

UNIVERSITY OF GRONINGEN

SOFTWARE ARCHITECTURE

GROUP 3

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# Smart Flood Monitoring (SFM)

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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[2, 3].

In the future more floods are expected because of global warming[4]. 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[5]. 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 thread 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[6]. 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 Table 2.1.

STRENGTHS	WEAKNESSES
<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>
OPPORTUNITIES	THREATS
<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 to 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 monitor 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 2.3, 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 2.3 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 [7]. 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)[8].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=  $100 \cdot 16.830 = 1.683.000$

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=  $4 \cdot 1500 \cdot 4 = 24.000$ . 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 describes our vision and uses it to derive stakeholders. This information helps us 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

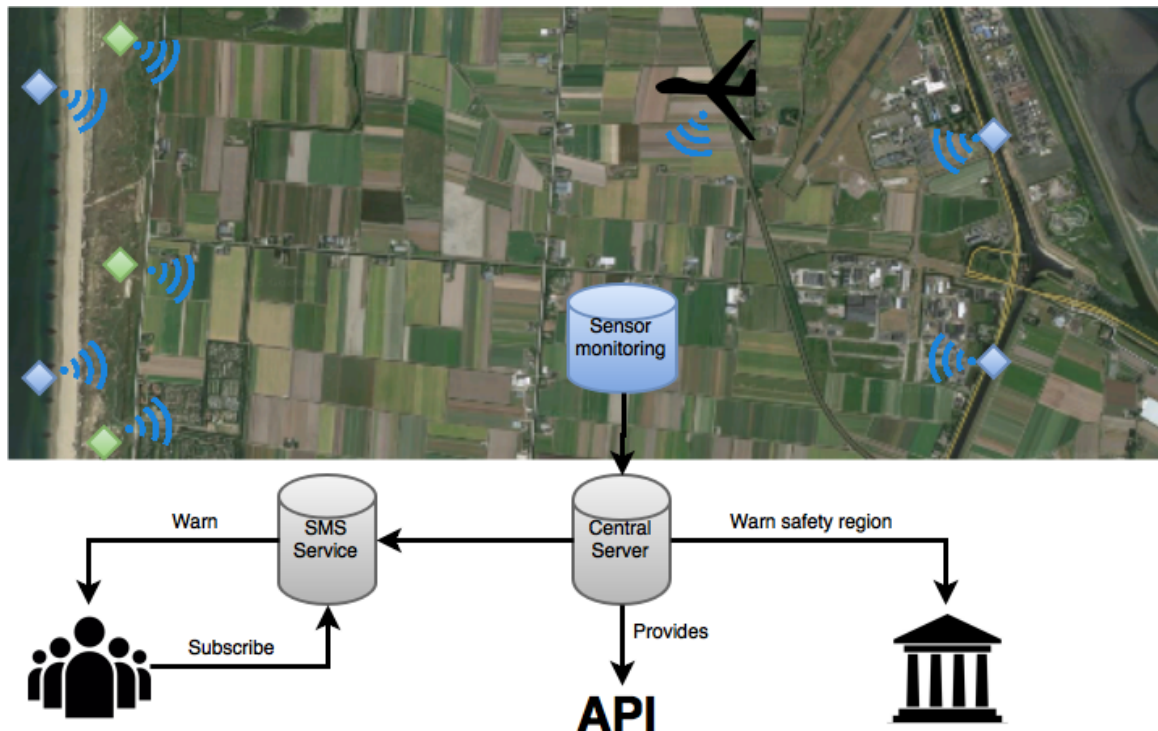


Figure 3.1: Schematic overview of the flood monitoring system

The smart flood monitoring system consists of multiple parts. These are represented in figure 3.1. First of all there is the monitoring part. This part monitors the current state of the environment. To achieve this, we need a lot of data, which we obtain using sensors, weather APIs and UAVs. 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. To see how far a flood has spread we use UAVs. The data that is obtained through all sensors will be sent 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 safe 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 [1]. Those quality standards are described in Table 3.1.

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 [1].

There are six quality attributes, as can be seen in Table 3.1, 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 the reliability and profitability of the system. The product owner funds the whole project and is highly concerned about the profitability. Thus, to gain big market share and extract large profit from this product, the product owner has to make this product reliable.

**Developers** are concerned about interoperability, performance 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 it is ready for production. Including architecting, designing, analyzing, testing and implementing this Smart Flood Monitoring System.

**Third party developers** are concerned about interoperability, availability, usability and reliability. Third party developers are important for our system since they need to provide an application that will give the users guidance in case of a flood.

**Competitors** are concerned about reliability 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 and reliability. The government will be the main customer of this product, specifically, The Dutch Ministry of Infrastructure and the Environment. The government will be part of mitigation when the flood is imminent. This system will help the government by notifying them when it detects a flood and supplying them with relevant information about the flood.

**Citizens** are also concerned about availability and reliability, but also usability, since they can subscribe to warning by SMS. The Dutch residents are indirect user of this systems. Furthermore, they want this system to always be available and run correctly and notify them with reliable information.

**Insurance companies** are concerned mostly about performance, reliability and availability. 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 availability and reliability. Local companies will also be affected by the flood, since they 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 set when the flood comes to save their assets.

