking to wrong. These properties of the Netherlands make it an ideal market to start deploying our system.

### 2.2 Business rationale

RugSAG3 will develop a new smart flood warning system to minimize the damage caused by floods. As previously mentioned, in the Netherlands the protection against floods is an important issue, because major part of the country itself is actually below sea level. Global warming will increase the urgency of this issue. Thus, the people within the Netherlands must be seriously protected against floods. The flood warning system will detect floods, warn people and governmental institutions located in the disaster area and provide guidance to the safety region.

RugSAG3 is a new player within the flood warning system domain. However, to gain significant market share and to compete against the existing player in the market, RugSAG3 will launch a reliable and adequate product that uses the newest technologies by using sensors and automated systems. RugSAG3 will also use hardware which is already on the market and is already tested as well. Buying third party hardware will also speedup the development of the system and lower the development costs.

It is important to evaluate the strengths and weaknesses of RugSAG3. Using this evaluation, we can reflect ourselves with respect to the competitors, which will lead to a better understanding of the opportunities and threats RugSAG3 owns in the market. We map our position on the market by using SWOT-analysis. This analysis maps our strengths, weaknesses, opportunities, and threats. The results of our analysis is shown in ??.

<b>STRENGTHS</b>	<b>WEAKNESSES</b>
<ul style="list-style-type: none"> <li>• Adjustable system that is future proof</li> <li>• Having a low selling price. Lower than the competitors</li> <li>• Diverse team with several skills in IT and management</li> <li>• Having a good management team</li> <li>• Frequent discussion with technical and business experts in the field.</li> <li>• Experience with working with sensors</li> <li>• Diverseness of cultures in the development team</li> </ul>	<ul style="list-style-type: none"> <li>• Complexity of decision making</li> <li>• New project team</li> <li>• No experience with creating environmental monitoring systems</li> <li>• No domain knowledge of floods</li> </ul>
<b>OPPORTUNITIES</b>	<b>THREATS</b>
<ul style="list-style-type: none"> <li>• Due to climate change, the market will grow and such a system becomes more urgent</li> <li>• Other kinds of natural disasters are threatening, which could be monitored</li> <li>• Smart sensors are a hot topic, new sensors will be developed. Making the system support and use the newest sensors allows it to obtain more, and a wider variety of valuable information</li> </ul>	<ul style="list-style-type: none"> <li>• High hardware costs</li> <li>• New competitors will enter the market because of a growing market</li> <li>• Climate change will force the system to be improved over time</li> <li>• External parties that affect our system could change or stop</li> </ul>

Table 2.1: SWOT analysis of Smart Flood Monitoring

The initial product price will be low in order to get a market share and prove the product in a real-time environment. By providing maintenance and updates in the future RugSAG3 will earn money to improve the product further and sell it to other potential customers. This in combination with the increasing need of a reliable warning system for imminent floods will result in a viable business. To extend the capability and the reliability, the system is also extendable with numerous additional and optional features.

To sum up, the unique selling points of our system are:

- Low initial product cost. This means customer can afford this system in a low price with basic functionality.
- High system extendability. Although the initial offer to the customer is a basic product, the system is actually highly extendable with additional support and feature

Citizens will get a notification in case of imminent flood — they will either receive notifications from the government or from the system directly through subscription. In this way, people will know when a certain area will be flooded, or when the flood is about to happen. These are some of unique features of our system, which will also drive the system to be successful. The main goal of this project, however, is to save lives, reduce costs and reduce social consequences. These main goals will be met when:

1. 99% of the people in a dangerous area regarding a flood, receive a warning message. This message must contain enough information for receivers to know whether they are safe or not and if not, how they can get to a safe location.
2. 99% of the people who receive a warning successfully get to a safe environment in time.
3. 99% of the people receiving information before or during a flood, find these messages helpful and reported that it guided them successfully in order to save extra lives and/or goods.

When the first version of Smart Monitoring is released and is used to start monitoring actual floods, its success will be measured according these statistics. Getting a warning message to the people who requested to be warned is the most important thing to do. Using this warning message, people can move to a safer location.

## 2.3 Product and service description

RugSAG3 offers a flood warning system. When a imminent flood is monitored by the sensors of the system a warning should be sent to governmental organizations and people within the danger area. Also a possibility of

guidance should be provided when a flood is happening to assist rescuers and guide inhabitants to safe areas. The guidance part will be done by third party application developers. The system will publish the data that these developers can use to build their service.

Basically the system will consist of four subsystems: monitor the state of dykes and water levels, analyze the data from the monitoring part to detect imminent floods, warn governmental organizations and inhabitants in the danger area, and provide data which third party developers can use to build applications which help search and rescue organizations and inhabitants for guidance.

The first subsystem (monitor the state of dykes and water levels) will consist of various sensors that are placed near and in dykes and water ways. The state of the dikes must be monitored continuously, i.e. pressure of the dyke. Also, sensors must be installed to monitored continuously the water level. The data of all the sensors will be sent to a server, in a safe location, to store all the data.

The second subsystem (analyze the data from the monitoring part to detect imminent floods) will analyze all the data from the sensors and data from weather forecasting service. Based on this data an algorithm will monitor continuously if there are dangerous situations.

The third subsystem (warn governmental organizations and inhabitants in the danger area) will send warning messages when the algorithm identified a dangerous situations. The safety region will receive a warning message that an area is in danger. Information like position, area, sort of danger and amount of danger will be send. The safety region will be responsible to take action based on this information. Inhabitants can receive warnings via sirens, mobile phone, radio, television.

The last subsystem (provides data to third party developers) will publish data that other companies can use to build applications. The data that will be published is mainly for provide guidance for emergency services and people which are in the dangerous area.

The service will consist of maintenance for the product and upgrades.

As described before, floods will be the first natural disaster the initial system supports. The system will be based on an architecture that other kind of disasters that can be monitored by sensors can be easily implemented. Natural disasters that can be monitored in the future by the system are: Volcano eruption, earthquakes, and slides. By implementing sensors and algorithm's for these natural disasters our system will become more viable for in the future. In figure there is an overview of the implementation of natural disasters over time.

### Business Plan , Roadmap and expansion of RUGSA3

#### **First release 2016 NETHERLANDS**

##### **2016-2018:**

Still focusing on flood

New features : Building our own application

Adding external input

Maintenance

Statistics about reliability

New sensors, New UAV's => more accuracy and follow the new technologies

**2018-2025 :** Expansion to Europe starting by countries which have high risk and history of floods ( documentation , studies in order to choose countries which really need our product , countries where this market doesn't exist yet or at least isn't in expansion => good business strategy ) => more production

Profit

Big data , new algorithm

**2025-2030** Expansion to the world starting by countries which have high risk and history of floods ( documentation, for instance Asia )

Work on others natural disasters like earthquakes , volcanoes.

## **2.4 System in the market**

All over the world floods are causing tremendous trouble to people. This makes that our system can be sold all over the world. First the system focuses on the Netherlands. When the system is working correctly other governments in the world must be informed about the system. First focusing on Europe and than other continents.

