Universidad de Valladolid

ESCUELA DE INGENIERÍAS INDUSTRIALES

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ESCUELA DE INGENIERIAS INDUSTRIALES

Grado en Ingeniería de Organización Industrial

Título del TFG

METROVIEW

SICK Competition 2019

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TFG REALIZADO EN PROGRAMA DE INTERCAMBIO

TÍTULO: METROVIEW. SICK competition, 2019

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FECHA: 14-5-2019

CENTRO: Novia University of Applied Sciences

TUTOR: Mika Billing

Cinco palabras claves que describen el TFG:

Cooperación, multidisciplinar, multicultural, innovación, mejora.

Resumen en español (máximo 150 palabras):

El proyecto fue llevado a cabo por un grupo multidisciplinar y multicultural de ingenieros cada uno de una disciplina y país distinto. Utilizamos técnicas de búsqueda y de Project Management durante todo el European Project Semester y el idioma común fue el inglés.

El proyecto se desarrolló de cara a participar en competición de innovación de la empresa SICK Inteligence. La empresa proporciona a los alumnos uno de sus sensores de última generación valorado en 8.000 € y ellos tienen que buscarle una aplicación innovadora y funcional además de una forma atractiva de comercializarlo.

El proyecto consistió en elaborar todas las fases de diseño de un nuevo producto además de crear un prototipo real para mostrar la idea seleccionada por el grupo.

Nos clasificamos entre los cinco finalistas entre todas las universidades de Finlandia con nuestra idea de usar el sensor para la seguridad en las estaciones de metro y presentamos la idea frente los altos cargos e ingenieros de SICK intelligence y obtuvimos un cheque de 1.000€.

METROVIEW

SICK competition 2019

Presented by Jan Van de Ven, Mario Montero Garrido, Annika Prehn, Carla Laborde, Silke Dable

SICK
Sensor Intelligence.

METROVIEW

Acknowledge

First and foremost, we would like to thank our supervisor Mika Billing to allow us to work on this project and for all his advice on our work. We could not wish a better supervisor for this project and it was a real pleasure for us to work with him.
We will not be at the fourth place of the SICK competition without the help, the expertise, the investment and the knowledge on the programming of the two Novia IT students Robin Snellman and Tran Minh Hien. They are definitely part of the team.
This project would have been impossible without the equipment provided by Novia University.
We would like particularly thanks Roger Nylund who provides us the materials to lead this project and to live this rewarding experience.
A special thanks to Britt van Bergen, Laura Ripoll and Niki Kuhär for their respective help on 3D-printing, on the use of 3D-modeling software and on the edit of the video.
Finally, we wish to acknowledge the whole EPS class for their support during all the project.

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10. Introduction

10.1. European Project Semester

Nowadays, the world of work is more and more competitive. Engineers must not only develop skills in scientific and technologic areas but as well a good communication ability. The new market trends demand more professionals that are able to combine a profound knowledge in engineering with a comprehension on economics and management while knowing how to be prepared to work in multicultural environment. These new environments require an international communication teamwork and a good aptitude in language. The EPS, European Project Semester, is an exchange learning program that allows engineering's students to reach these goals.

This program, developed in Denmark, has a huge success in whole Europe since 1997. Many European universities offered this international experience. At the beginning, the EPS program was only designed for engineering students but it is expanded to other students with a different study background such as economic, design, architecture and management.

The EPS program is based on two study topics subjects: teambuilding and project management. Through lectures, the program gives in short intensive times all the keys that will be used by the students to lead their project. The purpose of EPS is to allow students to put their knowledge into practice in a multicultural environment.

The students are working in an international team from 3 to 6 members on a scientific project in order to develop their cross-cultural communication skills.

10.2. The project

The project will take part in the SICK innovation competition 2019. This competition challenges student teams from different schools and fields to create a new and functional application for one of their products.

This year, the chosen product by SICK, is the 24-layer scan LiDAR SICK MRS6000. This is the latest LiDAR sensor launched by the company that can be used in different fields of applications.

The workflow is based on the traditional product development process and it is adapted to fit the assignment which focuses on TDD or Technology Driven Design. The process is divided into different phases with gates at the end of each phase which will be opened when the deliverables from the phase are reached. Through this method, the project will be developed in 8 steps.

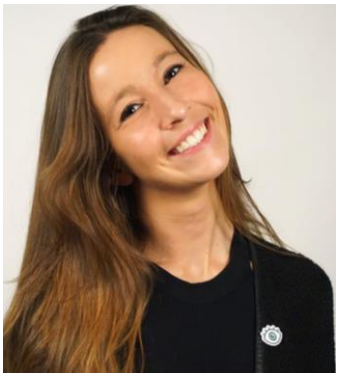
10.2.1. Mission and Vision

The mission or goal of this process is to design an application for the sensor that fits the market perfectly and shows the strongest and most valuable aspects of the technology given. The vision is to have the best and most original idea. It has to contribute to improve the world and to be environmentally friendly.

10.2.2. Objectives

The objectives are managing a working prototype with the implemented sensor, a final report with all the process steps and a booklet to present the concept.

10.3. Team members

<table>
<tr>
<td>Jan Van de Ven
 
From Belgium
Study: Product Development</td>
<td>Mario Montero Garrido
 
From Spain
Study: Engineering in Industrial Organization</td>
</tr>
<tr>
<td>Annike Prehn
 
From Germany
Study: International Sales and Purchasing Engineering</td>
<td>Carla Laborde
 
From France
Study: Packaging Engineering</td>
<td>Silke Debie
 
From Belgium
Study: Graphic and Digital Media</td>
</tr>
</table>

20. Project process

The project process is based on the technique of development product process. This system allows to successfully obtain new products from a concept to the market. The structure of this process was defined through many steps and tasks such as strategy, organisation, concept generation, economic plan and creation. The project process ensures a constantly improvement of the product.

The Work Breakdown Structure (WBS) is a management tool that defines and organises the work of the team into manageable sections. Each level of the WBS provides information and details on the steps of the project. To create the Work Breakdown Structure, the team defines the major features and sub-features of the project.
The representation of the WBS scheme is followed to complete the project. The numbering on this report does not follow the one of the schemes.

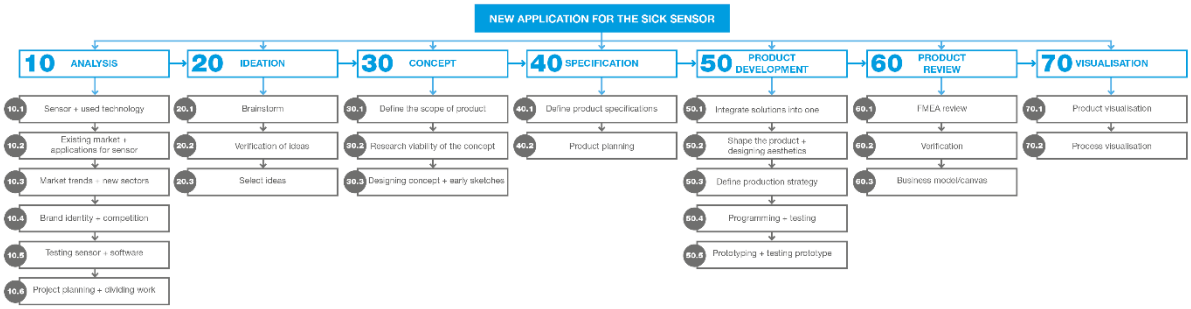


Figure 1 (in attachment)

20.1. Analysis

The project started with analysing all the areas connected to the goal that needed to be reached. The first obvious analysis was the sensor. It is important to understand the technology that is going to be used and to have a better knowledge of all the possibilities of the sensor.

20.1.1. Analysis of sensor and used technology

Product		Principle of operation				Applications									
		Navigation	Detection	Measurement	Multi-echo technology	Level measurement	Checking height	Area monitoring	Checking presence	Collision prevention	Position detection	Electronic routing	Range finding	Shape recognition	Classification
	MRS6000		■	■	■	■	■	■	■	■		■	■	■	■

Figure 2 contains the features of the sensor

Technical data overview	
Application:	Outdoor
Aperture angle:	
Horizontal:	120°
Vertical:	15°
Angular resolution:	0.13° horizontal
	0.625° vertical
Working range:	0.5 m ... 200 m
Scanning range:	
At 10% remission:	30 m
At 90% remission:	75 m
Scanning frequency:	10 Hz
Ambient operating temperature:	- 20 °C ... +60 °C
Ethernet:	✓
Weight:	2.2 kg

20.1.1.1. General information

The sensor is a 3D-scanner with 24 scanning layers, which uses 4 polygon mirrors with 6 flats.
The laser beams are emitted by 4 internally rotating polygon mirrors which send lasers and scan the environment in a circle.
The measured values are assigned by 6 receiving elements to the associated angle steps and thus to the direction. This shows where the object is located.

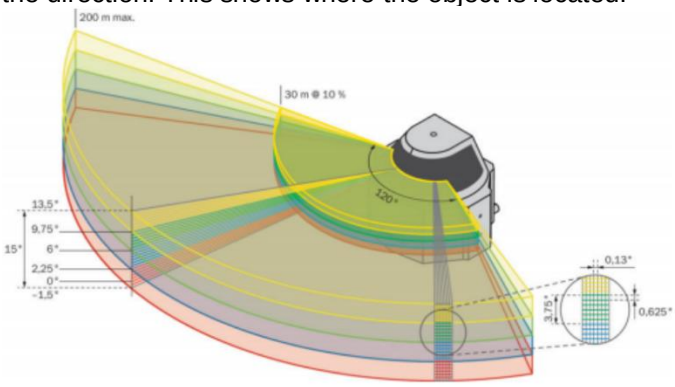


Figure 3

The device emits a laser signal and the sensor receives the reflection. The distance to the object is calculated based on of the time taken by the pulsed light beam.

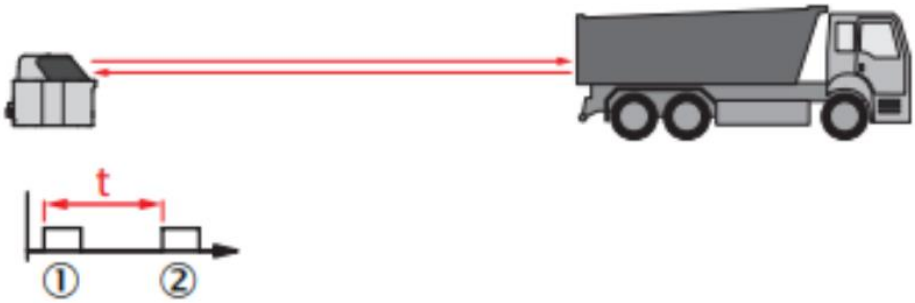


Figure 4

20.1.1.2. Influences of the object properties

Dark objects do not reflect the laser as well as lighter objects because the reach is shorter.
This phenomenon is the same for rough surfaces, contrary smooth surfaces which reflect the laser better.
When objects are smaller than the diameter of the laser beam, the parts are not visible in the data. The object will not be recognized by the sensor.

20.1.1.3. Multi-Echo

The sensor is able to evaluate up to four echo signals per measuring beam to ensure reliable measurement results, even under unfavourable conditions (rain, fog, dust, glass, …)

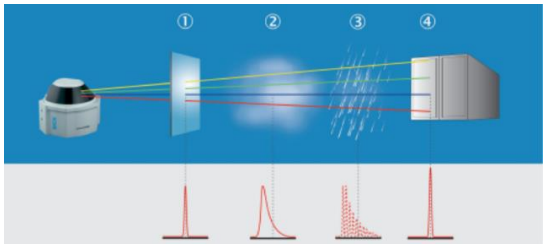


Figure 5

20.1.1.4. Assembly

No solar radiation
No significant temperature fluctuation

20.1.1.5. Software

Software SOPAS ET Version 3.3.3 or newer

20.1.1.6. Usage

- Security
- Home security
- Passenger monitoring
- Vehicle safety
- Robotics
- Emergency situations

20.1.1.7. RSSI-Data

(= Received Signal Strength Indicator)
The signal strength received by the device goes from 1 to 65534, with 1 being the weakest possible signal and 65534 being the strongest (could be a reflector for example). When the signal is 0 it means there is not enough energy reflecting, because the target is out of range or because it has an extremely low remission. The signal strength should always be at least 1.

20.1.1.8. Scan data

1) Scan counter

Datentelegramm (Beispiel):

```
1  <STX>sSN LMDscandata 1 0 10736D01 0 0 1CC0 56BB 86BD0263 88BFBE92 F0 0 0 0 F5B2 3E8 ...
2  <STX>sSN LMDscandata 1 0 10736D01 0 0 1CC1 56BB 86BD0263 86BFC40A F0 0 0 0 F62F 3E8 ...
3  <STX>sSN LMDscandata 1 0 10736D01 0 0 1CC2 56BB 86BD0263 86BFC88F F0 0 0 0 F6AC 3E8 ...
4  <STX>sSN LMDscandata 1 0 10736D01 0 0 1CC3 56BB 86BD0263 86BFCD77 F0 0 0 0 F729 3E8 ...
5  <STX>sSN LMDscandata 1 0 10736D01 0 0 1CC4 56BB 86BD0263 86BFD252 F0 0 0 0 F7A6 3E8 ...
6  <STX>sSN LMDscandata 1 0 10736D01 0 0 1CC5 56BB 86BD0263 86BFD51C F0 0 0 0 F823 3E8 ...
7  <STX>sSN LMDscandata 1 0 10736D01 0 0 1CC6 56BB 86BD640B 86BFDAE7 F0 0 0 0 F8A0 3E8 ...
8  <STX>sSN LMDscandata 1 0 10736D01 0 0 1CC7 56BB 86BD640B 86BFDF8F F0 0 0 0 F91D 3E8 ...
... ...
23 <STX>sSN LMDscandata 1 0 10736D01 0 0 1CD6 56BB 86BE275B 86C01C1C F0 0 0 0 70 3E8 ...
24 <STX>sSN LMDscandata 1 0 10736D01 0 0 1CD7 56BB 86BE275B 86C01F29 F0 0 0 0 ED 3E8 ...
```

Figure 6

Consecutive number, all 24 levels have the same number.