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

Table 3.2 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							
	Weight	Availability	Interoperability	Performance	Reliability	Security	Usability	Profitability
Product owner	1				60			40
Developers	1		40	30		30		
Competitors	1				40			60
Government	2	60			40			
Citizens	2	40			40		20	
Insurance companies	1	35		15	50			
Local companies	1	60			40			
Safety region	3	20	15	20	30		15	
Total		355	85	105	440	30	85	100

Table 3.2: Matrix of stakeholders concern.

As can be seen from Table 3.2, the most important concern of our system is the reliability, following availability as the second most important concern. This is also identical with our significant key driver.

### 3.3 Key-drivers

Table 3.2 has shown the concerns of the stakeholders of our system. Not every stakeholder is equally the same in our system. Each stakeholder receives 100 points to be distributed to all quality attributes, but is also assigned a weight. 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 **availability** as the second most important, and **performance** 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 High-level requirements

The high-level functionality of the system is described in several high-level requirements in this section.

Nr.	Prio	Description
HL-1	<b>Must</b>	The system monitors the environment to determine when a flood is developing.
HL-2	<b>Must</b>	The system issues a warning to the safety region and subscribed citizens when a flood is imminent.
HL-3	<b>Must</b>	The system can supply the safety region with relevant information regarding the flood.
HL-4	<b>Must</b>	To allow third-party developers to develop applications to guide citizens in case of a flood, the system exposes an API which can supply these developers with data related to the flood.
HL-5	<b>Must</b>	There is a control panel for maintenance, where warnings etc. can be viewed and the sensor data can be viewed manually.

## 3.5 Stories and use-cases

This section will give an overview of the different use-cases. Figure 3.2 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.

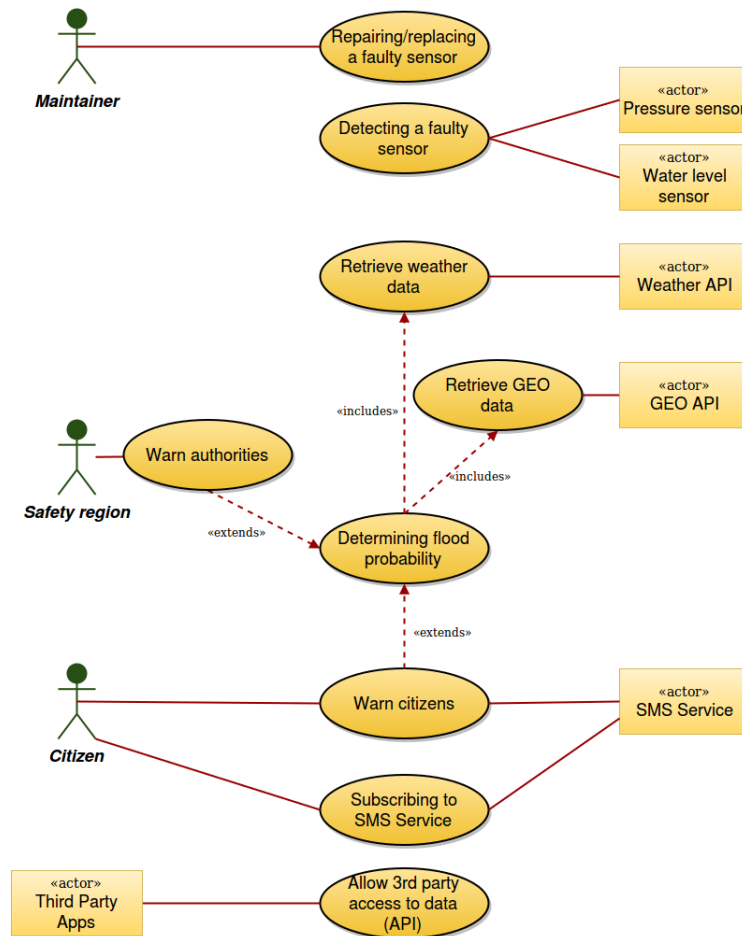


Figure 3.2: Use-case diagram

### 3.5.1 Receive sensor data

Number	UC-1
Description	The system receives data from the different sensors deployed
Stakeholders and interests	<b>Developers:</b> Developers need to work with the sensor data
Primary actor	System
Scope	Monitoring part of the system
Level	Sub process
Precondition	The sensor is connected to a processing unit
Main success scenario	<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>
Postcondition	The database received and stored the sensor data

<b>Extensions</b>	2a.	<ol style="list-style-type: none"> <li>1. The data cannot be sent</li> <li>2. Data will be lost</li> <li>3. The use-case ends</li> </ol>
<b>Related requirements</b>	FR-1, FR-3, FR-5, FR-6	

### 3.5.2 Receive weather data

<b>Number</b>	UC-2
<b>Description</b>	The system receives data from the weather forecast service
<b>Stakeholders and interests</b>	<b>Developers:</b> Developers would like to have a simple to use API
<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>Extensions</b>	<ol style="list-style-type: none"><li>3a. <ol style="list-style-type: none"><li>1. The data cannot be returned.</li><li>2. Repeat this process with another weather forecast service.</li><li>3. If none are available, proceed monitoring without weather forecast data.</li><li>4. After 5 minutes try to reconnect.</li></ol></li></ol>
<b>Related requirements</b>	FR-7