Third party application developers have the opportunity to build application that enables guidance for emergency services and people. First the focus is on finding one company that has experience with building such products. Then other software companies should get noticed about the system. The more third party applications are build, the better system will reach it's mission.

Safety regions are responsible when disasters are happening in the region. They consist of local governments, emergency services, the army, and water boards. Safety regions and the organizations that are part of the safety regions should be informed about the system. When they know about the system they can inform the government and put pressure to buy this system.

When a flood is happening and things go wrong inhabitants will ask governments what went wrong and state that they want to be better protected. They will pressure governments that they have the best flood warning system.

## 2.5 Financial model

The financial model will be a low product price. This in order to price the product low in the market. A service description for maintenance will be offered. Also updates will be sold to the customer

### 2.5.1 Software Architecture costs

The software architecture team of RugSAG3 consists of six members. Creating the architecture of the project is estimated to take ten weeks. All team members will spend 15 hours a week on the project. This totals  $6 * 10 * 15 = 1050$  working hours. Each working hour costs €150,-. Total spend on the software architecture is €157.500

### 2.5.2 Development costs

The costs of developing the system is approximated in table ??, shown below.

Description	Man hours
Get values from various sensors	160
Get weather forecasts	160
Flood prediction algorithm	3100
Warning messaging system	2000
Guidance information system	1500
Redundancy and fail over systems	1000
Testing & debugging	600
Release build	250
Overhead	1000
Total hours	9770

Table 2.3: Approximation of development costs

Development of the system comprises the development of several different aspects. For each of these aspects, table ?? shows an approximation of the hours needed for the development. Resulting in a total amount of 9770 hours needed to create the system.

The development is done by RugSAG3 self. Each member of the project team assigned to develop this system is paid €50 an hour. This results in a development cost of  $50 * 9770 = 488.550$ . As shown in the table below.

Description	Cost
Hours	9770
Cost per hour	€ 50
Total cost	€ 488.500

Table 2.5: Total costs of development

### 2.5.3 Hardware costs

Around 17.000 kilometres of dikes protect the Netherlands against flooding [?]. The monitoring system consists of MEMS sensor modules (e.g. GeoBeads) with a claimed life time of 10 years, which are installed with conventional CPT push-in techniques. Three sensors are installed per cross-section and a cross-section is installed every 100 m. Each CPT push-in costs about € 200 per sensor (Feitsma,2002)[?].The table below shows of this data.

Description	Value	UoM
Total length of all dikes to be monitored	250	km
Sensor cost	350	€
Installment cost per sensor	200	€
Distance between cross-sections	100	m
Sensors per cross-section	3	
Base installation cost factor like labor and wiring	0.2	
Period of investment	10	years

Table 2.7: Total costs of development. UoM=Unit of measurement

This results in an installation cost of: Installation cost per km=  $(350 + 200) \cdot 10 \cdot 3 \cdot (1 + 0.2) = € 16.830$   
 Installation cost=  $100 * 16.830 = 1.683.000$

The yearly maintenance and operation cost will be calculated as being a fraction of the installment cost.  
 Maintenance cost=  $0.2 \cdot 1.683.000 = 336.600$  per year

The system then needs several servers:

- Sensors
- State monitor server
- Danger check server
- Warning system server
- Guidance server

There are four servers and each server costs € 1.500. To enhance the availability, the servers will be redundantly set up four times. Resulting in a hardware cost for the servers of

Server cost=  $4 * 1500 * 4 = 24.000$ . The total hardware costs is shown in the table below.

Description	Cost
Installation costs	€ 1.683.000
Maintenance costs	€336.600
Server costs	€24.000
Total cost	€2.443.600

Table 2.9: Total hardware cost

## 2.5.4 Total costs

The total costs for the system is calculated in the table below.

Description	Cost
Software Architecture costs	€157.500
Development costs	€488.500
Hardware costs	€2.443.600
Total cost	€3.089.600

Table 2.11: Total cost of the system

So the total costs of the system is €3.089.600

## 2.6 Competitors

Siemens is a competitor that already has developed a flood-warning system in Belgium in 2006. When the system detects an imminent flood it sends a SMS to people that live near the rivers in order to warn them. The system is implemented in a small region, which consists of only 3 rivers. The total costs for this system were €230.000. Later on they continued engineering the system. The system uses sensor which measures: temperature, water pressure, and shifting. They participated with this system in the Urban Flood project from the EU. The strong point of this competitor is that they already have funding and also experience with building such a system. Siemens is the main competitor for RugSAG3. Their strength is that they already have a proven system in Belgium and have a lot of experience through participating in flood monitoring research projects. The opportunity for RugSAG3 is to engineer a flexible system that can be used in the future for other kind of disasters. Further on by selling the product at a low selling price and profit on the maintenance work and upgrades the Netherlands will be interesting in using the product.

Further there are Universities that do research on flood warning systems. At the Malaysian Institute Information Technology they developed a product prototype of a system called Intelligent Flood Information System via SMS. Waterlevel sensors are the only one they used. When there is a flood they send a warning SMS to people that are within the area. In the future this could become a competitor if they create a start-up or sell the idea to a company.

### 3 Requirements

This chapter will describe the vision and use it to derive stakeholders to be able to properly write use cases and stories. These will be used to extract functional, commercial, technical and evolution requirements. Afterwards, a risk assessment will take place, to ensure that the project is not at great risk.