2) Time stamp

Datentelegramm (Beispiel):

```
1  <STX>sSN LMDscandata 1 0 10736D01 0 0 1CC0 56BB 86BD0263 88BFBE92 F0 0 0 0 F5B2 3E8 ...
2  <STX>sSN LMDscandata 1 0 10736D01 0 0 1CC1 56BB 86BD0263 86BFC40A F0 0 0 0 F62F 3E8 ...
3  <STX>sSN LMDscandata 1 0 10736D01 0 0 1CC2 56BB 86BD0263 86BFC88F F0 0 0 0 F6AC 3E8 ...
4  <STX>sSN LMDscandata 1 0 10736D01 0 0 1CC3 56BB 86BD0263 86BFCD77 F0 0 0 0 F729 3E8 ...
5  <STX>sSN LMDscandata 1 0 10736D01 0 0 1CC4 56BB 86BD0263 86BFD252 F0 0 0 0 F7A6 3E8 ...
6  <STX>sSN LMDscandata 1 0 10736D01 0 0 1CC5 56BB 86BD0263 86BFD51C F0 0 0 0 F823 3E8 ...
7  <STX>sSN LMDscandata 1 0 10736D01 0 0 1CC6 56BB 86BD640B 86BFDAE7 F0 0 0 0 F8A0 3E8 ...
8  <STX>sSN LMDscandata 1 0 10736D01 0 0 1CC7 56BB 86BD640B 86BFDF8F F0 0 0 0 F91D 3E8 ...
... ...
23 <STX>sSN LMDscandata 1 0 10736D01 0 0 1CD6 56BB 86BE275B 86C01C1C F0 0 0 0 70 3E8 ...
24 <STX>sSN LMDscandata 1 0 10736D01 0 0 1CD7 56BB 86BE275B 86C01F29 F0 0 0 0 ED 3E8 ...
```

Figure 7

Time stamp since the first use of the sensor. All 6 levels have the same time stamp.
Level 1 to 6: 86BS0263 = 2260533859 = 2.260533,859 ms (26 days)
Level 7 to 12: 86BD640B = 2260558859 = 2.260.558,859 ms (26 days)
Difference is 25 ms

3) Layer angle

Datentelegramm (Beispiel):

```
1  <STX>sSN LMDscandata 1 0 10736D01 0 0 1CC0 56BB 86BD0263 88BFBE92 F0 0 0 0 F5B2 3E8 ...
2  <STX>sSN LMDscandata 1 0 10736D01 0 0 1CC1 56BB 86BD0263 86BFC40A F0 0 0 0 F62F 3E8 ...
3  <STX>sSN LMDscandata 1 0 10736D01 0 0 1CC2 56BB 86BD0263 86BFC88F F0 0 0 0 F6AC 3E8 ...
4  <STX>sSN LMDscandata 1 0 10736D01 0 0 1CC3 56BB 86BD0263 86BFCD77 F0 0 0 0 F729 3E8 ...
5  <STX>sSN LMDscandata 1 0 10736D01 0 0 1CC4 56BB 86BD0263 86BFD252 F0 0 0 0 F7A6 3E8 ...
6  <STX>sSN LMDscandata 1 0 10736D01 0 0 1CC5 56BB 86BD0263 86BFD51C F0 0 0 0 F823 3E8 ...
7  <STX>sSN LMDscandata 1 0 10736D01 0 0 1CC6 56BB 86BD640B 86BFDAE7 F0 0 0 0 F8A0 3E8 ...
8  <STX>sSN LMDscandata 1 0 10736D01 0 0 1CC7 56BB 86BD640B 86BFDF8F F0 0 0 0 F91D 3E8 ...
... ...
23 <STX>sSN LMDscandata 1 0 10736D01 0 0 1CD6 56BB 86BE275B 86C01C1C F0 0 0 0 70 3E8 ...
24 <STX>sSN LMDscandata 1 0 10736D01 0 0 1CD7 56BB 86BE275B 86C01F29 F0 0 0 0 ED 3E8 ...
```

Figure 8

Row			Degree	Layer
1	F5B2	-2638	-13,19°	24
2	F62F	-2513	-12,565°	23
23	70	112	0,56°	2
24	ED	237	1,185°	1

Difference is 0,625°.
The position address is an angle in degrees (a horizontal angle).

Taking the previous points into consideration, the data from the sensor can be extracted. The sensor has 24 layers and 924 points per layer that provide a 3D view. The collected data contains the coordinates of each point.

20.1.2. Analysis of the existing market

In this part there are multiple examples of companies that provide similar technologies like the LiDAR sensor.

LUMINAR	*https://www.luminartech.com/* Start-up Working on vehicle safety while driving LiDAR sensor: 1sec at 40 m to 7.5 sec at 250m
Velodyne LiDAR®	*https://velodynelidar.com/* Working on vehicle safety while driving Developed 7 LiDAR sensor
eolos FLOATING LIDAR SOLUTIONS	*https://www.eolossolutions.com/* Working on LiDAR integrate in offshore places Wind measuring system Performance measuring at height of more than 200m above the sea level
INNOVIZ TECHNOLOGIES	*https://innoviz.tech/* Develop LiDAR solution that allowed mass commercialization of self-driving vehicles Specializes in smart sensing solution: best known to produce time-of-flight LiDAR sensors Provider of perception software that is used in the real-time capture of 3D spatial data Field of application: Transportation/ agriculture/ robotics
LEOSPHERE A VAISALA COMPANY	*https://www.leosphere.com/lidar/applications* Developed application for LiDAR and nacelle-mounted LiDAR in the atmosphere observation Field of application: wind industry/ weather & climate/aviation weather/ Air quality industrial risk

Princeton Lightwave	*https://www.princetonlightwave.com/* Leading in the supply Geiger mode LiDAR Processing and detection of single photons digitally precisely and in real time Situation awareness and security Enable eye safe, long range autonomous during High speed, high resolution 3D mapping
TRILUMINA	*https://www.trilumina.com/* Powerful Infrared company Enable the use of LiDAR for advanced driver assistance systems and autonomous operation applications to expedite the move of high-quality LiDAR sensors into cars and illuminate the inside of cars with some of the most powerful Infrared Lighting to remind passengers to keep their heads on the roads.
neptec Technologies Corp	*http://www.neptectechnologies.com/products/opal/* Developed 3D machine vision product for automation and robotic application Developed OPAL 3D LiDAR scanner Used from the ground up using the latest innovations in laser optics detection range / data density/ acquisition speed/ obscurant-penetration capability
LeddarTech®	*https://leddartech.com/* Developed Leddar =patented solid-state LiDAR sensing Use light wave digital signal processing and software algorithms Use in mobility-related markets: automotive and intelligent transport systems/ drone/ industrial vehicles

20.1.3. Analysis of current applications for LiDAR

LiDAR is particularly useful in surveying operations to perform 'laser scanning' and generate 3D point cloud images.
The table below shows the current application of LiDAR technology.

DEM Digital elevation model (z,y,x) coordinates	- Capture the surface height of road building and bridge
Micro-topography	- Strike object or penetrate through an object to detect the surface value
Agriculture	- Help to find an area that uses costly fertilizer - Create an elevation map in the purpose to create slope and sunlight exposure area map - Create high medium and low crop production area
Forest planning management	- Use to measure the vertical structure of forest canopy - Measure and understand canopy bulk density and canopy base height - Estimate root expansion of the peak
Forest fire management	- Help to monitor the possible fire area called fuel mapping
Precision forest	- Use to increase the productivity of wood quality or maintain the environment quality thought creation of plan and operation
Tourism and parks management	- Find the best playground area
Environment assessment	- Protect the plants and environment

Biodiversity for birds	- Define which species of birds are available in the forest
Flood model	- Create high resolution and accurate surface model of the river. This extracted LiDAR information can be used for the 3D simulation for better planning of the structures or buildings on the river bank
ELC (Ecological and land classification)	- Help in the provision of both the physical and the biological classification of the land
Modelling of pollution	- Detect noise and light pollution. - Detect particles in both water and air
Mapping	- Urban, city, or town planning
Management of coastline	- Layout and variation of coastline
Oil and gas exploration	- Differential Absorption LiDAR (DIAL) can be used to detect trace amounts of gases in the atmosphere above hydrocarbon deposits. The detection of gases can be analysed for a measurable concentration of anomalies. This is a relatively new method of exploration that is being developed at the moment
Archeology	- Detect micro-topography that is hidden by vegetation which helps archaeologist to understand the surface
Exploring quarries and minerals	- Find the quarry and minerals site
Solar energy planning	- Find the best orientation of solar panels
Glacier volume changes	- Calculate the glacier change over a period
Accident scene	- Record the accident scene and use it later for investigation
Architecture	- Digital building structure and 3D printed designs
Vehicle automation	- Grab the information on the road and it is passed to a computerised system to make a human being like a decision
Sewer and Manhole Survey	- Send all this information from the sewer line (inaccessible area for human) the survey
Astronomy	- Use by NASA
Visualisation and Gaming	- Offside(football) - Automatic ball boy
Wind Farm	- Calculate the direction and strength of the wind on the wind farm.
Oceanography	- Measure surfaces and new animals
COPS	- Detect the speed of the vehicle
Railway Infrastructure	- Perform quickly the measurements of the railway track and the topographical and surrounding area of the railway path

Airport Infrastructure	- Capture features in the airport like runway, terminal building, hangar, and other objects
Tunnel Surveying	- Use to measure accurate and detailed measurements - Used for analysis, assessment, and modelling of the tunnel
Tsunami Inundation Modelling	- Help scientist to understand the area that will be covered when Tsunami happens

LiDAR technology is widely used in many areas. The most common ones are explained below:

20.1.3.1. Autonomous vehicles

LiDAR is especially used for autonomous cars. The LiDAR sensor allows to provide information from different directions at the same time and detects precisely the distance between an object and the car. LiDAR enables a self-driving car to view the surroundings with special powers.

20.1.3.2. Agriculture

LiDAR can be used to create 3D-elevation map of a particular land. This can be converted to create slope and sunlight exposure area map.
This information can be used to identify the areas which requires more water or fertilizer and helps the farmers to save on their cost of labour, time and money.

20.1.3.3. River Survey

Water penetrating green light of the LiDAR can be used to see things underwater and helps to create a 3D model of the terrain. Underwater information of a river can help to understand the depth, width, and flow of the water. It helps to monitor the floodplains.

20.1.3.4. Modelling Pollution

LiDAR wavelength is shorter. It operates in ultraviolet, visible region or near infrared. This helps to image the matter which is of the same size or larger than the wavelength. So, LiDAR can detect pollutant particles of carbon dioxide, sulphur dioxide, and methane. This information helps researchers to create pollutant density map of the area which can be used for better planning of the city.

20.1.3.5. Archaeology and Building Construction

LiDAR plays an important role for the archaeologist to understand the surface. LiDAR can detect micro-topography that is hidden by vegetation which helps archaeologist to understand the surface.
Ground-based LiDAR technology can be used to capture the structure of the building. This digital information can be used for 3D mapping on the ground which can be used to create models of the structure. It is very useful for maintaining a record of the structure.

20.1.4. Analysis of trends and new sectors

20.1.4.1. Drones and accessories

Became a colossal and relevant market in the last few years, this sector is used in significant different applications. However, it still remains a niche-product for a certain group of people.

20.1.4.2. Smart homes

This sector included numerous applications for sensor such as: controlled LED-lightning and kitchen applications, home security, adaptive learning and living together with technology.

20.1.4.3. Digital twin and digital thread

The sensor linked directly to a data tool can analyse the product in real time while they are working in the field. Engineers can ‘talk’ to their products to ask them important questions about possible improvements and their lifetime.
This enables predictive maintenance avoids unnecessary costs for the users.

20.1.4.4. Augmented reality
The sensor can be used for visualisation of project plans or interaction with 3D-models using augmented reality. This technology enables winning partnerships between man and machine.

20.1.4.5. Sustainable product design
Products that enable users to continue the same lifestyle without feeling bad about their impact on the environment.

20.1.4.6. Multi-functional design
Customers want to do more with less such as smart phones and a multifunctional kitchen tool.

20.1.4.7. Design for self-care
This sector focusses more on how products can influence the lives of the users and how they can improve the self-care of users.

20.1.4.8. Mobility technology
Such as Tesla and others, the market focuses more and more on different kinds of transportation and mobility plans.

20.1.4.9. Healthcare
Important and permanent, a lot of inspiration and ideas can be taken from this sector.

20.1.4. Analysis of brand identity

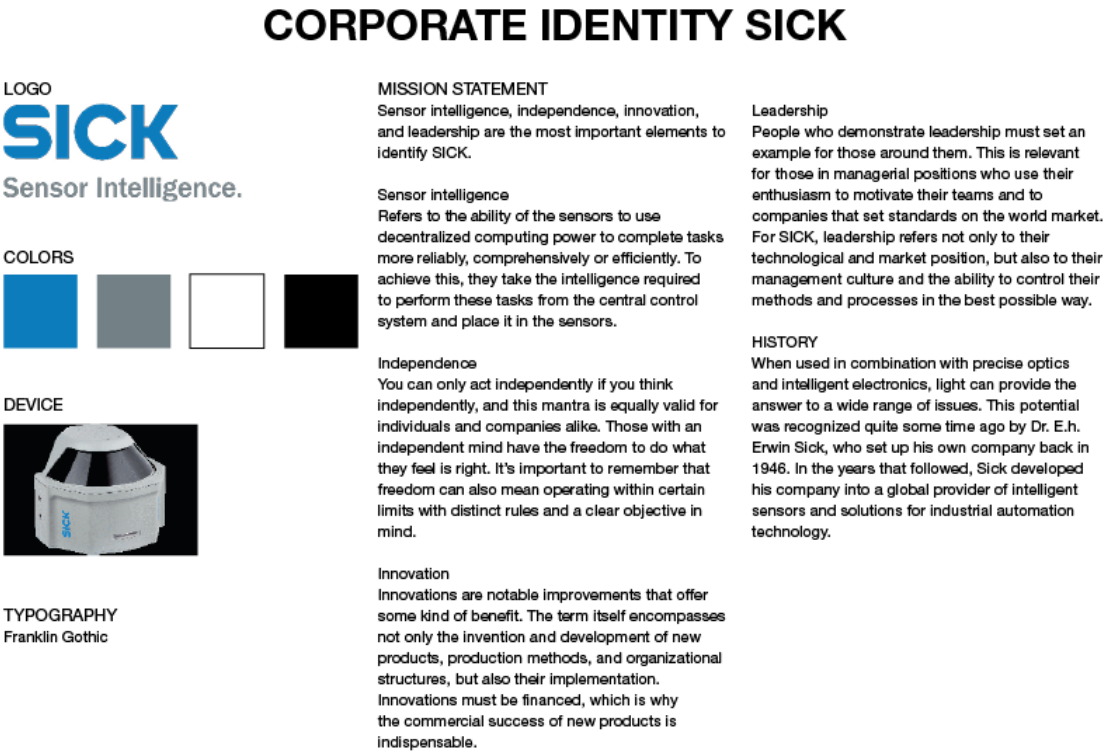


Figure 9

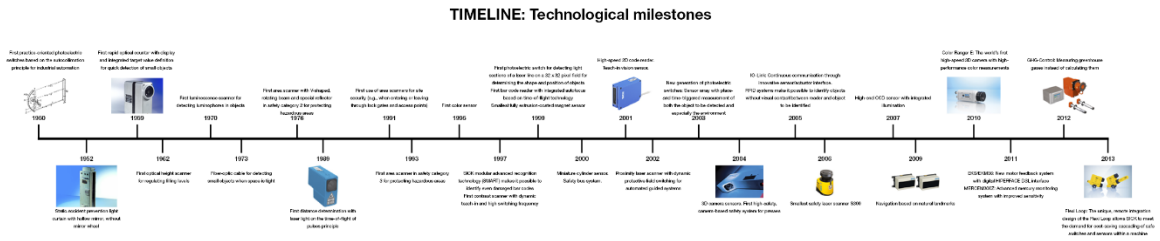


Figure 10 (in attachment)

20.1.6. Conclusion of the analysis part

At the end of the analysis phase, the sensor and the software are tested so everything is understandable. After this phase the goal of extracting a singular point in the data was not reached. There was significant information to learn about the program and the way the sensor interpreters an area.