### 3.5.3 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>	<b>Citizens:</b> Citizens want to be warned as soon as possible.
<b>Primary actor</b>	Citizen
<b>Scope</b>	Warning part of the system
<b>Level</b>	User goal
<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>Extensions</b>	<ol style="list-style-type: none"><li>2a. The text message is not received</li></ol> The use-case ends
<b>Related requirements</b>	FR-17

### 3.5.4 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>Safety region:</b> The safety region wants 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>	Sub 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 send to the emergency services (they will warn the government)</li><li>7. A warning is send 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>Extensions</b>	5a. The probability is not above the threshold The use-case ends
<b>Related requirements</b>	FR-8

### 3.5.5 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>	User goal
<b>Precondition</b>	There is an imminent flood and the 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>	<ol style="list-style-type: none"><li>3a. <ol style="list-style-type: none"><li>1. A message cannot be sent to the citizen</li><li>2. Wait a minute and resend</li><li>3. The use-case ends</li></ol></li></ol>
<b>Related requirements</b>	FR-18



### 3.5.6 Warn safety region in case of an imminent flood

<b>Number</b>	UC-6
<b>Description</b>	The safety region needs to 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>Safety regions:</b> The emergency services want to help the citizens in case of a flood</li></ul>
<b>Primary actor</b>	Safety region
<b>Scope</b>	Warning part of the system
<b>Level</b>	User goal
<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, FR-15

### 3.5.7 Third party accessing data through the systems API

<b>Number</b>	UC-7
<b>Description</b>	Third parties can use the API exposed by the flood monitoring system in third party applications (providing guidance to citizens)
<b>Stakeholders and interests</b>	<ul style="list-style-type: none"><li>• <b>Third parties:</b> Third parties want to access the data of the flood monitoring system to use in their applications</li><li>• <b>Citizens:</b> Citizens want to receive guidance in case of a flood.</li></ul>
<b>Primary actor</b>	Third party
<b>Scope</b>	The API part of the system
<b>Level</b>	User goal
<b>Precondition</b>	The third party has access to the flood monitoring systems API
<b>Main success scenario</b>	<ol style="list-style-type: none"><li>1. The third party application connects to and authenticates with the API</li><li>2. The third party application sends a request for certain data to the API</li><li>3. The system retrieves the requested data from the database</li><li>4. The system sends the retrieved data to the third party application</li></ol>
<b>Postcondition</b>	The third party application has received the requested data
<b>Related requirements</b>	FR-29

### 3.5.8 System detects a faulty sensor

<b>Number</b>	UC-8
<b>Description</b>	The system is able to detect when a sensor is not functioning properly
<b>Stakeholders and interests</b>	<ul style="list-style-type: none"><li>• <b>Product owner:</b> The product owner wants the system to be reliable and errors/broken sensors to be fixed</li></ul>
<b>Primary actor</b>	The system
<b>Scope</b>	The monitoring part of the system
<b>Level</b>	Sub process
<b>Precondition</b>	The sensor is not functioning properly
<b>Main success scenario</b>	<ol style="list-style-type: none"><li>1. The system receives the sensor data</li><li>2. The system compares the sensor data with other information, including data of nearby sensors and previous data of this sensor</li><li>3. The system detects that this reading is abnormal, but determines it cannot be caused by an (imminent) flood</li><li>4. The system ignores further readings from this sensor and reports the faulty sensor in the control panel</li></ol>
<b>Postcondition</b>	The faulty sensor is not used in future measurements and is reported in the control panel
<b>Alternatives</b>	<ol style="list-style-type: none"><li>3a. <ol style="list-style-type: none"><li>1. The system cannot determine the abnormal reading is not caused by a flood</li><li>2. The system keeps using this sensors data, until it can determine that the readings are not caused by a flood, or it determines that it is caused by a flood (in which case it will issue warnings, see UC-4)</li></ol></li></ol>
<b>Related requirements</b>	FR-19, FR-21, FR-22, FR-23, FR-24

### 3.5.9 Maintenance employee checks system state

<b>Number</b>	UC-9
<b>Description</b>	A maintainer of the system regularly checks the state of the system in the control panel to see if there are errors or sensors that need maintenance.
<b>Stakeholders and interests</b>	<ul style="list-style-type: none"><li>• <b>Product owner:</b> The product owner wants the system to be reliable and errors/broken sensors to be fixed</li></ul>
<b>Primary actor</b>	Maintainer
<b>Scope</b>	The maintenance part of the system
<b>Level</b>	User goal
<b>Precondition</b>	
<b>Main success scenario</b>	<ol style="list-style-type: none"><li>1. The maintainer uses his login credentials to get access to the control panel</li><li>2. The maintainer navigates to the errors/warning page</li><li>3. The maintainer checks on this page if there are problems with the system (errors/warning)</li><li>4. The maintainer takes necessary action to resolve any issues</li></ol>
<b>Postcondition</b>	The maintainer is aware of reported problems with the system
<b>Related requirements</b>	FR-20, FR-21, FR-22, FR-23, FR-24

### 3.6 Functional requirements

This section lists the functional requirements of the system.