#### 3.1 Architectural vision

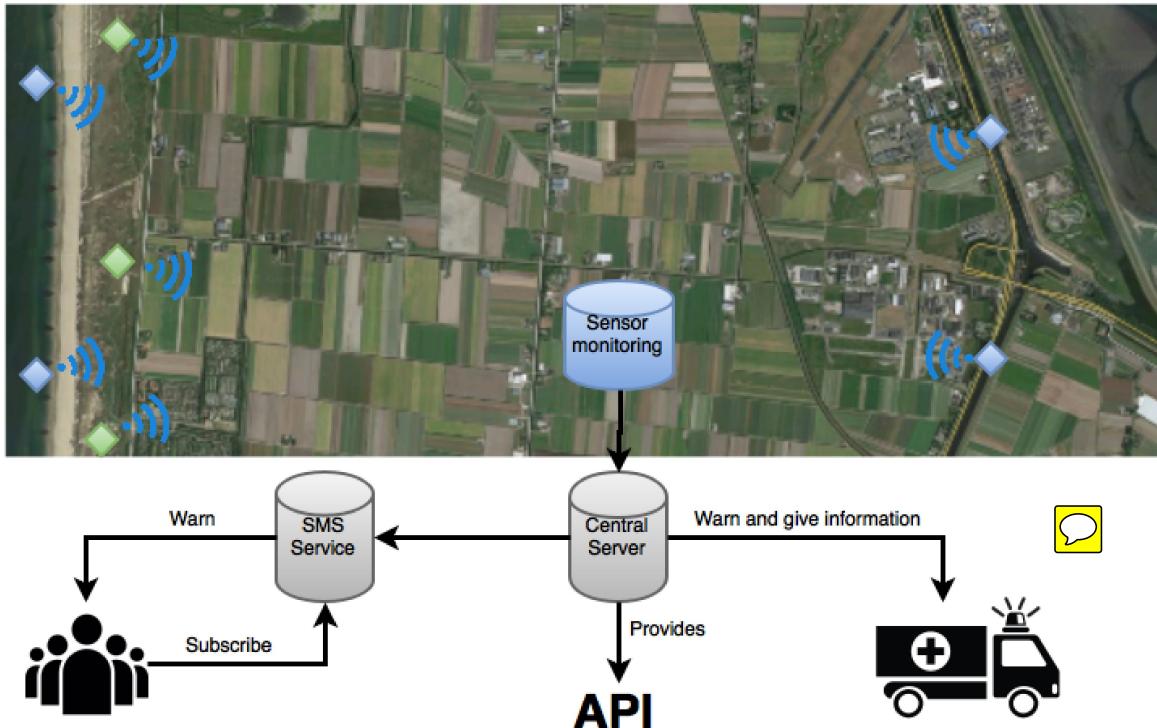


Figure 3.1: Schematic overview of the flood monitoring system

The smart flood monitoring system consists of multiple parts. These are represented in figure ???. First of all there is a monitoring part. This part monitors the current state of the environment. To achieve this, we need a lot of data. This data is obtained by sensors and weather data. We use sensors to get the current water level of waterways, these water sensors are shown in the figure as blue squares. We also measure the density and structure of dikes, this is done by pressure meters, temperature meters and tilt meters. These are represented as green squares. The data that is obtained through all sensors will be send to the central server. Here the information will be processed. The system then determines if there is an imminent flood.

In case of an imminent flood a warning will be issued to the government and the citizens who live in the threatened area. We do this by issuing a warning to the government. In their turn the government uses their infrastructure to warn the citizens. In the Netherlands this infrastructure consists of a siren system and an SMS-system. Besides this people can also apply for our SMS service. People who are subscribed to this service will receive a text message with more information about the imminent flood.

If people want to have more information on an imminent flood, they can always access the API. This API gives relevant raw data about imminent floods. To make a usable interface for the citizens, we want to cooperate with third party developers. These developers could create an application that can guide citizens to a save area.

## 3.2 Stakeholders and their concerns



This section defines all stakeholders of our system and describe the concerns of the stakeholders. A stakeholder might be a person, group of persons, or organization that are involved in our system. There are eight stakeholders, ranged from first parties to third parties stakeholders. We use several quality standards from "Software Requirements" book by Microsoft [?]. Those quality standards are described in ??.

Quality Attributes	Brief description
Availability	The extent to which the system's services are available when and where they are needed
Interoperability	How easily the system can interconnect and exchange data with other systems or components
Performance	How quickly and predictable the system responds to user inputs or other events
Reliability	How long the system runs before experiencing a failure
Security	How well the system protects against unauthorized access to the application and its data
Usability	How easy it is for people to learn, remember, and use the system

Table 3.1: Quality attributes of Software Architecture from "Software Requirements" Book [?].

There are six quality attributes, as can be seen in ??, for measuring stakeholders' concern regarding our system. Furthermore, we also add profitability as another quality standard to improve measuring stakeholders' concern. Detailed description of stakeholders and their concerns are explained below.



**Product owner** is concerned about performance, reliability, and profitability. Product owner funds the whole project. Product owner highly concerns about the profitability. Thus, to gain big market share and extract large profit from this product, product owner has to make this product reliable. Furthermore, to compete with other competitors in this area, product owner also concerns about the performance of the system.

**Developers** are concerned about availability, interoperability, performance, reliability, and security. We, the architect team of RugSAG3 company, are also part of this. This stakeholder is responsible for the development of the systems until its ready for production. Including architecting, designing, analyzing, testing and implementing this Smart Flood Monitoring System.

**Competitors** are concerned about performance, reliability, security, and profitability. Competitors give negative effect on the system because competitors will be aiming on the same customer target. On the other hand, competitors are also triggering us to make a really good system in order to be able to compete with them and to save more lives. Thus, competitors must also be kept in consideration.

**Government** is concerned about availability, interoperability, performance, reliability, and security. Government will be the main customer of this product, specifically, The Dutch Ministry of Infrastructure and the Environment. Government will be part of mitigation when the flood is imminent. This system will help the government by notifying them when this system detects flood and what is the recommendations to do next along with some data regarding this system's findings.

**Citizens** are concerned about availability, reliability, usability. The Dutch residents are indirect user of this systems. However, they are also able to directly subscribe to this service and thus they want this system to be adaptable to their current technological viewpoint. Furthermore, they want this system to always be available and run correctly and notify them with the reliable information.

**Insurance companies** are concerned about performance, reliability, and security. The damages caused by flood sometimes are also covered by the insurance companies. Thus, the insurance companies will also be part of the stakeholders and they will make sure that their business is running well.

**Local companies** are concerned about interoperability, reliability, and usability. Local companies will also be affected by the flood, they also have a lot of resources which are in danger. Local companies want to know whether or not this system is reliable so that they can arrange a proper action sets when the flood comes

to save their assets. Moreover, local companies are also willing this system to be as adaptable as possible to their current technological viewpoint.

**Emergency services** are concerned about interoperability, performance, reliability, and security. Emergency services are important when any accident happens, including flood. They will be really concerned about the thing that makes this system reliable, inter-operable to their current system.

?? illustrates the stakeholder concern matrix. In our approach every stakeholders are equally the same. Thus, each stakeholder receives 100 points in total that has to be distributed among all the concerns.

Stakeholder	Concerns						
	Availability	Interoperability	Performance	Reliability	Security	Usability	Profitability
Product owner			30	30			40
Developers	10	10	20	30	20		
Competitors			20	30	20		30
Government	20	10	25	25	20		
Citizens	30			40		30	
Insurance companies			30	35	35		
Local companies		30		35		35	
Emergency services		15	30	30	25		
Total	60	65	155	255	90	65	70

Table 3.2: Matrix of stakeholders concern.

As can be seen from ??, the most important concern of our system is the reliability, following performance as the second most important concern. This is also identical with our significant key driver.

### 3.3 Key-drivers

?? has shown the concerns of the stakeholders of our system. Every stakeholder is equally the same in our system. Thus, each stakeholder receives 100 points to be distributed to all quality attributes. By doing this, important quality attributes can be determined and those will be the key-drivers of our system.

It is clear that **reliability** is by far the most important quality attribute of our system, followed by **performance** as the second most important, and **security** as the third most important quality attribute. Thus, those three quality attributes will be the *key-drivers* of our system. We decided to choose only three quality attributes as the key drivers for our system because choosing more than three may possibly drive our system architecture to be more complex and consume more time to be developed.

## 3.4 Stories and use-cases



This section will give an overview of the different use-cases. Figure ?? displays the use-case diagram. This provides an overview of the use-cases with their actors. In the subsections below, the architectural important use-cases are explained in more detail.