20.2. Ideation

The end of the analysis phase leads to the next phase: looking for an application for the sensor. This step is important for the rest of the project and allows to find the most original and innovated idea.

20.2.1. Brainstorm

Different brainstorming techniques, converge and diverge method, are used to define a considerable number of different problems that had to be solved. Various approaches are used for choosing the right application.

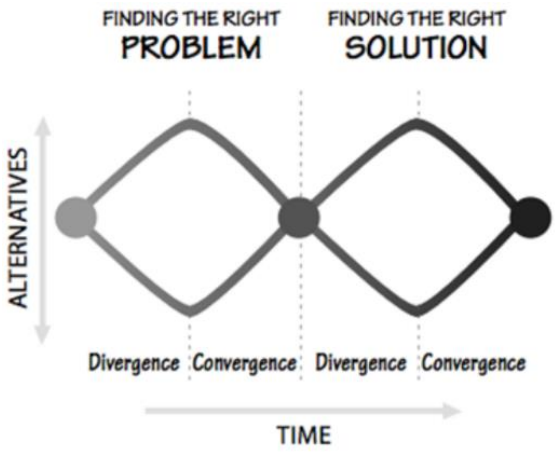


Figure 11

20.2.1.1. Mindmapping

The Mindmapping technique began by writing the problem in the middle of the paper. The problem defined is the following one:
''Come up with a non-existing application for the sick sensor.''
Then, the method focusses on all different uses of sensors. Through many questions, the mindmap can be built. What kind of function do they provide? This part can stay abstract.
In which sectors, places or applications are they used this way? Why? What can they provide in this situation? What are the strongest points of the sensor in these situations?

The main point is not leave anything out in the purpose to draw the mindmap as large as possible. Results from the brainstorm:

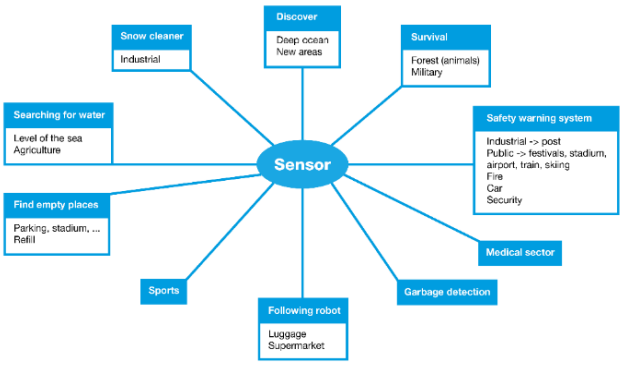


Figure 12

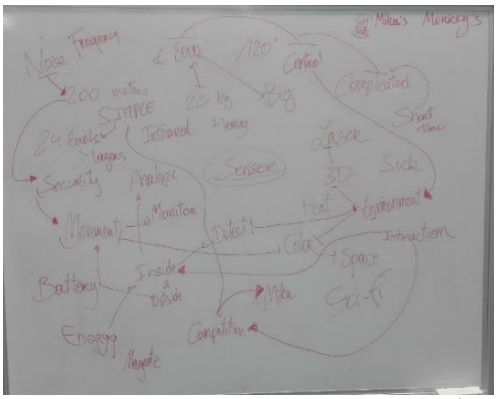


Figure 13

20.2.1.2. Switching/teleportation technique (Owling)

In this technique, it is important to have a better view on what the sensor can be used for and in which situations it could be implemented. This brainstorming exercise teleports team members into a different situation or special character. In 3 minutes, everyone has to come up with an application that would fit in the point of view of this character or situation. After this allotted time the team members presented the idea of what the character they embody will do with the sensor. The switching technique ends when there are no more characters left. The last step is to make connections and classify the idea in category.

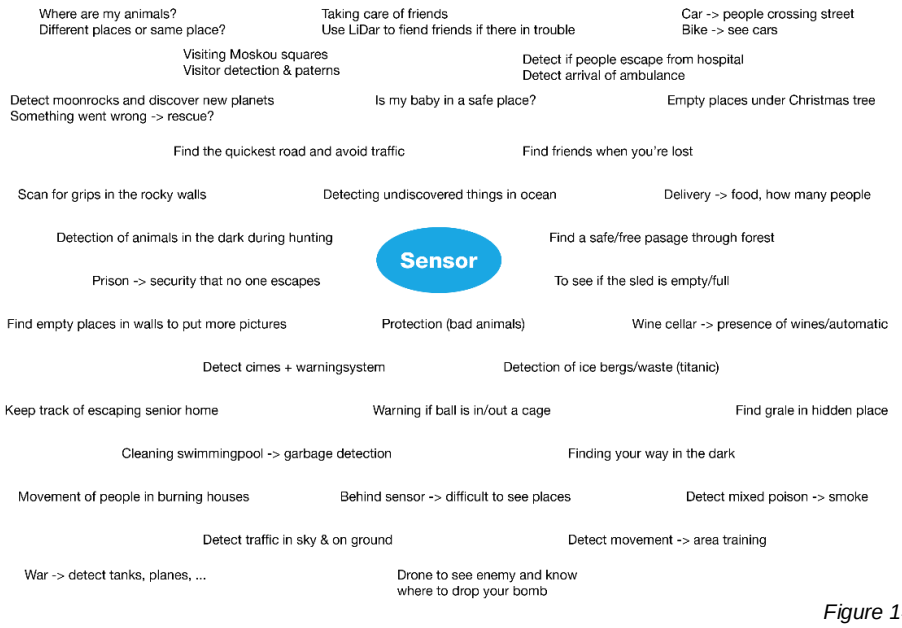


Figure 14

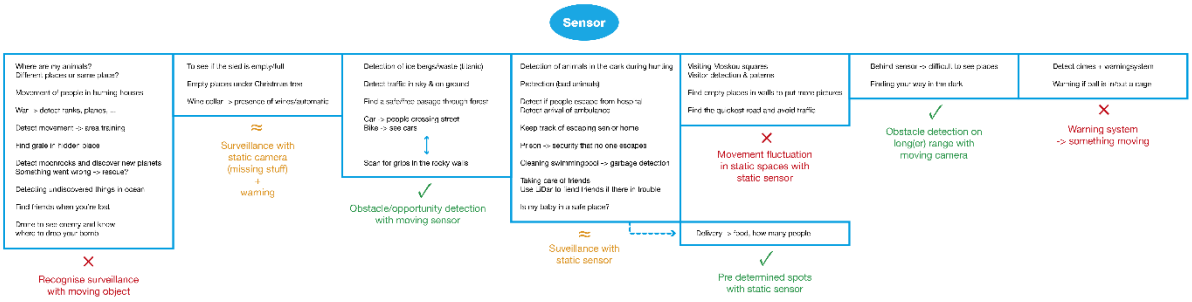


Figure 15 (in attachment)

20.2.1.3. Quick sketching/group sketching

Nobody has to be a designer or artist to be able to use sketching as an interesting and stimulating way to come up with ideas. The visualisation of ideas triggers different parts of the brain and in this way, it is possible to discover questions or inspiration that would otherwise not be found.

Everybody from the team starts with an empty paper and to make a quick sketch (30s) of an idea that sounds valuable. It can be realistic or completely imaginary. The sketch has to be about an application for the sensor or a problem that has to be solved by using the sensor.

Then each team member passes his/her paper on to the right, and everyone sketches another idea on the same piece of paper. This goes on until there is no more place left on the paper.

As last step everyone presents their drawings from the different papers to see the different ideas. These are the results from the drawings:

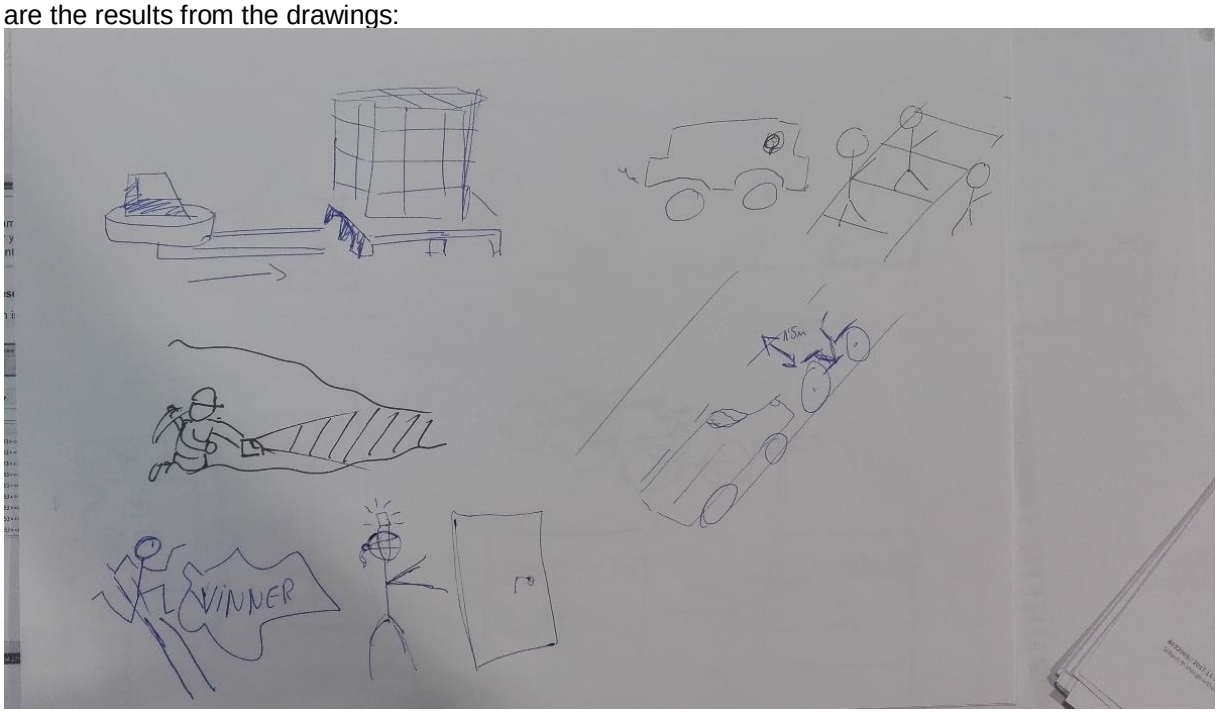


Figure 16

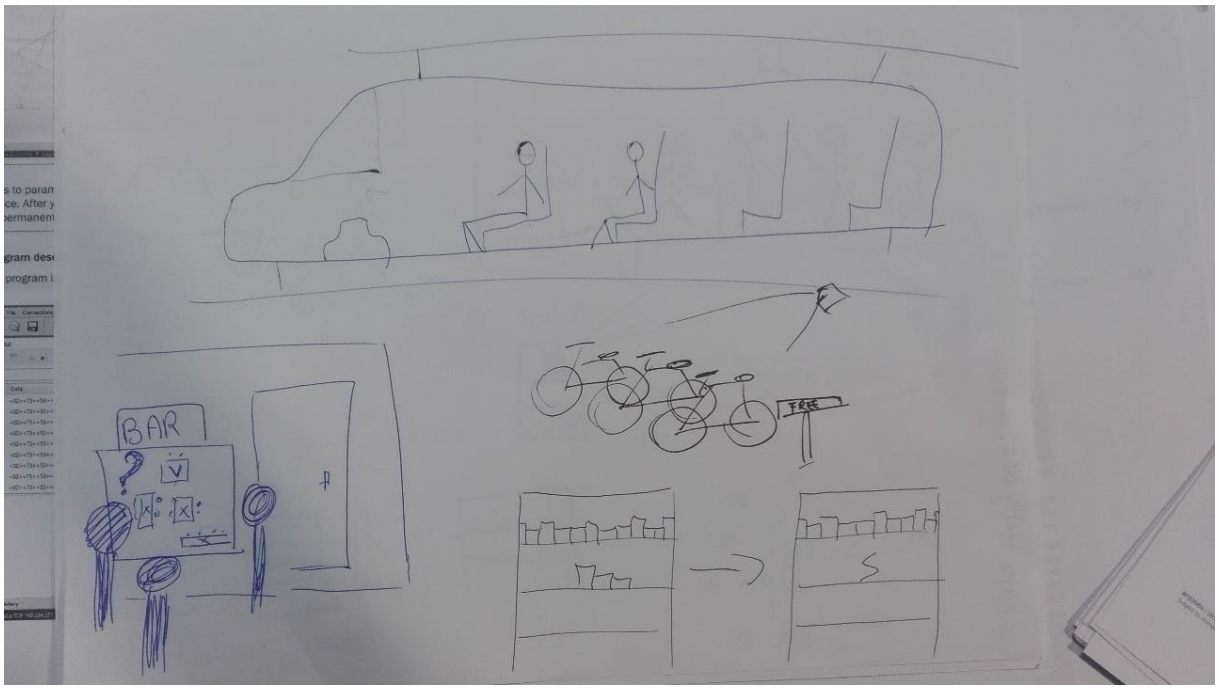


Figure 17

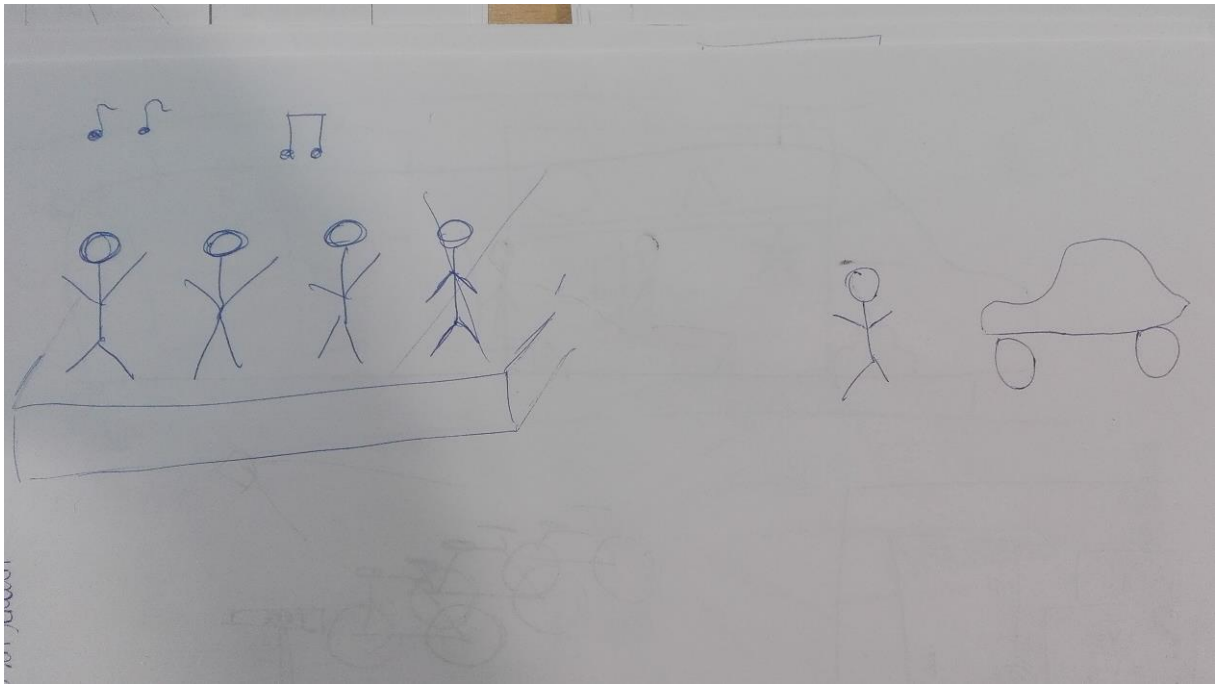


Figure 18

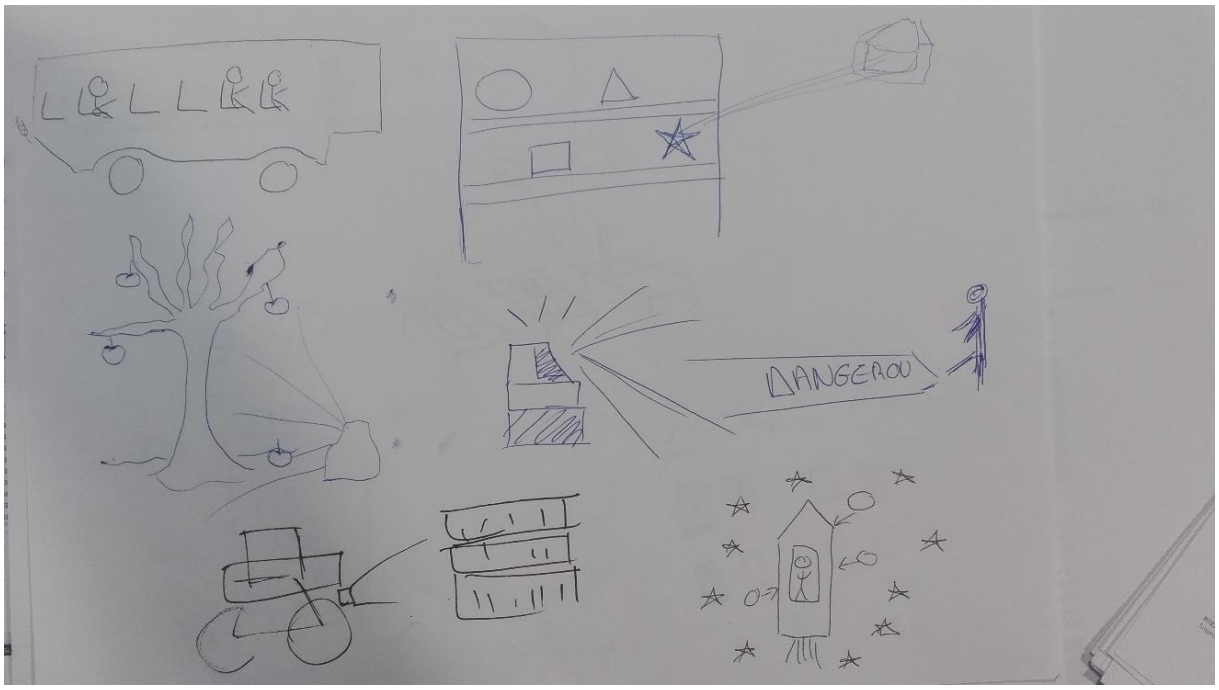


Figure 19

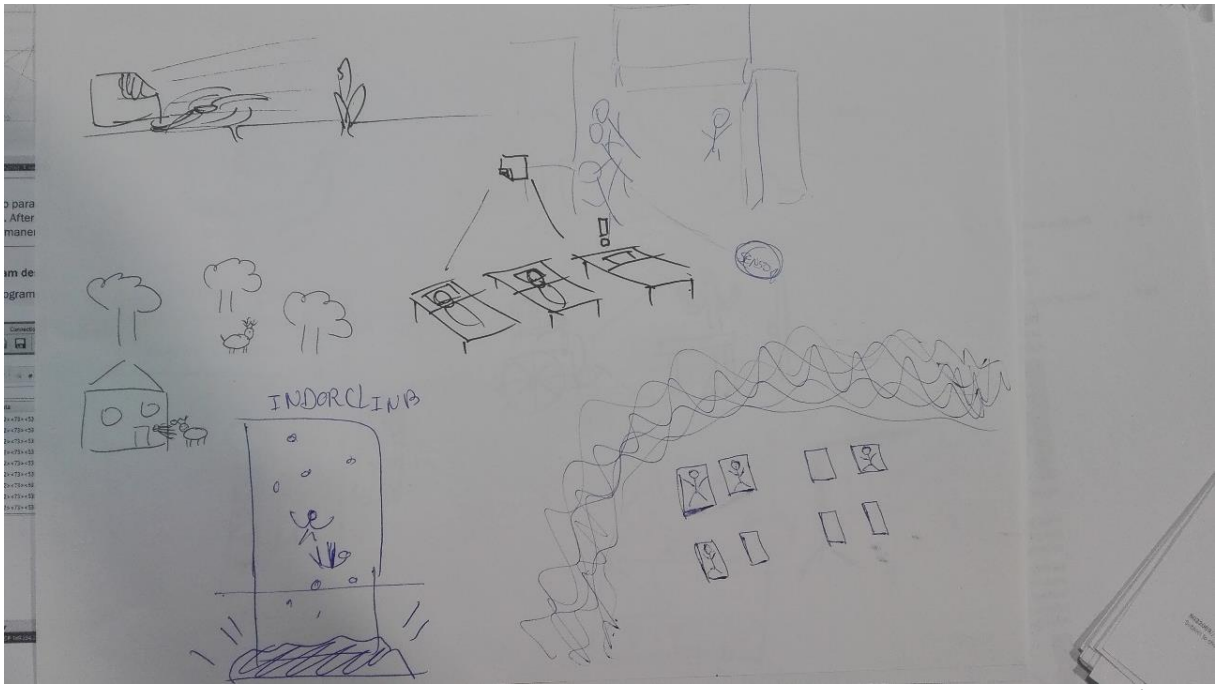


Figure 20

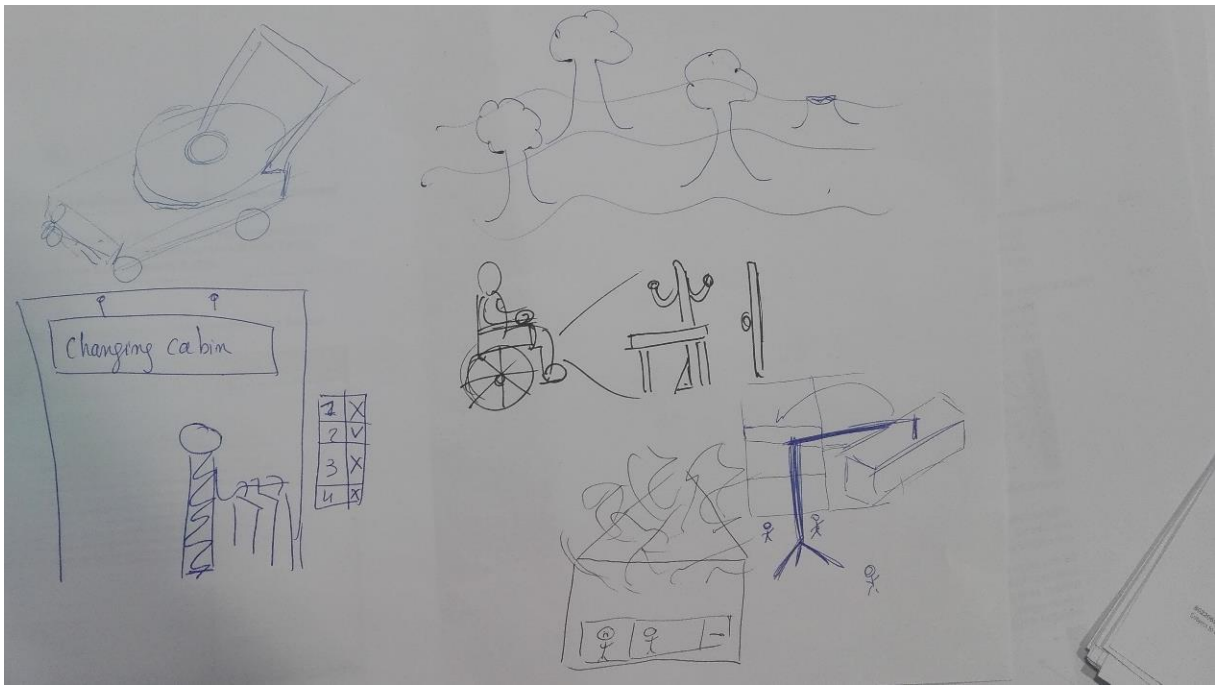


Figure 21

20.2.1.4. Conclusion

According the brainstorm sessions there were three ideas that came out such as smart city idea, forbidden areas and electric car parking. These three ideas were developed further in the verification part.

20.2.2. Verification of ideas

First select the top ideas based on different criteria:

- Commercial (market-based, customer need, ...)
- Organisational (changes to business, management, …)
- Financial (cost structure, possible revenue, …)
- Technological (used techniques, innovation level, …)
- Ecological (environmental impact, used materials, …)
- User based (user journey, impact on customers, …)
- Impact analysis (innovation level, change to system, ...)

The selected ideas of the brainstorming sessions are compared and analysed in each area. The SWOT-analysis defines positive points (strengths and opportunities) and negative points (weaknesses and threats) in different categories to summarise the results.

The SWOT-analysis is a good way to collect all the information that is gathered during the verification phase. The results from the SWOT-analysis of the primary ideas are presented below:

20.2.2.1. Smart city idea

Strengths	**Weaknesses**
Tendency Big user values Accurate	Expensive Several sensors needed
Opportunities	**Threats**
Application Smart cars Easy traffic Easy system in city	Smart cars know everything Better alternatives available

20.2.2.2. Forbidden areas (industrial and public)

Strengths	**Weaknesses**
Less accidents Consequent One sensor	Stupid stops Difference human/robot Critical knowledge (human)
Opportunities	**Threats**
More robots Another area Same sensor for several functions Smart factories	Less jobs Money loss for companies on short term

20.2.2.3. Electric car parking

Strengths	Weaknesses
Easy to charge One sensor Check empty places	Cheaper/easier alternative Expensive sensor Not enough parking lot existing already
Opportunities	**Threats**
More electric cars Develop an application Use for normal parking spaces	Not enough cars Electric spots disappear

20.2.3. Select ideas

In this process the weighted criteria method is used to help to select the best idea to develop further into a real concept. It is a valuable tool for decision-making because it defines individual criteria that are important to the project and grades the alternatives on these different criteria. This way a total value for each alternative can be identified by making a matrix and calculating all the values for all the alternatives. At the end the alternatives are ranked based on their total grade.
A fourth idea came up when the phase of selecting ideas started. This idea was interesting to take in consideration because it seemed different than the other ideas and the focus lays on the safety in metro stations.

The different criteria used in the method are:

- Is the idea or concept easy to develop with the resources available?
- Will it be useful to the customer in a real situation?
- Is the product environmental-friendly or the opposite?
- Can we make a working prototype of this concept in a later phase?
- Will it be fun to work at this concept or idea?
- Are we tackling a real and existing problem?
- Will we be able to finish the project in time with this idea?
- Are there easier alternatives already in existence?
- Do we use the full potential of the sensor?
- What will be the final price of our concept?
- Is the area of choice interesting for SICK?

	WEIGHT	PARKING	INDUSTRIAL	SMART CITY	METRO
Easy to develop?	8	6	8	4	5
Useful for the customer?	5	5	8	7	8
Friendly for the environment?	4	6	4	3	4
Can we make a prototype of it?	6	7	8	4	6
Fun to work at?	6	4	7	5	8
Is it a real problem?	8	3	9	3	6
Are we able to be on time?	7	4	6	7	5
Easier alternatives?	5	2	5	3	7
Do we use all the potential of the sensor?	4	6	6	7	8
The final price of our prototype?	2	8	6	2	3
Is it interesting for SICK?	3	2	7	5	5
	TOTAL SCORE	**271**	**406**	**268**	**351**

This table shows the grades for each of the alternatives from the SWOT-analysis. The safety alternatives stand out with scores of 406 for the industrial safety idea and 351 for the metro station idea.

20.2.4. Conclusion of the ideation part

The industrial safety and the metro station idea will be further specified in the concept phase to see which one is more interesting and better.

20.3. Concept

The concept phase defines if the ideas of the ideation phase are viable. In the following part the two chosen ideas will be presented in concept cards.

20.3.1. Concept cards

Two concept cards are created in the purpose to show the major points of interest of each idea. The strategic check of the cards analysis if the concept would survive in the existing market.
The stakeholders used the concept card to define what they think will be the most realisable idea.
The content of the concept cards is described in this report.

The lean canvas is a method for the strategic check. It gives good impressions of the important aspects of a new product on the market and how product developers should play into the needs of customers and concurrent.

Figure 22

20.3.1.1. Concept card 1: Industrial safety measures

INDUSTRIAL SAFETY MEASURES

1. MARKET ANALYSIS

All this products are just for one machine. Our sensor can manage to secure more areas

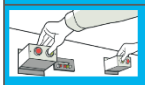
	Kind of protection device	Advantage	Application limits	Company's	Price
	Fixed separating guard (fence, cover)	Long lifetime, protection against injury caused by projected (thrown out) parts, objects.	Cannot be used if frequent access to the danger zone is required. More difficult access with maintenance work.	Brühl Kaiserkraft	€ 70-200 per piece of fence
	Light Beam Safety Devices, Multiple Light Beam Safety Devices, Safety Light Curtains	Access and ergonomic operation of the machine possible. Unobstructed material transport through the protective field is possible with combination with a muting function.	Safety distance required No protection against injury caused by projected (thrown out) parts, objects.	Pepperl- Fuchs Sick Leuze	€ 20-500
	Safety Laser Scanners	Access and ergonomic operation of the machine possible. Flexible adjustment of the protective field according to the respective danger zone.	Limited use in environments with heavy dirt build-up. No protection against injury caused by projected (thrown out) objects.	Sick Pilze Leuze Panasonic Omron	€ 3000-9000 € 4700-7200 € 3800 € 200-6000
	Two-hand controls	Location-dependent protective device with control function. Both of the operator's hands are required for machine activation and therefore protected against injuries	Only protects the person operating the two-hand control device. Other people nearby are not protected. Safety distance required.	Smersal Banner Osha	€ 100-500
	E-Stops	Press button(s) for stopping the machine to prevent immediate or threatening hazardous situations.	Additional cautionary measures for emergencies. Not a replacement for other protective measures. The press buttons must be placed within range of the points of operation.	Digi-Key Honeywell Idec	€ 20-100

Figure 23

2. INTRODUCTION

The application of the sensor has the purpose to increase the security in risky area in industrial field. The sensor will scan a huge area in 3D and will know which the forbidden area is. The sensor will be able to shut down the industrial equipment when a human cross the line of those forbidden area.