Nr.	Prio	Description
FR-1	<b>Must</b>	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	<b>Must</b>	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-3	<b>Must</b>	The system is able to receive input from pressure sensors of the dikes.
FR-4	<b>Must</b>	The system is able to perform an analysis for the pressure on the dikes based on the input from the pressure sensors.
FR-5	<b>Must</b>	The system can store the sensor data.
FR-6	<b>Must</b>	Sensor data, which has been previously stored, can be retrieved at a later moment.
FR-7	<b>Must</b>	The system retrieves weather forecasting data from weather forecasting services, which consists of predictions about the precipitation, wind data and tide information. This is used by the system to help in determining when a flood becomes imminent.
FR-8	<b>Must</b>	The system is able to detect when a flood is imminent by combining the retrieved sensor data and weather forecasting data.
FR-9	<b>Must</b>	The system retrieves geographic information, consisting of road data, terrain height data and demographic data (number of civilians living in affected area) from an external API.
FR-10	<b>Must</b>	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	<b>Must</b>	The system can construct a map, showing which areas are affected by the flood.
FR-12	<b>Must</b>	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-13	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-14	Should	The system can compute the number of civilians living in the areas affected by the flood.
FR-15	<b>Must</b>	When a flood is imminent, the system sends a warning to the safety region, containing 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-16	<b>Must</b>	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-17	<b>Must</b>	Citizens are able to subscribe to flood warnings about imminent floods.
FR-18	<b>Must</b>	Citizens who are subscribed for flood warnings are warned about imminent floods by text message.
FR-19	<b>Must</b>	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-20	<b>Must</b>	There is a control panel, where maintainers of the system have access to.
FR-21	<b>Must</b>	The system reports faulty sensors, so they can be viewed in the control panel.
FR-22	<b>Must</b>	Warnings of the system can be viewed in the control panel.
FR-23	<b>Must</b>	Errors of the system can be viewed in the control panel.
FR-24	<b>Must</b>	The readings of the sensors can be viewed in the control panel.
FR-25	<b>Must</b>	The system can make backups of its data (configuration data etc.).
FR-26	<b>Must</b>	The system can store created backups on a remote location.

FR-27	<b>Must</b>	The system can retrieve the backups it previously created.
FR-28	<b>Must</b>	The system can restore the backups it previously created after retrieving them.
FR-29	<b>Must</b>	The system exposes an API, allowing third parties to develop applications for guidance of the citizens during a flood.
FR-30	<b>Could</b>	The system is able to detect extreme weather phenomena, like storms etc.

### 3.7 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.

### 3.8 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.

#### 3.8.1 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.

#### 3.8.2 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).

### 3.8.3 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.

### 3.8.4 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 systems 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.

### 3.8.5 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.
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### 3.8.6 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	<b>Must</b>	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	<b>Must</b>	The system is configurable to run in different areas and with different sensors.
SCALE-3	<b>Must</b>	The system maintains the performance requirements when the geographic area the system covers is expanded.

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## 3.9 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 exmaple 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.



## 3.10 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.

### 3.10.1 Technical

<b>T-RISK1</b>	<b>The system does not detect a flood</b>
<b>Probability of occurrence</b>	Low
<b>Consequences</b>	Severe. There can be a loss of human lives and damages, loss of trust in the system by end-users.
<b>Prevention</b>	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.
<b>Reaction</b>	Make changes in the algorithm for the flood detection, improve the sensors used or add more sensors.
<b>T-RISK2</b>	<b>The system sends warnings of a non-existing flood (false positive)</b>
<b>Probability of occurrence</b>	Low
<b>Consequences</b>	Significant. People can become more negligent to future messages and unneeded social disturbance can be caused.
<b>Prevention</b>	UAVs watching the area where the supposed flood is to confirm.
<b>Reaction</b>	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>	<b>The system cannot send messages to the necessary people because the communication platform is also destroyed by the flood</b>
<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>	<b>Hacker gets access to the system</b>
<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.

### 3.10.2 Business

<b>B-RISK1</b>	<b>Wrong estimation of the budget</b>
<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>	<b>The money invested in the fabrication and achievement of the product/system is not covered by the sales (shortfall/deficit)</b>
<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>	<b>Sensor becomes unavailable (is not sold anymore)</b>
<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.

### 3.10.3 Schedule

<b>S-RISK1</b>	<b>The project is not finished at the deadline</b>
<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	DEC-1																																													
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></p> <p>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></p> <p>A Unix-based system that is famous for it's 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><tr><td></td><td>Reliability</td><td>Resilience</td><td>Performance</td><td>Interoperability</td><td>Security</td><td>Scalability</td><td>Cost</td><td>Score</td></tr><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>Linux</td><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><td>Windows</td><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><td>OpenBSD</td><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></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