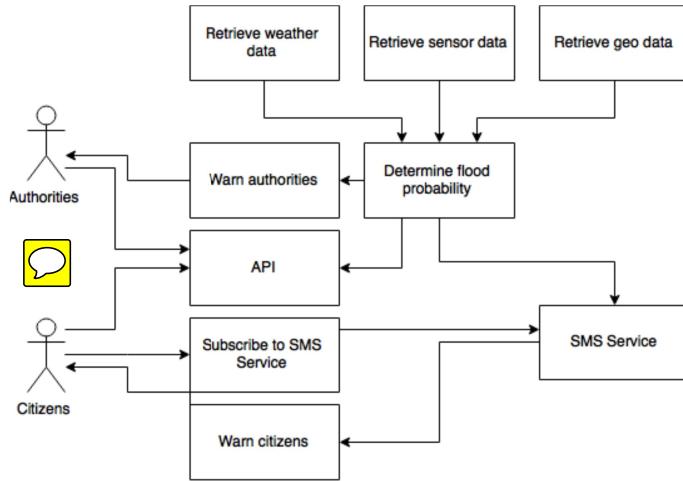


Figure 3.2: Use-case diagram

### 3.4.1 Retrieve sensor data

<b>Number</b>	UC-1
<b>Description</b>	The system receives data from the different sensors deployed
<b>Stakeholders and interests</b>	<ul style="list-style-type: none"> <li><b>Developers:</b> Developers need to work with the sensor data</li> </ul>
<b>Primary actor</b>	System
<b>Scope</b>	Monitoring part of the system
<b>Level</b>	Sub process
<b>Precondition</b>	The sensor is connected to a processing unit
<b>Main success scenario</b>	<ol style="list-style-type: none"> <li>1. The sensor does a measurement</li> <li>2. The sensor sends the data to a monitoring unit</li> <li>3. The monitoring unit normalizes the received data</li> <li>4. The monitoring unit sends the normalized data to the database</li> <li>5. The database stores the data</li> </ol>
<b>Postcondition</b>	The database received and stored the sensor data
<b>Alternatives</b>	<ol style="list-style-type: none"> <li>2a. The data can't be sent. Data will be lost The use-case ends</li> </ol>
<b>Related requirements</b>	FR-1, FR-2, FR-3, FR-4, FR-5, FR-6

### 3.4.2 Retrieve weather data

<b>Number</b>	UC-2
<b>Description</b>	The system receives data from the weather forecast service
<b>Stakeholders and interests</b>	<ul style="list-style-type: none"> <li>• <b>Developers:</b> Developers would like to have a simple to use API</li> </ul>
<b>Primary actor</b>	System
<b>Scope</b>	Monitoring part of the system
<b>Level</b>	Sub process
<b>Precondition</b>	The system needs external weather data to predict floods
<b>Main success scenario</b>	<ol style="list-style-type: none"> <li>1. The processing unit determines it needs forecast weather data</li> <li>2. A call is made to the weather forecast service</li> <li>3. The weather forecast service returns the requested data</li> </ol>
<b>Postcondition</b>	The system received the forecast data
<b>Alternatives</b>	<p>3a. The data can't be returned.  Repeat this process with another weather forecast service.  If none are available, proceed monitoring without weather forecast data.  After 5 minutes try to reconnect.</p>
<b>Related requirements</b>	FR-7

### 3.4.3 Citizens subscribe to the SMS service

<b>Number</b>	UC-3
<b>Description</b>	Citizens can subscribe to the SMS service, so when a flood happens they will get a direct text message
<b>Stakeholders and interests</b>	<ul style="list-style-type: none"> <li>• <b>Citizens:</b> Citizens want to be warned as soon as possible.</li> </ul>
<b>Primary actor</b>	Citizen
<b>Scope</b>	Warning part of the system
<b>Level</b>	Sub process
<b>Precondition</b>	Citizen has a mobile phone and is not subscribed to the SMS service
<b>Main success scenario</b>	<ol style="list-style-type: none"> <li>1. Citizen sends a text message to our service</li> <li>2. The SMS service receives the text message</li> <li>3. The SMS service stores the phone number in the database</li> <li>4. A text message is sent back to the citizen with confirmation</li> </ol>
<b>Postcondition</b>	Citizen is subscribed to the SMS service
<b>Alternatives</b>	<ol style="list-style-type: none"> <li>2a. The text message is not received The use-case ends</li> </ol>
<b>Related requirements</b>	FR-16

### 3.4.4 Determining flood probability

<b>Number</b>	UC-4
<b>Description</b>	The central processing unit calculates the probability of a flood
<b>Stakeholders and interests</b>	<ul style="list-style-type: none"> <li>• <b>Developers:</b> Developers have to work on this part</li> <li>• <b>Emergency Services:</b> Emergency services want to know when a flood warning is triggered</li> <li>• <b>Government:</b> The government would also like to know when a flood warning is triggered</li> </ul>
<b>Primary actor</b>	System
<b>Scope</b>	Monitoring and warning part of the system
<b>Level</b>	Main process
<b>Precondition</b>	The sensor data is available
<b>Main success scenario</b>	<ol style="list-style-type: none"> <li>1. The central processing unit gets the latest sensor data from the database</li> <li>2. The central processing unit gets the latest weather forecast data</li> <li>3. The central processing unit calculates the probability of a flood</li> <li>4. The central processing unit stores the probability value in the database</li> <li>5. The central processing unit determines that a flood is imminent based on the probability value</li> <li>6. A warning is sent to the emergency services</li> <li>7. A warning is sent to the government</li> <li>8. A warning is sent to the citizens</li> </ol>
<b>Postcondition</b>	The flood probability is calculated and stored. If the probability exceeds a certain threshold, a warning is sent to the authorities and citizens
<b>Alternatives</b>	5a. The probability is not above the threshold The use-case ends
<b>Related requirements</b>	FR-8

### 3.4.5 Warn citizens in case of an imminent flood

<b>Number</b>	UC-5
<b>Description</b>	Citizens who are subscribed to the SMS service will be warned through text messages in case of an imminent flood
<b>Stakeholders and interests</b>	<ul style="list-style-type: none"> <li>• <b>Citizens:</b> When they are subscribed, they want to be warned in case of an imminent flood</li> </ul>
<b>Primary actor</b>	Citizen
<b>Scope</b>	Warning part of the system
<b>Level</b>	Sub process
<b>Precondition</b>	There is an imminent flood and citizen is subscribed to the SMS service
<b>Main success scenario</b>	<ol style="list-style-type: none"> <li>1. The processing unit sends a warning about an imminent flood to the SMS service</li> <li>2. The SMS service composes a list with phone numbers to warn</li> <li>3. The SMS service sends a warning to all phone numbers on the list</li> </ol>
<b>Postcondition</b>	The citizens who are subscribed received a warning
<b>Alternatives</b>	<p>3a. A message can't be sent to the citizen          Wait a minute and resend          The use-case ends</p>
<b>Related requirements</b>	FR-17