3. CANVAS

3.1. Problem

Program the sensor to distinguish human of the robot movement

3.2. Solution

Define the forbidden area:

- How can the sensor know which space is forbidden?
- How close do we defined the forbidden area?
- How can we avoid stupid stops?

3.3. Unique Value Proposition

To create a norm for human with different levels of layers
To drown on the floor the forbidden area that the sensor can see
Not the knowledge yet

3.4.Unfair Advantage

This sensor use a large scanning technology.
This technology can defined a specific area in 3D and can distinguish movement and shape of human.
it would be interesting to have a sensor which can distinguish move of robot in all coordinated direction in one time.

3.5. Customer Segments

Employed who work in industrial area to ensure there security at work.
The company which have to make sure that these employed are safe, to promote a good image, to not loose money and times.

3.6. Key Metrics

- Send the sensor and the software
- Propose the installation
- Propose the maintenance service
- Propose formation on the use of the sensor, software, maintenance

3.7.Channels

- Ad on industrial revue
- Demonstration on industrial show
- Intervention about security in company
- Marketing campaign

3.8. Product Scope

3.8.1. What are the needs of these users/customers?
The needs of user: to improve their security and the security values of the company

3.8.2. Is the sensor used to its maximum potential?
The sensor will use the 3D scanning and the movement's detected

3.9. Revenue Stream

3.9.1. Revenue Model

- To create a licence for the software use
- To propose maintenance service at the company which use the sensor and our application

3.9.2. Life Time Value

- There will be more robot in industrial area
- And more action of human for maintenance so more dangerous situation

3.9.3. Revenue
Can be decreased if new sensor more efficient appears on the market.

Figure 24

4. SKETCHES

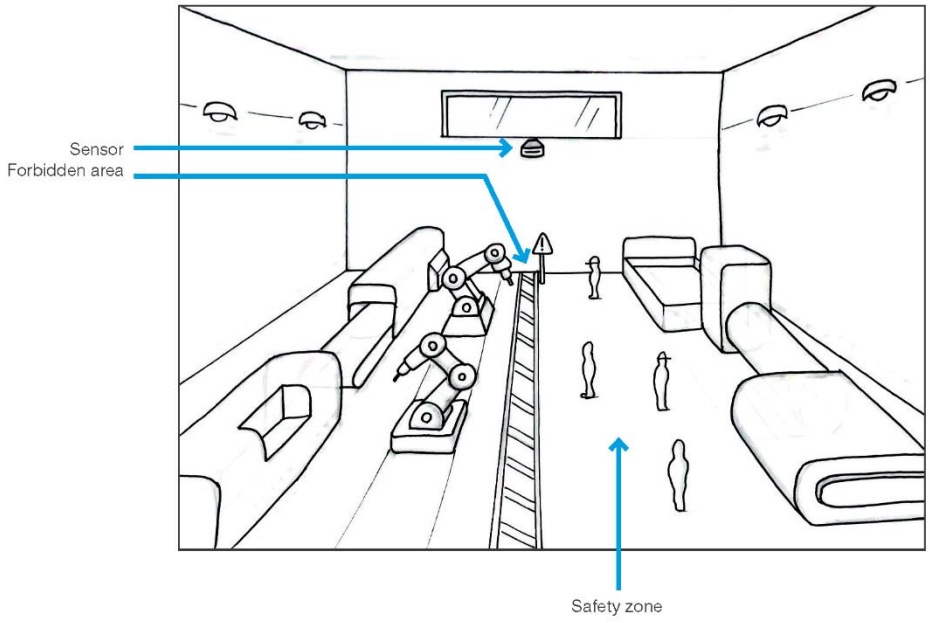


Figure 25

20.3.1.2. Concept card 2: Metro platform sensor

METRO PLATFORM SENSOR

1. MARKET ANALYSIS

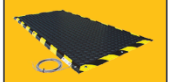
	Kind of protection device	Advantage	Application limits	Company's	Price
	Safety switching mat Used in Hongkongs metro	If a person steps onto the safety mat, an electrical cross-circuit is established between the metal plates. The connected safety relay module SRB evaluates this signal and forwards it to the safety controller Protect PSC, which in turn sends it to the master computer. Signal lights are activated in the control station and movement of the train is stopped.	Frequent maintenance	Schmersal Haake Tapeswitch Mercateo	€ 300-1100
	Camera	Record periods. After meeting with employees. Additional evidence of criminal cases. Small maintenance intervals. 360° view	Vandalism Disturbed signals Big central	Bosch Arlo Abus	€ 20-500
	E-Stops in trains	Press button(s) for stopping the machine to prevent immediate or threatening hazardous situations.	Additional cautionary measures for emergencies. Not a replacement for other protective measures. The press buttons must be placed within range of the points of operation.	Digi-Key Honeywell Idec	€ 20-100
	Safety barriers/ platform screen doors/gates	Only opens when the trains stops. Brings more order to the chaotic boarding and disembarking process. Can check which car is the best to enter (which one is the fullest). The passengers know exactly where the doors will open and that helps to cut down delays.	Squeeze through when the trains is stopped. Problems when the metro doesn't stop at the his place. Subway riders would still need to be taught to stay clear of departing passengers.	Gilgen-Door-System	7.5 million dollar (Newest ones with visual passenger queue)

Figure 26

2. INTRODUCTION

The MRS 6000 sensor will be placed in the highest place of the train station platform to provide an overview of the railway zone and the waiting zones of each side. The sensor is programmed to identify a forbidden area (the railroad is going to be this area).
If the sensor detects people or object presence in the forbidden zone, it will send a signal to an auto-break system to stop the train and avoid the collision. Moreover, the sensor is able to detect and count human presence, so it will allow us to gather data of the busiest hours, days, weeks... These data can be recovered and used to send more trains if it is necessary or to predict future flows of people. Furthermore, the sensor can detect where people usually wait for trains and show the best walls for advertising aims.

3. CANVAS

Who are going to be the users/customers?
The main costumers for this application will be every city that has underground or a similar way of rail public transport. Both public institutions (federal/ provincial governments) and private train companies will be interested in our product.

What are the needs of these users/customers?
The principal worry of the costumer is to avoid train accidents to protect the integrity of people. A secondary need would be to cope with train delays and very crowded and uncomfortable trains.

Which are the most important functions and features of the concept?
The detection of people/object presence to activate an auto-break system.
The possibility to record data of travellers depending on the day and hour and use this information to predict future needs.

Why is it better than other similar products or alternatives?
The best feature of our product is that it offers a huge range of uses with only one sensor. And also to connect every sensor located in different stations and have a global of the railway status. Implementing the complete sensor network heighten the utility of all the facilities offered.

Is the sensor used to its maximum potential? And how/why?
The sensor is used to detect presence in a forbidden area and also to count people. Even using the 3D to detect how far is the object/people to control de break time and distance. To detect common waiting areas too.

How much will it cost?
difficult to say right now. Taken into consideration that the sensor itself costs 8.000€ and adding software and auto-break devices € +5.000. The estimated price would be around € 14.000.

3.1. Market

- Existing market and players on the market
- Used products in the sector right now

3.2. Visuals

Add in visuals which show the concept, possible product looks and environments

- Early concept sketches
- Pictures of the environment it will be used in

Figure 27

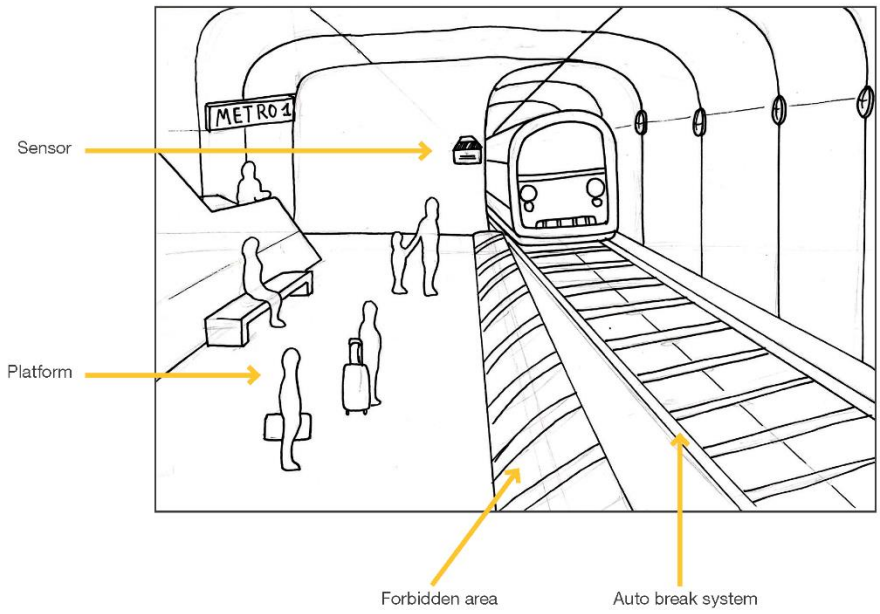


Figure 28

20.3.2. Conclusion of the concept part

In the beginning the team decided to combine both concepts because the same product and method could be used for the industrial and the metro station safety. In a later state of the project, stakeholders were consulted about the ideas and the concept cards were used as an easy reference to the content of it. After the feedback the team decided to focus on the metro station safety. The reason is that metro station platforms are more universal and will give the team not only the possibility to ensure the safety in metro platforms but also to develop a wider concept to have an impact in worldwide society.

20.4. Specifications

This phase of the product development process defines the specified aspects of the concept. It gives a good overview of the aspects that still need to be developed.

The product specification is the first step to determine before developing the final product. The specifications are a list of requirements that are divided into technical, user-related and financial parts. This list allows better communication between the team and towards stakeholders in the purpose to make the realisation of the process easier and quicker.

20.4.1. How to define product specifications

20.4.1.1. Short summary (after the concept)

First the team defines the product definition. This includes the added value, the main function of the product, the market and the technology used. The next step is defining the different subfunctions and features in the product. It leads to choose the unity in the product and the system architecture. The product gets a specific innovation level based on this information. Now the requirements can be specified in the specification list.

20.4.1.2. Product specifications

- Characteristics (weight, price, colour, ...)
- Sub-functions
- Key function
- Requirements and wishes

20.4.1.3. Define the specifications

The first step is to analyse the functional and physical processes by using knowledge and extensive research on this subject. An interdisciplinary analysis is also the key to make the specifications as interconnected as possible which helps to do a creative analysis based on the co-dependent fields of the product. This analysis is based on users, technology and economy. It makes sure that the product will be realistic and viable in the end.
After these different analyses the specifications can be written down using the checklist method. This method checks every aspect of the product life cycle so all the requirements can be divided into the corrected areas. The different aspects are:

- Origin (materials, production techniques, assembly, ...)
- Distribution (transport, packaging, ...)
- Usage (installation, saving, use, ...)
- End (recycling, disassembly, ...)

The team should look for goals, functions and possible borders for each topic.

20.4.1.4. Dividing into categories

This list contains different categories in which the product specifications could be divided:

- Different types of specifications
- Design drivers (stimulates innovation)
- Criteria (keep the quality)
- Descriptive (quantify the borders)

20.4.2. Specification list

20.4.2.1. Presentation of the concept

20.4.2.1.1. The application

The focus of the application is on the use of the sensor inside a metro station. The concept tries to tackle some of the main problems on a platform: accidents happening on the railway, crowdedness on a platform and the platform itself being poorly adapted to the passenger's needs. Using the sensor the metro station owners can collect data from the different platforms and get an overview of the whole metro network.

The collected data from the Metroview allows the owners to provide more safety in the station, to adapt the platform to better suit the needs of the passengers and to control the flow of the crowd across the metro network.

Provide safety
The sensor will be programmed to trigger an alarm and the automatic braking system of the metro. This application will only work when the metro is not at the platform, otherwise if the metro is at the platform, the safety feature will enter to the standby mode until the platform is empty again.

The program discerns two areas on the platform. The 'warning area', shown by the yellow zone in the picture, will trigger an alarm when it is crossed. The 'forbidden area', shown by the red zone in the picture, will induce the automatic braking system for all metros that are arriving at the platform.
This application will increase the safety without making big changes or renovations to the platform and without obstructing the flow of passengers through the station.

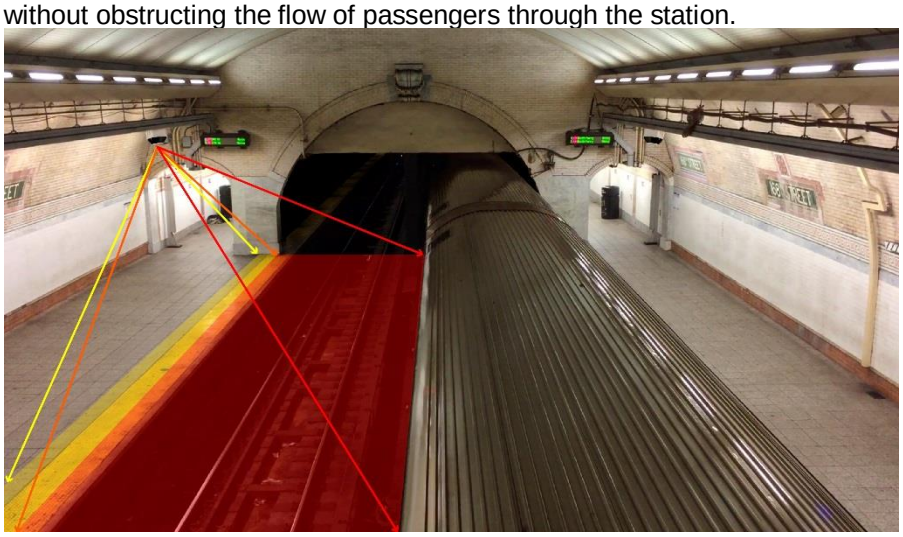


Figure 29

Adapt the platform
The sensor scans the platform and is programmed to count the number of passengers who are waiting. The laser technology can pinpoint the location of each passenger that will provide information about the most and least popular spots where people are standing and how they move around the station.