Name	Connectivity of the sensors								
Decision	DEC-2								
Status	New								
Problem/Issue	The sensors need to deliver their data to the system and are located outdoors with at least 100m distance between each other.								
Decision	The sensors will send their data to the system using mobile broadband. Using cellphone towers to communicate with the system.								
Alternatives	<i>Landline</i>								
	Connecting the sensors to the telephone network and use that network to communicate with the server.								
	<i>Satellite</i>								
	Set up a satellite connection between the sensors and the system.								
	<i>Direct lines</i>								
Connection the sensors to the system by drawing a cable from all sensors to the system.									
Arguments									
		Reliability	Resilience	Performance	Interoperability	Security	Scalability	Cost	Score
Weight	1	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>	<b>Cassandra Database</b>																																																						
<b>Decision</b>	<b>DEC-3</b>																																																						
<b>Status</b>	<b>New</b>																																																						
<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>	<p>A short discussion of the cons and pro’s is described by the table below</p> <table><tr><td></td><td>Reliability</td><td>Resilience</td><td>Performance</td><td>Interoperability</td><td>Security</td><td>Scalability</td><td>Cost</td><td>Score</td></tr><tr><td>Weight</td><td>1</td><td>1</td><td>1</td><td>1</td><td>1</td><td>1</td><td>4</td><td></td></tr><tr><td>Cassandra</td><td>4</td><td>3</td><td>5</td><td>3</td><td>3</td><td>5</td><td>4</td><td>27</td></tr><tr><td>Redis</td><td>2</td><td>3</td><td>3</td><td>3</td><td>3</td><td>2</td><td>4</td><td>20</td></tr><tr><td>MongoDB</td><td>2</td><td>3</td><td>3</td><td>3</td><td>3</td><td>3</td><td>4</td><td>21</td></tr><tr><td>HBase</td><td>3</td><td>3</td><td>4</td><td>3</td><td>3</td><td>4</td><td>4</td><td>24</td></tr></table>		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
	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																																																						
Decision	DEC-4																																																						
Status	New																																																						
Problem/Issue	To measure the water level in the water ways and along the coast, a sensor is needed to measure the water level.																																																						
Decision	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.																																																						
Alternatives	<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. <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. <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.																																																						
Arguments	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.																																																						
<table><tr><td></td><td>Reliability</td><td>Resilience</td><td>Performance</td><td>Interoperability</td><td>Security</td><td>Scalability</td><td>Cost</td><td>Score</td></tr><tr><td>Weight</td><td>3</td><td>2</td><td>1</td><td>0</td><td>0</td><td>0</td><td>3</td><td></td></tr><tr><td>Pressure sensor</td><td>3</td><td>3</td><td>3</td><td>-</td><td>-</td><td>-</td><td>4</td><td>30</td></tr><tr><td>Float-operated sensor</td><td>3</td><td>4</td><td>3</td><td>-</td><td>-</td><td>-</td><td>3</td><td>29</td></tr><tr><td>Non-contact sensor</td><td>2</td><td>4</td><td>3</td><td>-</td><td>-</td><td>-</td><td>2</td><td>23</td></tr><tr><td>Bubbler sensors</td><td>4</td><td>5</td><td>2</td><td>-</td><td>-</td><td>-</td><td>1</td><td>29</td></tr></table>			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
	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.																																				
	<table><tr><td></td><td>Reliability</td><td>Resilience</td><td>Performance</td><td>Interoperability</td><td>Security</td><td>Scalability</td><td>Cost</td><td>Score</td></tr><tr><td>Weight</td><td>3</td><td>-</td><td>2</td><td>2</td><td>3</td><td>2</td><td>2</td><td></td></tr><tr><td>Cloud computing</td><td>4</td><td>-</td><td>4</td><td>3</td><td>3</td><td>5</td><td>3</td><td>51</td></tr><tr><td>Own server park</td><td>3</td><td>-</td><td>4</td><td>5</td><td>4</td><td>3</td><td>4</td><td>53</td></tr></table>		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
	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 two sections: system context and verification.

### 5.1 System context

The system context is a fundamental artifact in the software architecture of a system. Developing the system context view is important, because this view is used as a mechanism to trace back to the business context, and downstream to the functional and operational architecture.

#### 5.1.1 Diagram

The system context diagram of the system is outlined in Figure 5.1.

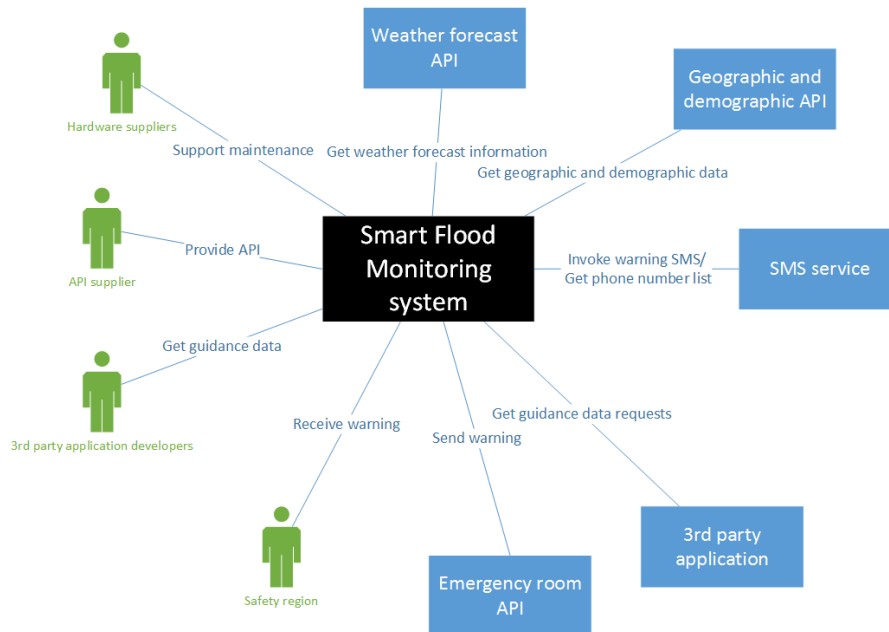


Figure 5.1: System context diagram

#### 5.1.2 Users and Roles

**Safety region** The safety region has the responsibility to protect citizens when a dangerous situation occurs, in this **system floods**. They receive a warning when there is a imminent flood. When the warning is received, the safety region can warn citizens and emergency services. The safety region needs information about time to evacuate, location , and severity of imminent flood.