### 3.4.6 Warn authorities in case of an imminent flood

<b>Number</b>	UC-6
<b>Description</b>	Government and emergency services receive a warning about an imminent flood
<b>Stakeholders and interests</b>	<ul style="list-style-type: none"><li>• <b>Government:</b> The government wants to warn the citizens in case of a flood</li><li>• <b>Emergency services:</b> The emergency services want to help the citizens in case of a flood</li></ul>
<b>Primary actor</b>	Government, Emergency services
<b>Scope</b>	Warning part of the system
<b>Level</b>	Sub process
<b>Precondition</b>	There is an imminent flood
<b>Main success scenario</b>	<ol style="list-style-type: none"><li>1. The processing unit determines what area will be under water in case of a flood</li><li>2. The processing unit determines how many people will be affected by the imminent flood</li><li>3. The processing unit predicts how the flood will develop in the following period</li><li>4. The processing unit will create a map based on the current state and predictions</li><li>5. The processing unit sends the map to the government and emergency services</li></ol>
<b>Postcondition</b>	A map with current and predicted data is sent to the government and emergency authorities
<b>Related requirements</b>	FR-10, FR-11, FR-12, FR-13, FR-14

### 3.5 Functional requirements



This section lists the functional requirements of the system.

Nr.	Prio	Description
FR-1	Must	The system is able to receive input from water level sensors. This information will be used to determine if there is an imminent flood.
FR-2	Must	The system is able to process input from water level sensors.
FR-3	Must	The system is able to receive input from pressure sensors of the dikes.
FR-4	Must	The system is able to perform an analysis for the pressure on the dikes based on the input from the pressure sensors.
FR-5	Must	The system is able to receive input from water level sensors of waterways.
FR-6	Must	The system is able to perform an analysis for the water level in the waterways based on the input from the water level sensors.
FR-7	Must	The system retrieves weather forecasting data from weather forecasting services, which consists of predictions about the precipitation and wind data. This is used by the system to help in determining when a flood becomes imminent.
FR-8	Must	The system is able to detect when a flood is imminent by combining the retrieved sensor data and weather forecasting data.
FR-9	Must	The system retrieves geographic information (road data and terrain height data) from an external API.
FR-10	Must	The system computes the area affected by a flood, in zones of 5 by 5 km, by using the location data of the sensors and geographic information.
FR-11	Must	The system is able to perform an analysis, resulting in an estimated expected water level for areas which are affected by a flood, based on the water level sensor data, geographic data and weather forecast information.
FR-12	Should	The system estimates how the water level in the areas affected by the flood will develop for every hour, up to 12 hours in the future.
FR-13	Should	The system can compute the number of civilians living in the areas affected by the flood.
FR-14	Must	When a flood is imminent, the system sends a warning to the emergency center. The warning contains information about the flood: the area affected by the flood, the expected water level in those areas, how the water level will develop in the coming hours and the number of civilians living in the affected area.
FR-15	Must	The system can compute a safe area, not affected by the flood, where citizens can be evacuated to in case of an (imminent) flood.
FR-16	Must	Citizens are able to subscribe to flood warnings about imminent floods.
FR-17	Must	Citizens who are subscribed for flood warnings are warned about imminent floods by text message.
FR-18	Must	The system can detect a faulty sensor, either when the sensor raises an error or when the data from the sensor is inconsistent with other sensor data.
FR-19	Must	There is a control panel, where maintainers of the system have access to.
FR-20	Must	The system reports faulty sensors, so they can be viewed in the control panel.
FR-21	Must	Warnings of the system can be viewed in the control panel
FR-22	Must	Errors of the system can be viewed in the control panel.
FR-23	Must	The readings of the sensors can be viewed in the control panel.
FR-24	Must	The system can make backups of its data (configuration data etc.).
FR-25	Must	The system can store created backups on a remote location.
FR-26	Must	The system can retrieve the backups it previously created.

FR-27	<b>Must</b>	The system can restore the backups it previously created.
FR-28	<b>Could</b>	The system is able to detect extreme weather phenomena, like storms etc.

## 3.6 Commercial non functional requirements

In this section commercial non functional requirements are presented.



Nr.	Prio	Description
CNFR-1	<b>Must</b>	The system is affordable. The initial price of the system is lower than 70% of the competitors price in the same market.
CNFR-2	<b>Must</b>	The sensors have a good quality, so we don't have to replace the sensors often. The expected lifetime of the sensors should be at least three years.

## 3.7 Technical non-functional requirements

This section describes the technical aspects that are important to the system as requirements. These requirements determine various APIs and programs that the system will rely on.

### 3.7.1 Reliability

Reliability is an important non-functional requirement for the system, and a key-driver of the architecture as well.

Nr.	Prio	Description
REL-1	<b>Must</b>	Data from the sensors is sent via a TCP connection
REL-2	<b>Must</b>	The system must have an uptime of 99.7%. This effectively means, that the system should not be down for more than 2 hours per month. $AV = \frac{MTTF}{MTTF+MTTR} = \frac{6 \text{ months}}{6 \text{ months} + 12 \text{ hours}} = \frac{4380 \text{ hours}}{4380+12 \text{ hours}} = 99.7\%$
REL-3	<b>Must</b>	The system must not experience a period of downtime, spanning more than 12 hours. Within twelve hours of the system going offline, it should be back up again.
REL-4	<b>Must</b>	The system must detect if a sensor supplies wrong measurements, which can be caused, e.g. by improper calibration or defects in the sensor.
REL-5	<b>Must</b>	The system must at no time fail to detect a flood when this flood becomes imminent ( <i>false negative</i> ).
REL-6	<b>Must</b>	The system must not detect a flood, when this flood is not there in reality ( <i>false positive</i> ), on average more than once per 5 years.

### 3.7.2 Resilience

The system needs to be resilient to recover from errors and mistakes without impacting the systems functionality.

Nr.	Prio	Description
RES-1	<b>Must</b>	The system recognizes failures within half an hour
RES-2	<b>Must</b>	The system recovers from failures without the Quality of Service or the functionality of the system being affected.
RES-3	<b>Must</b>	All system data must be backed up every 24 hours, so that in case of data loss, this data can be restored.
RES-4	<b>Must</b>	In case of a data loss, the data should be retrieved and restored from a backup within 2 hours.

RES-5	<b>Must</b>	Backup copies are stored in a secure location which is not in the same area as the system (50 km).
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### 3.7.3 Performance

Nr.	Prio	Description
PERF-1	<b>Must</b>	Data is transmitted from and to the system with a minimum average speed of 10 megabits per second
PERF-2	<b>Must</b>	The data transmission between the sensors and the system is on average at least 10 megabits per second for each sensor.
PERF-3	<b>Must</b>	The time for the system to compute if there is a flood or not according to a critical level and the data received from the sensors is at most 5 minutes.

### 3.7.4 Interoperability



The system has dependencies on several third-party systems and also allows third parties to retrieve information from it.