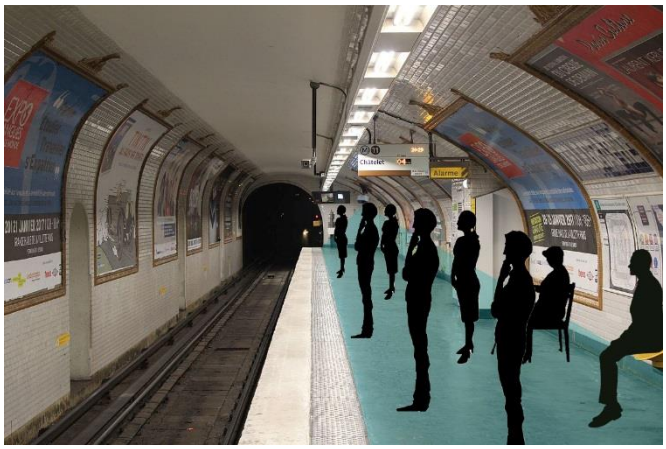


Figure 30

The goal is to adapt the platform and increase the comfort of passengers by adding benches, vending machines and other features. This will allow more dispersion of the crowd along the platform and make the station more adapted to their needs.

Figure 31

Figure 32

Upgrade passengers flow

The sensor has the ability to discern the amount of passengers waiting on the platform and assess a specific number. This number will be analysed and combined with the size and location of the station and its connection to the metro network. With the overview of the whole metro network, the metro company can fluidize the traffic during peak hours and adapt the timing of arrivals and departures, according to hours of the day in purpose of saving energy.

20.4.2.1.2. Added value proposition

The Metroview system is more than just a product, it is an interconnected network of different sensors and different metro stations. Prices for this system are expensive when the metro company has to buy all the devices and install them themselves. For this reason, a circular business model will be implemented for the application. The product will be rentable for the company and there are extra services included that the product provided such as the installation of the devices, the use of the data analysis software, training of safety of employees, the maintaining and monitoring of the network.

Some features of the concept are directed towards more temporary use of the system. If the metro company is more interested in these branches of the application, they can rent the Metroview system temporarily to save money. The sensors can be used again in a different location or context with the purpose to preserve materials and technology.

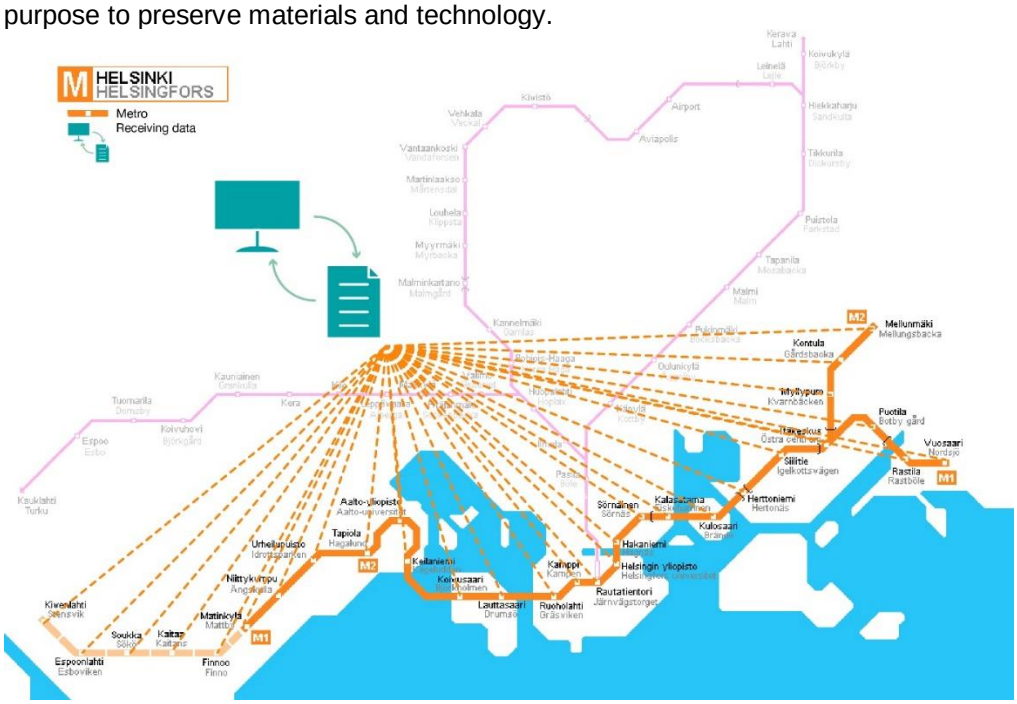


Figure 33

20.4.2.2. Product specifications

Area	Specification	Technological, Economical or User-based	Design Drivers, Criteria or Borders
Origin	Product should be produced in Finland.	E	C
	The materials needed are available in Finland or neighbouring countries	T	B
	Use recycled materials for the casing of the sensor	T	C
	The product is assembled close to the production site of the sensor	E	C
Distribution	The product will be sold B2B	E	B
	Marketing is introduced on specific events for railway companies and global tech events	E	DD
	The cost of the total product will be no more than 12.000 euro	E	B
Installation	The sensors will be implemented into the stations design and layout by experts from our company	T	DD
	The areas are within 200 meters of the sensor's location	T	B
	Workers from our company install the sensor and everything needed	U	C
	The forbidden areas are clearly visible and within range of the sensor	T	B
	The sensor can be mounted on the wall or ceiling and cannot be reached from the platforms	U	C
	The mount can carry maximum 5 kg of weight from the sensor	T	B
	Controls for the sensor are present in the station	U	C
	The product can be plugged into a type F socket with 230V (regular Finnish socket)	T	B
	The temperature of the environment cannot be below -20 or above 60 degrees	T	B

Use	The emergency brake system is activated when a person accesses the forbidden area	T	B
	The emergency brake system is able to start working within 3 seconds	T	C
	The sensor is visible for passengers on the platforms	U	C
	The sensor collects data on the crowdedness in the different areas	T	B
	Application shows passengers the crowdedness in the different stations	U	DD
	Data from the passenger flow is saved and collected in neat data sheets for the railway company	U & E	DD
	The data collection of each sensor is connected to the cloud in a certain way	T	C
	The forbidden areas are clearly visible to the passengers and visitors	U	C
End	The product is built to last the whole lifetime of the station	E	C
	If broken the sensor can be easily reached and replaced	T	C
	The casing is meant to be taken apart and is made of mostly one type of material (DfD)	T	B
	The connections and software can be easily replaced by newer models in case of fast innovation	E	C

20.4.2.3. Specification verification

The use of the SMART(i) method helps the team to verify the specification list. This method checks each individual specification and values if it is:

- Specific and defined
- Measurable and informative
- Acceptable
- Realistic and fitting for the project
- Time limited
- (Inspiring to be creative in the process)

The specification list in this report was verified and adapted in case of shortcomings.

20.4.2.4. The final specification list

The final specification list is a living document which keeps changing through the project. It will be distributed among all parties to allow clear communication about the specifications, so all the parties have to agree upon the list. This list will be the base of most of the upcoming verifications and reviews.

20.4.3. Product planning

20.4.3.1. Introduction

The TOI-list is an enumeration of items that still need to be developed during the development phase of the project. It consists of all the goals that have to be achieved within the project and the obstacles that need to be crossed to get there.

20.4.3.2. List

The goals that are the most important are marked with “I”. These are the goals that are handled first before the others which are marked with “II” and “III”.

Area	Description	Technological, User-related	Importance
Sensor	Defining areas in the sensor	T	I
Sensor	Define the trespassing object in the forbidden areas	T	II
Sensor	Defining the line of sight of the sensor (dark vision, counting...)	T	II
Sensor	Mounting the sensor inside metro station	T	II
Sensor	Counting crowdedness on platform	T	II
Sensor	Controls for the sensor	U	II
Station	Reaction of sensor in emergency situations (power outlet, fire, ...)	T	III
Station	Develop a good brake system (checking out existing systems)	T	II
Station	Output from the sensor to the train/station	T	I
Station	Signal the passengers about the safety measures on the platform	U	II
Station	Calculate best place to mount the sensor	T	I
Interface	Data collection and graphical visuals for company	U	II
Interface	Data collection and graphic visuals for passengers	U	III
Product	Developing a case/mount for the sensor (materials, production method, …)	T	II
Product	Working out the aesthetics of the product	U	III

20.5. Product development

The next step in the product development process is the current development of the product.
This phase contains different steps.
The first one is to find solutions for all the problems that are encountered and integrate all these solutions into one final concept. The next step is shaping of the product and defining the product architecture focusing on designing the aesthetics. The product strategy, already widely defined, analyses the details about the market more precisely.

20.5.1. Corporate identity

20.5.1.1. Brand

Safety, innovation and saving energy are the main elements to identify Metroview.

Safety

Safety is in general an important aspect. For the safety of the passengers there are two main points in the application: the forbidden areas and the warning areas. This will provide more safety for the passengers in the metro stations.

Innovation

In the present and the future, innovation is an aspect that comes back multiple times in different sectors. The platform will be innovated to calculate the future passengers needs and the comfort of passengers will be increased by adding benches, vending machines and other features.

Saving energy

Saving energy is thinking about the future. With a network overview of the amount of people on the platforms combined with all the locations, the metro company will be able to fluidise the traffic during peak hours. The timing of arrivals and departures according to hours of the day will be adapted in purpose of saving energy.

20.5.1.2. Colours

	CMYK	RGB	Pantone Solid Coated	Pantone Solid Uncoated	Hexadecimal
	C: 50% M: 0% Y: 41% K: 0%	R: 159 G: 200 B: 172	352 C	344 U	# 9FC8AB
	C: 93% M: 0% Y: 41% K: 0%	R: 42 G: 159 B: 162	3262 C	7711 U	# 2A9FA2
	C: 0% M: 0% Y: 0% K: 0%	R: 63 G: 62 B: 62	Black 7 C	Neutral Black U	# 3E3E3D

20.5.1.3. Typography

Helvetica – Black
Helvetica – Heavy
Helvetica – Bold
Helvetica – Roman
The titles can contain every colour of the corporate identity depending on the media. According to the style of the document and the amount of information, the style of the titles can be different.

20.5.1.4. Logo

Figure 34

Placing the logo

Figure 35

The X is standing for the space between all the letters of the logo. The logo must be scaled proportional and the space around the logo has to be minimum 3 times X. It is forbidden to use other colours and place the logo different than described.

20.5.1.5. Graphic elements

The graphic elements are existed out of lines. The lines must contain one of the colours of the corporate identity depending on what is the best for the design. They have a minimum thickness of 10 pt. The length depends on the design and the thickness can be thicker than 10 pt.

20.5.2. Sensor casing

The sensor needs the whole range of the laser to work the best. Therefore, the angle and the upside-down placement of the product are the main requirements to take into account for the casing.
The design of the structure around the sensor allows to mount and to fix the sensor against the wall. The weight of the sensor requires a strong structure and at the same time, the structure of the casing has to be quite open to allow the heat of the sensor to be evacuated.
The second point concerns the overview of the platform. The sensor has to be adapted to different stations and the positioning angle should be movable. Thus, the design of the casing integrates inside a mobile part that allows to choose the right angle for the sensor.

Figure 36

20.5.3. Installation of the sensor

20.5.3.1. Location in the metro station

Analysis of the metro station shows that the average size of a platform is between 100m to 200m. For both, it is necessary to install at least two sensors to have the best overview of the platform.
A study of the shape of the metro station exposes that most of them have two train tracks on both sides of the platform. According to this configuration, this example of two different options to place the sensor comes up.

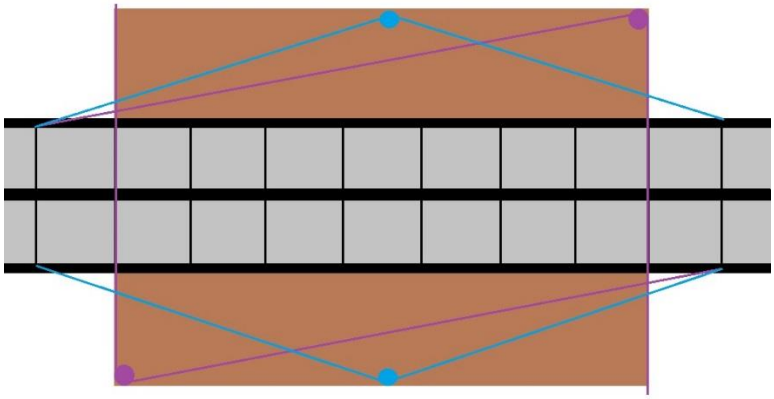


Figure 37

Option 1 (blue):
The sensor will be mounted in the middle of the station. The sensor will have a perfect overview of the front of the platform, but the ends of the stations will be more difficult to see by the sensor.

Option 2 (violet):
The sensor will be mounted on both opposite corners of the platform. This position will provide a perfect view of the whole platform all the way to the back. However, the sensor might not be able to see if there is an object in the middle of the station.

In conclusion, the better option to mount the sensor in the metro platform is the option 2. This location of the sensor allows the use of all the capacity and features of the sensor.

20.5.3.2. Placing the sensor

The Metroview will be mounted upside down on the ceiling or walls of the station using a movable casing. The position combined with the location in the corner of the station provides the best possible overview of the platforms and rail tracks.

Figure 38

20.5.4. Programming

The description of the team members shows that none in the group is able to program. First a second-year student of IT, Robin Snellman, joined the team to help. However, Robin´s help was not enough to extract the data out of the sensor in order to treat it. Our supervisor, Mika Billings, found an extra programmer who leads us to succeed in this task.