**Third party application developers** This user will build an application to provide guidance when a flood is imminent. They use the data provided by the API of the SFM. They are allowed to get all relevant data from the system.

**Hardware suppliers** This user will provide different kind of hardware to the system and repairs when hardware is failing

### 5.1.3 External Systems

**Weather Forecast API** The system will utilize weather forecast services from third party sources. To make this input reliable, the system uses **multiple weather forecast providers**. To predict floods correctly the system will need: rain data, temperature data, tides data, air pressure data and wind data.

**Geographic and demographic API** To predict how floods will evolve over time, we need geographical data. This data consists of maps of the area. There are multiple parameters that are needed by the system: ground height and waterways. To calculate the impact of an imminent flood on society, we also need to know how many people live in the affected area. This data is retrieved through the demographic API.

**SMS service** The SMS system will communicate with the system and the mobile phones of the citizens. The SMS service keeps a list with all phone numbers that are subscribed to the service. When a warning is triggered by the central system, the SMS service gets a notification about this and sends the appropriate warning to the mobile phones that are within the area that is affected by the imminent flood.

**Third party application** To guide citizens to a safe area in case of an imminent flood, we rely on third party applications. These applications get data from our API and deliver an app for citizens that provides guidance to a safe area.

**Emergency room API** In case of an imminent flood we need to warn the safety region. This is done by invoking the emergency room API. In this way we send a message to the emergency room, which in their turn distributes this warning to the safety region.

#### 5.1.4 Channels and Information Flows

<i>SFM <math>\Leftrightarrow</math> Weather forecast API</i>	
<b>Description</b>	The system gets rain, temperature, tides, airpressure and wind data.
<b>Connection</b>	Wired, internet
<b>Protocol</b>	TCP/IP
<b>Transaction occurrence</b>	Real time
<i>SFM <math>\Leftrightarrow</math> Geographic and demographic API</i>	
<b>Description</b>	The system gets ground height data, waterway data and the amount of people who live in the affected area.
<b>Connection</b>	Wired, internet
<b>Protocol</b>	TCP/IP
<b>Transaction occurrence</b>	Real time
<i>SFM <math>\Leftrightarrow</math> SMS Service</i>	
<b>Description</b>	The SMS service receives subscriptions and sends warning messages to the right phone numbers when it gets warned by the system.
<b>Connection</b>	Wired, internet
<b>Protocol</b>	TCP/IP
<b>Transaction occurrence</b>	In case of an imminent flood

<i>SFM ⇔ Third party applications</i>	
<b>Description</b>	The system will provide data to the third party applications through the API.
<b>Connection</b>	Wired, internet
<b>Protocol</b>	TCP/IP
<b>Transaction occurrence</b>	Real time
<i>SFM ⇔ Emergency room API</i>	
<b>Description</b>	The system warns the the safety region through the emergency room API.
<b>Connection</b>	Wired, internet
<b>Protocol</b>	TCP/IP
<b>Transaction occurrence</b>	In case of an imminent flood

### 5.1.5 Alternatives

#### Geographic and demographic data

The system will use an API to get the latest geographic and demographic data. It would also have been possible to download the data and import it just one time. However, the data needs to be up to date. This means the data needs to be updated once in a while, the easiest way to do this is by invoking an API.

#### SMS Service

To warn the citizens in case of an imminent flood, we use an external SMS service. Citizens can subscribe to this service and receive a warning. Another option is that the system uses its own SMS service. The advantage of this is that we keep control of the process of warning citizens. However, it would be expensive to implement such a service. Besides this, outsourcing is more scalable since we don't have to cope with problems of sending text messages to other countries.

Another way of informing citizens would be to send a whatsapp message. However, all mobile phones are able to receive text messages, while not all mobile phones have internet access to receive whatsapp messages.

#### Emergency room

The emergency room will be warned by invoking their API. This decision was made to make sure all data will be received correctly. By warning the emergency room through telephone it would be possible the employee could accidentally forget or change some of the information. If this would be implemented the SFM would need an employee 24/7, which is expensive.

Another option would have been to send an email in case of an imminent flood. However, in this case it wouldn't be possible to continuously update the information in the dashboard of the emergency service. This could also be achieved by continuously sending mails, but this would take more time to open and interpret the emails.

## 5.2 Verification

The feasibility of the Smart Monitoring is verified in the following section.

### 5.2.1 Reliability

To determine the reliability of the system we determine the reliability of the separate components. Let:

MTBF: Mean Time Between Failure

MTTR: Mean Time To Repair

The reliability of the complete system is given as  $x$   
$$x = \frac{MTBF}{MTBF+MTTR}$$

### **5.2.2 Time to Market**

All external services already exist.

### **5.2.3 Cost**

Cost of API's we use for our system.