Nr.	Prio	Description
INTR-1	<b>Must</b>	The system pulls weather forecasts from at least two weather forecasting services.
INTR-2	<b>Must</b>	When the system detects a flood, it notifies the safety region through an API provided by them.
INTR-3	<b>Must</b>	The system sends out a SMS to all users who are subscribed to flood warnings using the mobile network.
INTR-4	<b>Must</b>	The system is able to connect to different types of sensors.
INTR-5	<b>Must</b>	The system is able to retrieve geographical data from an API.
INTR-6	<b>Must</b>	The system exposes an API, allowing third parties to develop applications using the systems data.
INTR-7	<b>Must</b>	The sensors are able to communicate with the system using a mobile broadband connection.

### 3.7.5 Security

The security of the system is very relevant to its success. The system should be secure, because unauthorized access can have a big impact on society (when e.g. false flood warnings are triggered).

Nr.	Prio	Description
SEC-1	<b>Must</b>	Access to the system is restricted to users, which are authorized and authenticated using a password protected user account.
SEC-2	<b>Must</b>	All communication to, from and within the system are encrypted.
SEC-3	<b>Must</b>	User account information is hashed using bcrypt after being salted with 128 randomly generated characters.
SEC-4	<b>Must</b>	The system is protected by a firewall that at least scans at the application layer, while also scanning for and mitigating DDoS attacks.
SEC-5	<b>Must</b>	The system communicates with its sensors via a REST API that only allows for HTTPS connection.

### 3.7.6 Scalability

The system has to be designed in a way that it can expand over time. Not only should it span larger geographic areas, but more functionality will be added later as well.

Nr.	Prio	Description
SCALE-1	Must	The database and services of the system should run in a cloud environment where they can scale, when the systems resource usage increases.
SCALE-2	Must	The system is configurable to run in different areas and with different sensors.
SCALE-3	Must	The system maintains the performance requirements when the geographic area the system covers is expanded.

## 3.8 Evolution requirements

When establishing the project, architects of the system listed a certain number of requirements which describe the features of the system. But due to environmental changes and end-users requests for example the requirements may evolve.

### ER-1 Changes in the display of the map

*Evolution of FR-19* Citizens who subscribed for flood warnings get a map with specific route information (according to their location) to a safe area through the API (in association with Google Map).

**ER-2 : Adding of external input** Citizens can contribute to the guidance by giving extra information(for example if they identified a safe route near their location) but this information will be checked by an operator (thanks to photograph by the UAV's for example). 

**ER-3 : New OS** The system is able to work with other operating systems than Linux, for example Windows and MacOS.

**ER-4 : New sensors** The system is able to work with new sensors technologies, which are coming on the market over the years.

### 3.9 Risk assessment



The system is confronted by several risks which are determined and mitigated in this section. Taking those risks into account allows to avoid them or at least reduce their impact. The risk management involves the identification of the risks, their probability and potential impact or consequences.

The tables below explain the meaning of the definition for probability and consequence.

Probability	Likelihood of occurrence
High	0.65 - 1.00
Medium	0.35 - 0.65
Low	0.00 - 0.35

Severity	Explanation
Severe	A risk that can lead to loss of live or casualties.
Significant	A risk that can lead to damages, can delay the project more than 3 months or causes one of the high-level requirements not to be fulfilled.
Moderate	A risk that can lead to one of the high-level requirements not to be fulfilled to an acceptable level.
Minor	A risk that can lead to one of the high-level requirements not being fully fulfilled, but still fulfilled in an acceptable level.

#### 3.9.1 Technical

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T-RISK1		The system does not detect a flood
Probability of occurrence	Low	
Consequences	Severe.	There can be a loss of human lives and damages, loss of trust in the system by end-users.
Prevention		Make sure the number of sensors is sufficient and that they are in good state (as low failure rate as possible, when necessary repair or replace them). Perform regular checks of the sensors.
Reaction		Make changes in the algorithm for the flood detection, improve the sensors used or add more sensors.

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T-RISK2		The system sends warnings of a non-existing flood (false positive)
Probability of occurrence	Low	
Consequences	Significant.	People can become more negligent to future messages and unneeded social disturbance can be caused.
Prevention		UAVs watching the area where the supposed flood is to confirm.
Reaction		Send a message as soon as the mistake is detected to tell the population/emergency center it was a false alert.

<b>T-RISK3</b>	The system cannot send messages to the necessary people because the communication platform is also destroyed by the flood
<b>Probability of occurrence</b>	Medium
<b>Consequences</b>	Severe. If the warning is not send, the area might not be evacuated timely. Potential loss of human lives, casualties and damages to property.
<b>Prevention</b>	
<b>Reaction</b>	Send the warning to the government using a different medium.

<b>T-RISK4</b>	Hacker gets access to the system
<b>Probability of occurrence</b>	Low
<b>Consequences</b>	Severe. The hacker may sent incorrect information deliberately during the flood. This can cause unneeded evacuation, but in the case of a flood also loss of human lives. The system is not reliable anymore.
<b>Prevention</b>	Change password and hash codes every three months. Hire specialists in the security field to audit the security system on a regular basis (penetration testing).
<b>Reaction</b>	Update the security system / change it. Find a new algorithm for the creation of password and hash codes.

### 3.9.2 Business

<b>B-RISK1</b>	Wrong estimation of the budget
<b>Probability of occurrence</b>	Medium
<b>Consequences</b>	Significant. The final product does not have the features expected.
<b>Prevention</b>	The team needs an accountant or at least someone taking care of the follow-up of the money. Make sure there are regular evaluations to keep track of the money flow.
<b>Reaction</b>	Remove some requirements or features of the product, or change the hardware components used.

<b>B-RISK2</b>	The money invested in the fabrication and achievement of the product/system is not covered by the sales (shortfall/deficit)
<b>Probability of occurrence</b>	Medium
<b>Consequences</b>	Moderate. Stopping the sale
<b>Prevention</b>	The team needs an accountant or at least someone taking care of the follow-up of the money.
<b>Reaction</b>	Adding more features to the product in order to make it more competitive in the market.

<b>B-RISK3</b>	Sensor becomes unavailable (is not sold anymore)
<b>Probability of occurrence</b>	Medium
<b>Consequences</b>	Moderate. Sensors will fail and need replacing over time, if new sensors are not available anymore, this becomes impossible.
<b>Prevention</b>	Choose a sensor that is not too old and is expected to be available for at least the next 5 years.
<b>Reaction</b>	Use a different sensor and modify the system so it can operate with this sensor.

### 3.9.3 Schedule

<b>S-RISK1</b>	The project is not finished at the deadline
<b>Probability of occurrence</b>	Low
<b>Consequences</b>	Significant. Pressure for all the team members, loss of credibility regarding the customers, selling a product with less features than expected.
<b>Prevention</b>	SRA , Schedule Risk analysis : Estimation of the duration of the project by its manager ( with the use of probability and statistics ) . Meeting for the team members every week to keep track of the timing and take decisions according to the deadline.
<b>Reaction</b>	Remove some requirements or features in order to finish the project as soon as possible.