The first step to execute was setting up a TCP (*Transmission Control Protoco*l) connection with the sensor. The TCP enables two hosts to stablish a connection and to exchange streams of data. It guarantees the delivery of data and that the packets will be delivered in the same order in which they were sent. Secondly, it was time to load some settings into the sensor. This is shown in the *config* line of the code. All the arguments are default excepted for the retention rate, which mean that, instead of waiting for 100 measurements before updating the data, it will update the data immediately.

```
def config(self):
    self._send(b'sMN SetAccessMode 03 F4724744')
    self._recv()

    # set output rate to 1 (no remission)
    self._send(b'sWN LMDscandatacfg 1F 0 0 1 0 0 0 0 0 0 0 1')
    self._recv()
    self._send(b'sMN Run')
    self._recv()
```

Figure 39

Then, the measurement starts. The sensor will do repeatedly measurements every 100 milliseconds. After that, “Python 3.7” is used as the main programming tool for the rest of the task. In Python, A request is sent to the sensor to get back the data. The sensor sends back the data and the program verifies if it is new information to update it to the screen.

gfx_model.py is the file with the code used to extract and to treat the data from the sensor. It uses this information to know the location of the points. If the points enter in some predefined areas it will update a counter.
config.tolm is the name of the file used to establish the basic settings for the prototype. For example, defining the dimensions of the areas or simple settings as how many points inside an area are needed to generate a warning alarm.
gui.py is the name of the file with the code used to run the program itself and add some restrictions.

gfx_model.py

```python
from math import sin, cos, pi
from gfx_view import deg2rad, in_rec, WARNING, DANGER, SAFE

class gfxModel:
    def __init__(self, config):
        sensor = config['sensor']
        self.ip = sensor['ip']
        self.port = sensor['port']

        display = config['display']

        # size per one grid arc (mm)
        self.grid = display['grid']
        # max distance (mm)
        self.max = display['max']
        # angle resolution (degree)
        self.angle_resolution = display['resolution']
        # sensor size (radius, in mm)
        self.sensor_size = display['sensor_size']
        self.margin = display['margin']

        detect = config['detect']
        self.trigger_count = detect['count']
        self.detect_count = dict()
        self.reset_detect_count()
        self.detect_zones = list()
        self.detect_zones.extend([(x, DANGER) for x in detect['danger']])
        self.detect_zones.extend([(x, WARNING) for x in detect['warning']])
        self.detect_color = SAFE

    # process result from the sensor into data
    def process_result(self, result):
        raw = self.extract(result)
        self.data = self.oversample(raw, self.angle_resolution)
        self.zones, self.detect_color = self.detect_zone()

    # extract raw data, also update config
    def extract(self, result):
        # distance channel 1
        channel = result.channel['DIST1']

        # value = A*x + B
        A = channel['scale_factor']*cos(result.layer_angle*pi/180)
        B = channel['scale_offset']

        # extracting the data
        points = list()
        for i in range(0, channel['length']):
            x = int(channel['data'][i], 16)
            if x >= 16:  # value under 16 is invalid data
                value = (A*x + B)
                phi = channel['angle_start'] + i*channel['angle_step']
                points.append((value, phi))

        # side effect, update config
        self.angle = (
            channel['angle_start'],
            channel['angle_start'] + channel['length']*channel['angle_step']
        )
        self.min = A*16 + B
        return points

    # take avarage value of one small cone
    def oversample(self, points, resolution):
        if resolution == 0:
            return points
        angle_i = 0
        i = 0
        new_points = list()
        while i < len(points):
            while angle_i < points[i][1]:
                angle_i += resolution
            sum_phi = 0
            sum_value = 0
            count = 0
            while points[i][1] <= angle_i:
                sum_value += points[i][0]
                sum_phi += points[i][1]
                count += 1
                i += 1
                if i >= len(points):
                    break
            new_points.append((sum_value/count, sum_phi/count))
        return new_points
```

Figure 40

```
    def detect_zone(self):
        points = list()
        for value, angle in self.data:
            phi = deg2rad(angle)
            x = value*cos(phi)
            y = value*sin(phi)
            points.append((x, y))
        zones = list()
        self.reset_detect_count()
        for zone, unsafe_color in self.detect_zones:
            count = 0
            for p in points:
                if in_rec(*p, *zone):
                    count += 1
            if count > self.trigger_count:
                color = unsafe_color
                self.detect_count[unsafe_color] += 1
            else:
                color = SAFE
            zones.append((zone, color))
        detect_color = SAFE
        if self.detect_count[DANGER] > 0:
            detect_color = DANGER
        elif self.detect_count[WARNING] > 0:
            detect_color = WARNING
        return zones, detect_color

    def reset_detect_count(self):
        self.detect_count[DANGER] = 0
        self.detect_count[WARNING] = 0
```

Figure 41

config.tolm

```
[sensor]
ip = "192.168.69.245"
port = 2111

[display]

# max display distance (mm)
max = 5000

# size per one grid arc (mm)
grid = 1000

# angle resolution (degree)
# lower resolution give higher result
# recommended value: 0 or 1
resolution = 1

# sensor size (radius, in mm)
sensor_size = 80

# margin around the sensor view (in pixel)
margin = 30

[detect]

# minimum point detected in a zone for a zone to be triggered
count = 4

# list of danger zones
danger = [
    [-500, 800, 500, 4000]
]

# list of warning zones
warning = [
    [-1000, 800, -500, 4000],
    [500, 800, 1000, 4000]
]
```

Figure 42

gui.py

```python
from gfx import gfxControl
from gfx_model import DANGER, WARNING, SAFE
from pidar import MRS6000
from time import sleep
import toml
from playsound import playsound
from threading import Thread

def sound_alarm(name):
    playsound(name+'.wav')

def main():
    config = toml.load('config.toml')
    sensor = config['sensor']
    PIDAR_IP = sensor['ip']
    PIDAR_PORT = sensor['port']

    gfx = gfxControl(config)
    gfx.draw_first()
    sensor = MRS6000(PIDAR_IP, PIDAR_PORT)

    sensor.config()
    sensor.start_scan()

    alarm = Thread()
    while gfx.running:
        gfx.draw(sensor.scan_result())
        if not alarm.is_alive() and gfx.model.detect_color != SAFE:
            name = 'danger' if gfx.model.detect_color == DANGER else 'warning'
            alarm = Thread(target=sound_alarm, args=(name,))
            alarm.start()
        sleep(0.1)
    sensor.end_scan()

if __name__ == '__main__':
    main()
```

Figure 43

Another file called **gfx_view.py** contains the code to build the window to visualise the prototype. It considered this code not as important as the others and it will not be added any picture about it. Nevertheless, a video of how the prototype looks in the screen will be added in the following point.

20.5.5. Prototype

Although the application involves a wider concept, we focus our prototype in the safety of metro platforms.

The MRS6000 LiDAR sensor covers a range of 200m length. To show our idea in “SICK INNOVATION COMPETITION 2019” and in the final report presentation, an easy 4 meters prototype has been developed avoiding thus space problems. A 3D view, 24 layers and 924 points per layer, makes the programming task more difficult. To make it easier the final choice to show our idea was a 2D prototype using only one layer.

The 2D prototype was developed with the programming tool “Python 3.7”. This allows to know the location of the 924 points distributed in the layer selected. The main idea now is to determine two different areas and be able to detect the presence of objects or people inside. These objects or people are visualised in the prototype as an aggrupation of points that have changed their position.

The areas mentioned above are:

- The yellow area or “WARNING AREA”: divided in two parts represents the proximities of the railway tracks. In other words, it is the part of the platform where people are not allowed to wait for the metro/train because it is dangerous. If someone enter in this area a warning sound will appear. This sound will keep people aside avoiding possible absorptions to the railway tracks caused by unwilling distractions of the users.
- The red area or “DANGER AREA”: represents the railway tracks itself. If someone or something enters into this area, a different warning sound and the auto-braking system of the train will be activated. The auto-brake system is activated by a wireless signal received by the trains that are going to enter or leave the platform in a short period of time.

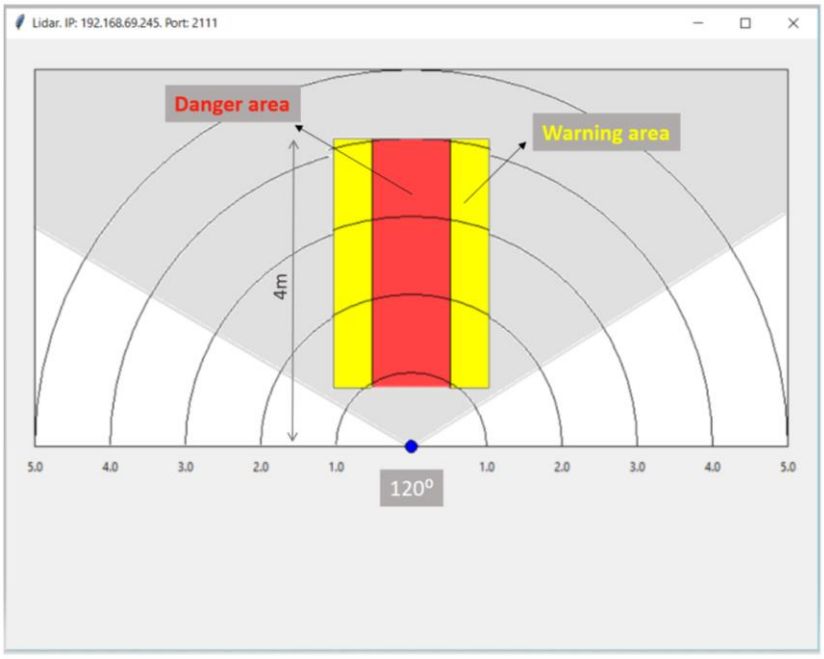


Figure 44

This picture shows how the prototype screen will be if no one enters in the warning or danger area. The aggrupation of points in the sides represents people waiting in the platform.

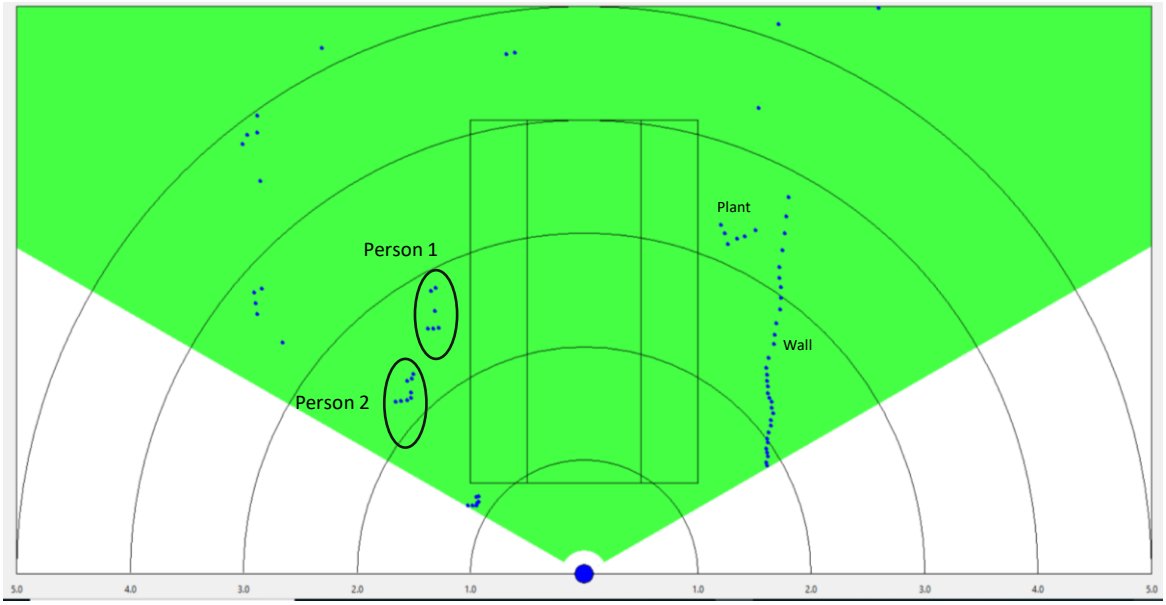


Figure 45

The second picture shows how the prototype screen will be if someone enters in the warning area. The circled points represent the person inside the warning area. The warning sound is activated.

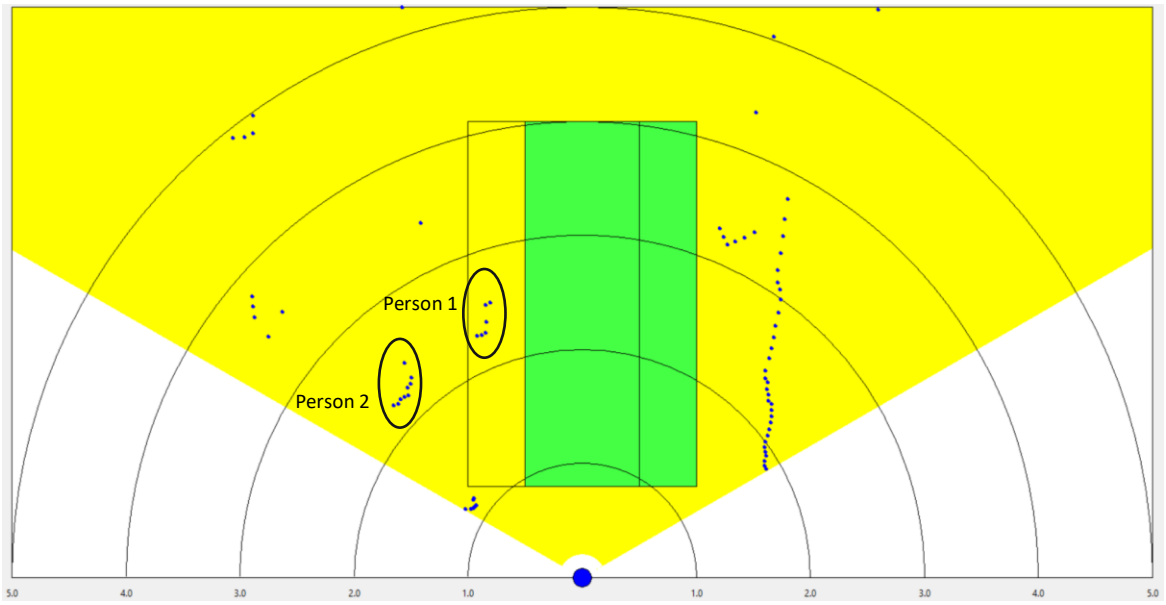


Figure 46

The las picture shows the presence of someone in the danger area.