## **5.3 Elaborated Model**

## 6 Hardware Architecture

This section describes the hardware architecture of Smart Monitoring. The description will be more high-level along with explanation about the hardware platform and the application interfaces between each components of the system. The rest of this chapter is organized as follows. First section, section 6.1, presents an overview of the hardware implemented in this system depicted in big schema. Decisions made in this system are detailed in section 6.2 with tables. Lastly, hardware description is described in section 6.3.

### 6.1 Hardware Overview

The Smart Monitoring hardware components can be categorized into four main components: sensing part, data storing part, analytics part, and data presentation part. The data flow starts from wired and wireless sensors located across the Netherlands that collects information for monitoring. The process will end at data presentation and warning dispatch in the users' side. The overview of the hardware and its application interfaces are depicted in Figure 6.1 below.

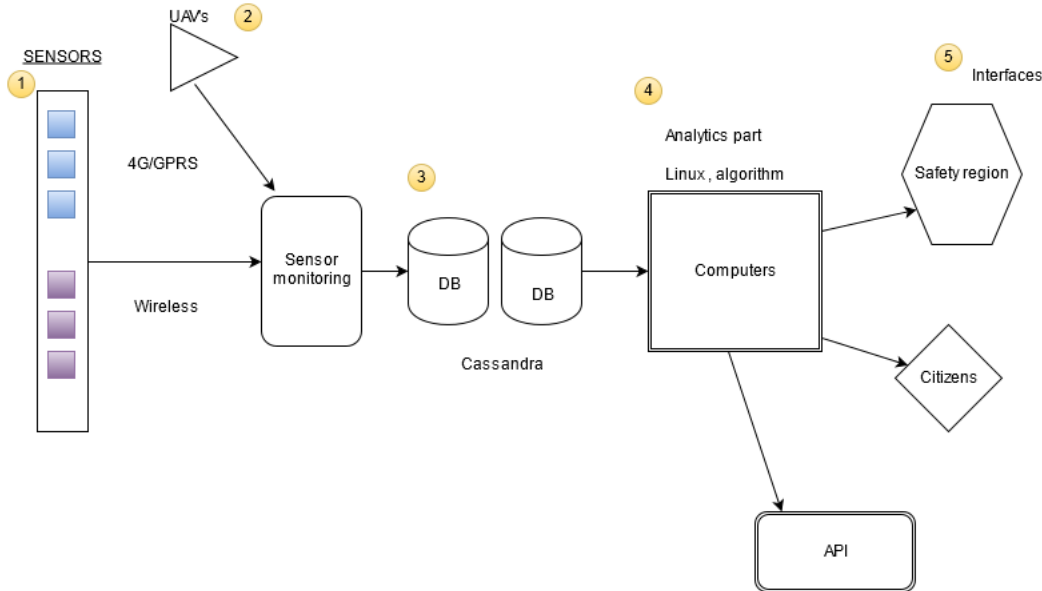


Figure 6.1: Schematic overview of the hardware architecture of Smart Monitoring

Here is an overview of the Hardware Architecture. Each number corresponds to a decision which will be detailed in the Hardware Design Decision part.

The Smart Monitoring will utilize wired and wireless sensor for monitoring water ways and dykes. Wired sensor will be placed in congested dykes and waterways where wired connection is possible. Wireless sensor will be planted in remote areas where wired connections are impossible or too costly. UAVs will fly to check reported faulty sensors. UAVs will also be used to take required pictures for further analytics or to examine some portion of the system which is hard or impossible for a personnel to access. Then all measurement will be forwarded to sensor monitoring part to be normalized before getting in to the analytics part.

The next part of the hardware is the cluster for carrying out analysis. This will be a collection of servers that is coordinated using clusters. This part also handles the logic for detecting faulty sensors, as the sensor monitoring parts contain no logic behind it.

We will use other cluster to store our important data. This cluster will run Cassandra database on top of it. This cluster will also have several interfaces to communicate with other instances, such as main analytics part, third party data gathering cluster, and API cluster.

The last part of the hardware architecture is third party data gathering cluster and API cluster. Third party data gathering cluster is responsible for collecting weather forecast and demographic information of the Nether-

lands. Meanwhile, API cluster is responsible for handling request from actors that will consume our practical information and for notifying safety region in case of imminent flood. Both of this cluster are merely collections of server computer that works together.

## 6.2 Hardware Design Decisions

This section defines decisions made regarding the hardware selection. Tables will be used to make our justification in regard to hardware selection more crystal clear.

Name	Choice of the computer for data analyze																																																				
Decision	DEC-4																																																				
Status	Approved																																																				
Problem/Issue	The system needs computer to analyze data from sensors, UAV's ,weather forecast.																																																				
Decision	IBM Supercomputer ...																																																				
Alternatives	BB Other brand . BB BBBB.																																																				
Arguments	<table><tr><td></td><td>Reliability</td><td>Resilience</td><td>Performance</td><td>Security</td><td>Scalability</td><td>Cost</td><td>Score</td><td></td></tr><tr><td>IBM</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>BB</td><td>5</td><td>4</td><td>5</td><td>4</td><td>5</td><td>4</td><td>4</td><td>31</td></tr><tr><td>BB</td><td>4</td><td>3</td><td>4</td><td>4</td><td>4</td><td>5</td><td>4</td><td>28</td></tr><tr><td>BB</td><td>3</td><td>3</td><td>4</td><td>4</td><td>4</td><td>4</td><td>4</td><td>26</td></tr></table>									Reliability	Resilience	Performance	Security	Scalability	Cost	Score		IBM	1	1	1	1	1	1	1		BB	5	4	5	4	5	4	4	31	BB	4	3	4	4	4	5	4	28	BB	3	3	4	4	4	4	4	26
	Reliability	Resilience	Performance	Security	Scalability	Cost	Score																																														
IBM	1	1	1	1	1	1	1																																														
BB	5	4	5	4	5	4	4	31																																													
BB	4	3	4	4	4	5	4	28																																													
BB	3	3	4	4	4	4	4	26																																													

IBM supercomputer uses Linux which is the oS we chose.