# 4 Analysis

This chapter describes the analysis of the system. It lists the assumptions that are made about the system and its environment. Next, an overview of the high-level design decisions is given.

## 4.1 Assumptions

There are several assumptions made about the system and its environment:

1. The safety region / government has means to alert citizens in an area to evacuate.
2. The safety region is informed about our system and will alert citizens if needed when our system alerts the safety region.
3. People who are subscribed for flood warnings/guidance have a mobile phone that can receive text messages.
4. Sensors can be placed in the water ways and dikes in locations where they can provide representative measurements.
5. Information is available to the system with regards to the population density and terrain height in different areas.
6. Supplying information about the areas affected by the flood in a resolution of 5 by 5 km (as described in ??) is sufficient for the government/safety region to make decisions regarding alerting and evacuating citizens.
7. It is possible to predict the expected water level up to 12 hours in the future.
8. A weather forecasting API is available that provides precipitation and wind data.
9. The safety region provides an API, which can be used by the system to warn the safety region.

## 4.2 High-level Design Decisions

This section discusses the high-level design decisions.

Each decision is explained in a table. The arguments section of the table lists for each alternative a score for every important quality attribute. A higher score means a more favourable result. For example, a high score for costs means a low cost for the system.

Name	Operating system																																													
Decision	<b>DEC-1</b>																																													
Status	New																																													
Problem/Issue	The warning system software for the natural disasters need a platform to work on.																																													
Decision	The warning system will use Linux as a platform. Based on Unix, Linux is a free platform that has proven itself and is used by many servers. It's open source meaning that everyone can check out how it works.																																													
Alternatives	<p><i>Windows</i>            Operating system is a closed platform developed by one of the biggest tech companies who provide a big development environment with it.</p> <p><i>OpenBSD</i>            A Unix-based system that is famous for its proactive security and runs most of the Linux applications. However, some software packages aren't certified to run on OpenBSD, but are for Linux.</p>																																													
Arguments	<table border="1"> <thead> <tr> <th></th> <th>Reliability</th> <th>Resilience</th> <th>Performance</th> <th>Interoperability</th> <th>Security</th> <th>Scalability</th> <th>Cost</th> <th>Score</th> </tr> </thead> <tbody> <tr> <th>Weight</th> <td>1</td> <td>1</td> <td>1</td> <td>1</td> <td>1</td> <td>1</td> <td>1</td> <td></td> </tr> <tr> <th>Linux</th> <td>4</td> <td>4</td> <td>4</td> <td>4</td> <td>4</td> <td>4</td> <td>5</td> <td>29</td> </tr> <tr> <th>Windows</th> <td>3</td> <td>2</td> <td>3</td> <td>2</td> <td>3</td> <td>3</td> <td>1</td> <td>17</td> </tr> <tr> <th>OpenBSD</th> <td>5</td> <td>4</td> <td>4</td> <td>3</td> <td>5</td> <td>4</td> <td>3</td> <td>28</td> </tr> </tbody> </table>		Reliability	Resilience	Performance	Interoperability	Security	Scalability	Cost	Score	Weight	1	1	1	1	1	1	1		Linux	4	4	4	4	4	4	5	29	Windows	3	2	3	2	3	3	1	17	OpenBSD	5	4	4	3	5	4	3	28
	Reliability	Resilience	Performance	Interoperability	Security	Scalability	Cost	Score																																						
Weight	1	1	1	1	1	1	1																																							
Linux	4	4	4	4	4	4	5	29																																						
Windows	3	2	3	2	3	3	1	17																																						
OpenBSD	5	4	4	3	5	4	3	28																																						

Table 4.1: Decision – Operating system

<b>Name</b>	<b>Connectivity of the sensors</b>																																																						
<b>Decision</b>	<b>DEC-2</b>																																																						
<b>Status</b>	<b>New</b>																																																						
<b>Problem/Issue</b>	The sensors need to deliver their data to the system and are located outdoors with at least 100m distance between each other.																																																						
<b>Decision</b>	The sensors will send their data to the system using mobile broadband. Using cellphone towers to communicate with the system.																																																						
<b>Alternatives</b>	<p><i>Landline</i>            Connecting the sensors to the telephone network and use that network to communicate with the server.</p> <p><i>Satellite</i>            Set up a satellite connection between the sensors and the system.</p> <p><i>Direct lines</i>            Connection the sensors to the system by drawing a cable from all sensors to the system.</p>																																																						
<b>Arguments</b>	<table border="1"> <thead> <tr> <th></th> <th>Reliability</th> <th>Resilience</th> <th>Performance</th> <th>Interoperability</th> <th>Security</th> <th>Scalability</th> <th>Cost</th> <th>Score</th> </tr> </thead> <tbody> <tr> <td>Weight</td> <td>1</td> <td>1</td> <td>1</td> <td>1</td> <td>1</td> <td>1</td> <td>1</td> <td></td> </tr> <tr> <td>Mobile broadband</td> <td>4</td> <td>4</td> <td>4</td> <td>4</td> <td>2</td> <td>5</td> <td>4</td> <td>27</td> </tr> <tr> <td>Landline</td> <td>2</td> <td>2</td> <td>3</td> <td>4</td> <td>3</td> <td>3</td> <td>5</td> <td>22</td> </tr> <tr> <td>Satellite</td> <td>3</td> <td>1</td> <td>2</td> <td>4</td> <td>4</td> <td>4</td> <td>3</td> <td>21</td> </tr> <tr> <td>Direct lines</td> <td>2</td> <td>1</td> <td>5</td> <td>2</td> <td>5</td> <td>1</td> <td>1</td> <td>17</td> </tr> </tbody> </table>		Reliability	Resilience	Performance	Interoperability	Security	Scalability	Cost	Score	Weight	1	1	1	1	1	1	1		Mobile broadband	4	4	4	4	2	5	4	27	Landline	2	2	3	4	3	3	5	22	Satellite	3	1	2	4	4	4	3	21	Direct lines	2	1	5	2	5	1	1	17
	Reliability	Resilience	Performance	Interoperability	Security	Scalability	Cost	Score																																															
Weight	1	1	1	1	1	1	1																																																
Mobile broadband	4	4	4	4	2	5	4	27																																															
Landline	2	2	3	4	3	3	5	22																																															
Satellite	3	1	2	4	4	4	3	21																																															
Direct lines	2	1	5	2	5	1	1	17																																															