Table 6.1: Decision – Choice of computer

Name	Data representation - Interface with the third parties							
Decision	DEC-4							
Status	Approved							
Problem/Issue	The system needs a display to send warnings to the emergency services.							
Decision	Dashboard for the emergency services							
Alternatives	<i>BB</i> DRAFT . <i>BB</i> BBBB.							
Arguments								

Table 6.2: Decision – Interface with third parties

## 6.3 Hardware Description

This section outlines describes description of the hardware implemented in this system. This section also supports decisions of hardware selection in previous section.

<b>Name</b>	<b>GeoBeads MEMS Sensor</b>																																		
<b>Decision</b>	<b>3</b>																																		
<b>Status</b>	<b>Approved</b>																																		
<b>Problem/Issue</b>	The system needs a reliable sensor system to measure condition of water ways and dykes.																																		
<b>Decision</b>	The system will implement GeoBeads MEMS Sensor in water ways and dykes.																																		
<b>Alternatives</b>	<i>LiDAR</i> Remote sensing mechanism to measure condition of water ways.																																		
<b>Arguments</b>	<table> <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> <tr> <td>GeoBeads</td><td>4</td><td>3</td><td>4</td><td>3</td><td>3</td><td>4</td><td>5</td><td>26</td></tr> <tr> <td>LiDAR</td><td>2</td><td>4</td><td>3</td><td>3</td><td>4</td><td>4</td><td>2</td><td>22</td></tr> </table>									Reliability	Resilience	Performance	Interoperability	Security	Scalability	Cost	Score	GeoBeads	4	3	4	3	3	4	5	26	LiDAR	2	4	3	3	4	4	2	22
	Reliability	Resilience	Performance	Interoperability	Security	Scalability	Cost	Score																											
GeoBeads	4	3	4	3	3	4	5	26																											
LiDAR	2	4	3	3	4	4	2	22																											

Table 6.3: Decision – Choice of Sensors

### 6.3.1 Sensing Components

Roughly 17.000 kilometers of dikes protect the Netherlands against flooding [7]. 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)[8].

### 6.3.2 Database Cluster and Data Collection

In the previous chapter, we decided to use Cassandra database as the database platform. However, Cassandra requires computers to run its environment. We decided to use clusters of computer to manage database system and to store our data. The cluster will also be accessible by other portions of our hardware, such as main analytics parts, third party data gathering part, and API part.

### 6.3.3 Analytics Components

### 6.3.4 Data Presentation



## 7 Software Architecture

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

### 7.1 Software architecture design

This section states software architecture design of the system with attribute-driven design method. As mentioned in [9], the Attribute-Driven Design (ADD) method is a systematic step-by-step method for designing the software architecture of a software-intensive system. It is an approach to defining software architectures by basing the design process on the architecture's quality attribute requirements. It follows a recursive decomposition process where, at each stage in the decomposition, tactics and architectural patterns are chosen to satisfy a set of quality attribute scenarios.

### 7.2 Architectural view

The following section will elaborate the views of the system into 4+1 Model: logical view, implementation view, process view, and deployment view.

#### 7.2.1 Logical View

This view shows the structural elements, key abstractions and mechanisms that are used within HPS to realize the system's functionality. At first an overview of the components is provided. After that the main components are decomposed and desired in terms of responsibilities and interfaces. In the end, the variability guide mentions parts of the software, which clarification is deferred until development/design phase.

#### 7.2.2 Implementation View

This view deals with, for example, code organization Configuration, building operating system, data base, and middleware.

#### 7.2.3 Process View

This view mainly discusses about runtime, concurrency, communication, and synchronization of the process running in the system.

#### 7.2.4 Deployment View

This subsection outlines physical distribution of hardware and software, typically the topology of the system.

## 7.3 Components

This section outlines the components of the software system, including their functionality, interfaces, and interactions.

## 7.4 Software design decision

This section highlights some of the design decisions that have been made, especially those that are not covered in the previous views.

## 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
Schaefer	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
Schaefer	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
Schaefer	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	Coaching session, meetings, business chapter, review 3, presentations, peer review	13
Putra	Coaching session, meetings, presentation prep., improving business rationale, review chapter 2, making draft of chapter 5, 6, and 7	14
Fakambi	Coaching session , meetings , Work on and improvements chapter 3.5 to 3.8	12
Schaefer	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	16.5
Menninga	Coaching session, presentation prep., meeting, improvements FR and risks, review ch. 4, improvements to NFR and Risk Assessment	14.0

### A.5 Todo

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