Table 4.2: Decision – Connectivity of the sensors

<b>Name</b>	Cassandra Database							
<b>Decision</b>	<b>DEC-3</b>							
<b>Status</b>	New							
<b>Problem/Issue</b>	A reliable database, which is the best in scalability and availability is needed to store our data for further processing and analysis.							
<b>Decision</b>	Smart Flood Monitoring system will use Cassandra, which will run on top of the Linux platform, to store great amount of data from huge sensor arrays needed to carry out analytics and logging.							
<b>Alternatives</b>	<p><i>Redis</i>  Redis is a database that is best for storing data that changes rapidly with foreseeable database size which mostly fits in memory. This database is good to store real-time stock prices.</p> <p><i>MongoDB</i>  MongoDB is suitable for a database that needs dynamic queries. Indexes are mainly needed to runs this database system rather than Map/Reduce functions.</p> <p><i>HBase</i>  HBase is also written in Java. HBase is the database for Hadoop. This database is the best way to run Map/Reduce tasks on huge datasets.</p>							
<b>Arguments</b>	A short discussion of the cons and pro's is described by the table below							
	Reliability	Resilience	Performance	Interoperability	Security	Scalability	Cost	Score
Weight	1	1	1	1	1	1	4	
Cassandra	4	3	5	3	3	5	4	27
Redis	2	3	3	3	3	2	4	20
MongoDB	2	3	3	3	3	3	4	21
HBase	3	3	4	3	3	4	4	24

Table 4.3: Decision – Cassandra Database

Name	Type of water level sensor							
<b>Decision</b>	<b>DEC-4</b>							
<b>Status</b>	<b>New</b>							
<b>Problem/Issue</b>	To measure the water level in the water ways and along the coast, a sensor is needed to measure the water level.							
<b>Decision</b>	The system will use pressure sensors to measure the water level. Pressure sensors are submerged at a fixed level in the water body. By measuring the pressure on the sensor of the water above it, these types of sensors are able to determine the water level.							
<b>Alternatives</b>	<p><i>Float-operated sensor</i>  These types of sensors are mechanical and have a floating element which can move up and down with the water level. The floating element is protected in a ‘stilling well’ and therefore, the risk of damage is low.</p> <p><i>Non-contact sensor</i>  These types of sensors use (ultra)sonic waves to determine the water level. Sediment in the water can cause issues with the measurements.</p> <p><i>Bubbler sensors</i>  Bubbler sensors can measure the water level by measuring the pressure needed to force an air bubble through a submerged tube. Bubbler sensors have good resistance against damage from floods and debris.</p>							
<b>Arguments</b>	For this decision the interoperability and security have a weight of 0, because those depend on the specific sensor used and not on the type of sensor. Scalability was not taken into account because this depends mostly on the costs of the type of sensor.							
	Reliability	Resilience	Performance	Interoperability	Security	Scalability	Cost	Score
Weight	3	2	1	0	0	0	3	
Pressure sensor	3	3	3	-	-	-	4	30
Float-operated sensor	3	4	3	-	-	-	3	29
Non-contact sensor	2	4	3	-	-	-	2	23
Bubbler sensors	4	5	2	-	-	-	1	29

Table 4.4: Decision – Type of water level sensors

<b>Name</b>	<b>Server</b>							
<b>Decision</b>	<b>DEC-5</b>							
<b>Status</b>	<b>New</b>							
<b>Problem/Issue</b>	To connect all sensors and to process all the data, we need computing power and storage space.							
<b>Decision</b>	We will use our own server park. When managing our own server park, we have more technical freedom. Especially when our system will scale up, it can be profitable to maintain our own server park instead of a cloud solution.							
<b>Alternatives</b>	<i>Cloud computing</i> There are different cloud computing providers in the world. An advantage of cloud computing is the degree of scalability. However, when storing data at a cloud provider, we can never be sure if we are the only ones with access to our data.							
<b>Arguments</b>	For this decision we will not take resilience into account. Resilience can also be seen as reliability and interoperability.							
	Reliability	Resilience	Performance	Interoperability	Security	Scalability	Cost	Score
Weight	3	-	2	2	3	2	2	
Cloud computing	4	-	4	3	3	5	3	51
Own server park	3	-	4	5	4	3	4	53

Table 4.5: Decision – Server park

## **5 System architecture**

This chapter describes the general system architecture of the Smart Flood Monitoring. This will be described in these three sections: initial model, elaborated model, and verification.

### **5.1 Initial Model**

### **5.2 Elaborated Model**

### **5.3 Verification**

## 6 Hardware Architecture

# **7 Software Architecture**

This chapter describes the software architecture of the Smart Flood Monitoring. This will be described in these three sections: software architecture design (attribute-driven design), architectural view, and components.

## **7.1 Software architecture design**

## **7.2 Architectural view**

## **7.3 Components**

## **8 Architecture evaluation**

## 9 System evolution

# A Time Tracking

## A.1 Week 1

Person	Task	Hours
Eedema	Reviewing the document, reading the assignment, initializing requirements, & installing environment for project	8
Putra	Initial preparation for the course	5
Fakambi	Reading the document and assignment, Preparation and drafts with ideas	5
Schaefers	Setting up the working environment, create the context page and analysis page drafts. Setting up and improving the the document structure.	8
Klinkenberg		
Brandsma	Creating working environment, reading assignment, first draft business part	8
Menninga	Reading assignment, setting up working environment, first non-functional requirements	5

## A.2 Week 2

Person	Task	Hours
Eedema	Coaching session, project planning session and work on business information chapters	9
Putra	Coaching session, project planning session, project meeting, first version of stakeholder part of requirements	7.5
Fakambi	Coaching session , project meeting, work on Non functional requirements	7
Schaefers	First coaching session, improved and enhanced the context and business information chapters. Also created a quality attributes prioritization table.	8
Klinkenberg	Coaching session, meetings, providing feedback on requirements	5.5
Brandsma	First version of use-cases, coaching session, meeting, use-cases, architectural vision	6.5
Menninga	First version of the functional requirements, coaching session, meeting	10.25

### A.3 Week 3

Person	Task	Hours
Eedema	Coaching, meetings, analysis, business part, reviewing	14
Putra	Coaching session, meetings, proofread on chapter 1 and 2, revising stakeholders, database decision part of analysis, and preparing L <sup>A</sup> T <sub>E</sub> X file for the presentation	10
Fakambi	Coaching session, meetings, Non functional requirements and Risk assessment	10.5
Schaefers	Coaching session, meetings, reviewing, Business section	12
Klinkenberg	Coaching session, meetings, technical requirements, analysis, reviewing	13.5
Brandsma	Coaching session, meeting, architectural vision, use-cases, analysis	9
Menninga	Coaching session, meetings, updates functional requirements, reviewing entire document, updated assumptions and some improvements to structure of analysis, added decision about type of water level sensor.	14.0

### A.4 Week 4

Person	Task	Hours
Eedema		
Putra	Coaching session, meetings, presentation prep., improving business rationale, review chapter 2, working on chapter 5,6,7	12
Fakambi	Coaching session , meetings , Work on and improvements chapter 3.5 to 3.8	12
Schaefers	Researched on sensors and other EWS's. Then created the system architecture model diagram and vision diagram for the presentation I had to present in. Created/improved other diagrams. Researched about the costs of these kinds of systems and created/enhanced the business cost section.	20
Brandsma	Coaching session, meetings , reviewing group 1, architectural vision, use-cases, reviewing, improving chapter 4	15.5
Menninga	Coaching session, presentation prep., meeting, improvements FR and risks, review ch. 4, improvements to NFR and Risk Assessment	14.0

### A.5 Todo