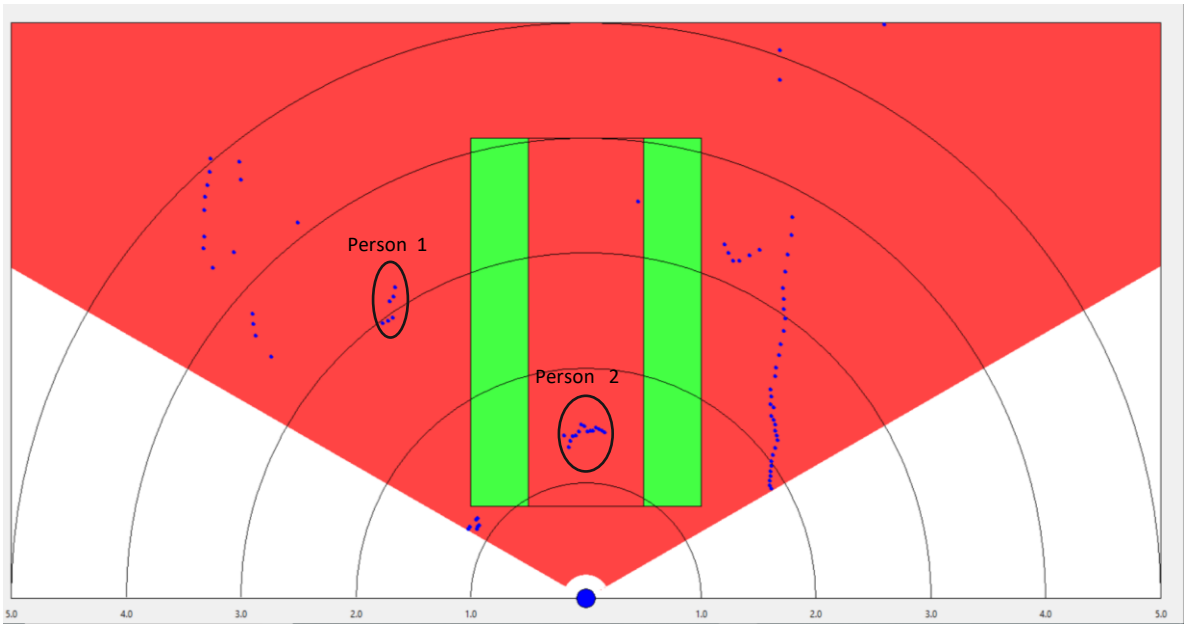
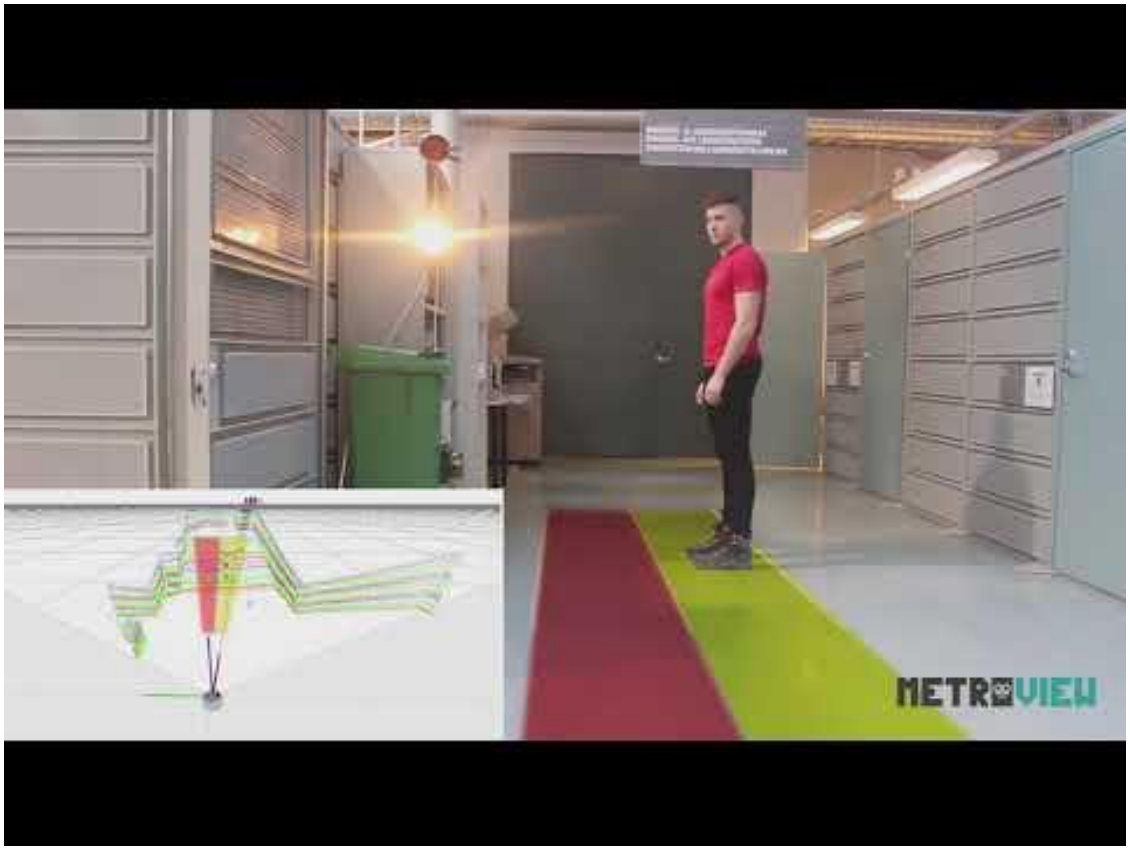


Figure 47

The video for SICK INNOVATION COMPETITION 2019 is presented below.



Video in attachment

20.6. Product review

Verifying and validating is very important to product development and it is a necessary step to take when designing a viable and realistic product. When going through the product design process it is important to implement the right reviewing steps at the right moment, this way a lot of problems can be prevented. Usually, a team of developers goes through 4 steps in the process.

Figure 48

Verification and validation are two concepts that are commonly used together but are two different things. They are not necessarily applied using a specific order or structure. Most of the time both are ongoing and overall processes happening at different points in our workflow at the same time. They are the main drivers behind our most important design decisions, and consequently, our product design.

20.6.1. Verification

The question to answer while performing a product verification is "*Are we building the product right?*" The system and platforms that the team used to build the product and the concept are verified to check if they are working well. This way the quality of the product is determined. After the specification phase, every step is verified looking back at the specification list and the product scope. The team completed

this verification mostly verbally, to check if everything still fits within the chosen specifications or if anything should be changed prematurely. The final verification used is the Eco-Star.

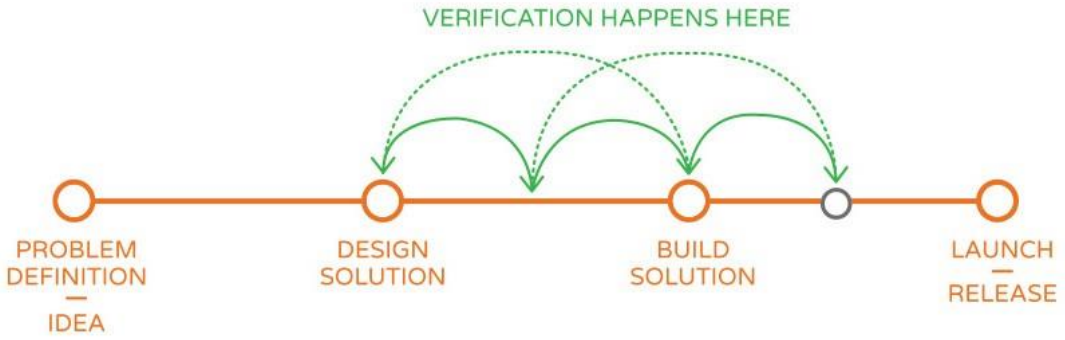


Figure 49

20.6.1.1. Eco-Star

The Eco-Star was used as a method to verify the final product and to check if the ecological opportunities could be improved. It maps these opportunities and encourages the team to look for more eco-efficient solutions and alternatives. Doing the test requires excessive knowledge about the usable materials, production techniques, recyclability…. So, the team uses online research and some expert input to add to our own knowledge.

The different steps in the product lifecycle are verified first in an ecological aspect. The steps are divided into materials, production techniques, assembly, use and end of use.

20.6.1.1.1. Materials

The Metroview casing uses a limited amount of different materials and also optimises the use of these materials, by using only PLA Ingeo series 3D-printing filament. The parts will not be coated or treated afterward, which restricts harmful excipients. This type of filament is not locally produced in Finland and does not use recycled materials which makes it less ecological.

20.6.1.1.2. Production techniques

The casing of the Metroview is 3D-printed locally in Finland. 3D-printing big parts can take a lot of time and energy, but it is the only technique used in this product which makes it better for the transport of emissions. The process does not produce any waste material and has no need for auxiliaries like water or support materials. The toxic emissions of 3D-printing with the selected material are also reduced to a minimal amount, which is one of the main reasons we chose 3D-printing.

20.6.1.1.3. Assembly

The verification of the assembly steps greatly influenced the design decisions made for the casing. By using less energy consuming techniques such as snaps and standard parts like screws and bolts, the connections between the parts are easier and faster to make and cost less. The amount of product parts is limited to 12 3D-printed and internal technological parts. So, this also limits the assembly parts needed to connect them.

20.6.1.1.4. Use

The period of use is perhaps the most ecological part of the lifecycle of the sensor. There are no emissions during the use which was important for the team. The sensor is connected to the energy grid or to a battery, but the product does not use a lot of energy and any consumables in order to work because the batteries are rechargeable. If the casing of the sensor might break during installation or use, the parts are easily replaceable and repairable using 3D-printing. When new sensor technology or techniques are available, they will be easily implemented in the existing product.

20.6.1.1.5. End of use

During the process, the decision was made to design the casing for disassembly to fit in the marketing strategy of the product. In a circular economy, it is necessary for the parts to be reusable or the materials to be recyclable. The materials used in the casing are easily identified and the parts like the sensor last a long time and can be reused in new products easily.

20.6.1.1.6. Star model

The star model shows in which aspects the ecological opportunities are maximised. The product scores well overall but especially the *use* and *end of use* were greatly improved during the development phase. Only the *materials* could still be better adapted to the casing but they are the best-suited choice for 3D-printing a strong and durable part.

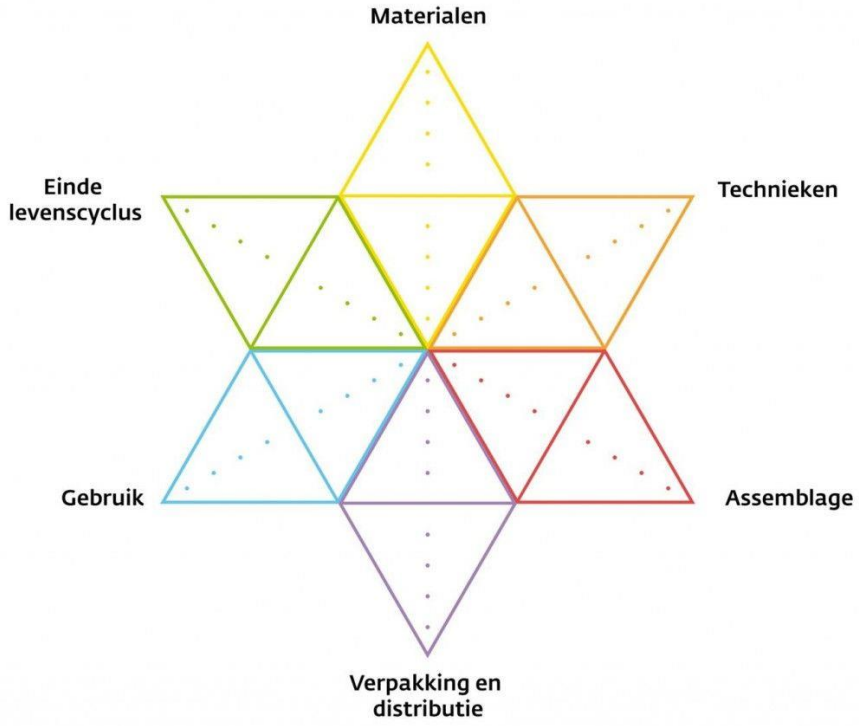


Figure 50

20.6.2. Validation

Validation is an on-going process that should not only occur during a specific step, but it should be present during the whole product development process. During this process, it is necessary to check if the product still matches the users and business needs. The main question here is "*Are we building the right product?*" or something more specific: *"Is there a market big enough for this product?*". Validation should take place from the early to the final stages of our product lifecycle and even after the release of the final solution.

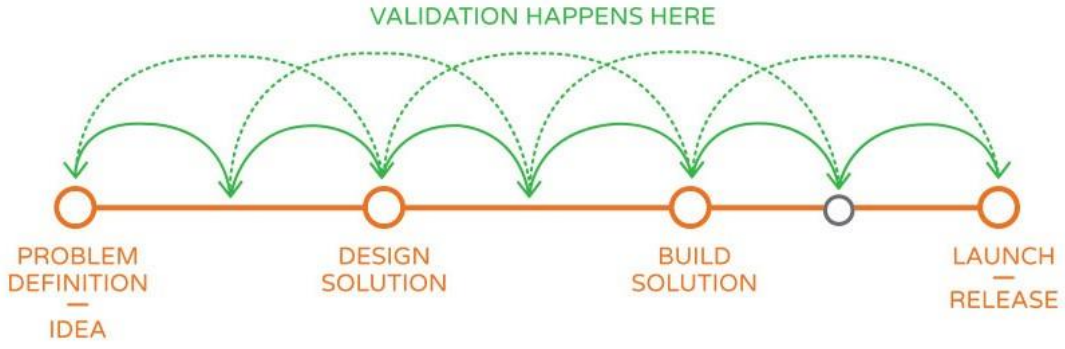


Figure 51

20.6.2.1. SWOT-analysis

While using the SWOT-analysis repeatedly during the design process the team could keep an overview of the whole project. This method, as explained earlier in this report, differentiates between the positive and negative aspects of the concept by dividing them into strengths, weaknesses, opportunities, and threats. Different aspects were considered such as the structural viability, ergonomics, usability and ecology. By defining how well the product scores on these aspects, the validation of the concept is completed. In points below, the SWOT-analysis of the final product and system is described.

Figure 52

Strengths

- Perfectly uses the strengths of the sensor by being able to measure the distance to obstacles
- Fits into the circular economy principle by being 3D-printed and rentable instead of sold. This assures the product will always be up to date and working at peak performance
- 3D-printing makes the casing for the sensor durable and strong, while still being easily adaptable to different environments
- Multifunctional by being a safety system and also being able to gather data about the passenger flow on metro platforms

Weaknesses

- Needs constant connection to the internet and the data cloud
- More sensors should be placed to work efficiently
- Expensive product with a sensor of 8000 euros

Opportunities

- The same system can be implemented in other situations or environments, for example, industrial environments or public outside spaces
- Using the circular economy as a marketing technique more attention will go to the rental system and this will boost our companies' sales

Threats

- Already existing systems that are better specified
- New technologies being created that make ours useless
- Metro stations structurally changing in the future with the disappearance of safety systems and our sensor

20.6.3. Final lean canvas

At the end of the product review a final lean canvas was created to describe changes in the usage and additions to the first lean canvas.
The MRS 6000 sensor will be mounted in the opposite corners of the metro station to provide an overview of the metro station and waiting areas.
The platform is divided into 3 different areas:
The first area is green and it is the safe area where people can wait for the metro.
The second area is yellow and is still on the waiting platform but next to the tracks. This area triggers only a warning sound when entering.
The third area is red and is the area on the tracks. This area triggers an auto-brake system which stops the arriving train. In addition an warning sound is triggered which is clearly distinguishable from the yellow area. The sensor is also able to create a passenger flow analysis. For example, this analysis can show the busiest times at the station in order to be able to use more trains at these times if necessary.

20.6.3.1. Problem

There are always accidents in metro stations or railway stations where people are pushed in front of the train, suicide or slip off from the platform.
At the same time many stations are overrun at peak times and don not allow a comfortable transport of passengers

20.6.3.2. Solution

Each metro station will have 1 or 2 sensors that have defined areas. These areas are green, yellow and red. The yellow and red area will make different warning sounds and the red area will also send a signal to the train to start the auto-brake.
In addition, the sensors will count the passengers flow to adapt the metro station to their needs and to control the crowdedness on the metro platform better.
This allows to see where the best place for advertisement is and where the people waited the most.

20.6.3.3. Users/customers

In the world there are 57 metro lines in 24 countries. These countries are the main costumers for the application. There are more than 3600 metro stations in the world that need to be protected.
The application is also an interesting product for public institutions like the federal and provincial governments.

20.6.3.4. Most important functions and features of the concept

The most important function from the sensor is to detect people presence to activate an auto-brake system from the train.
The possibility to record data of travellers depending on the day and hour uses this information’s to predict future needs.

20.6.3.5. Strengths of the product according to the current market

The sensor offers many possible uses and can continue to get more functions over time. All the feature of the application can take place in one sensor and no extra sensors are needed.
Since the sensor has a range of 200m, only 1 or 2 sensors are needed to monitor a complete metro station.
Instead of only an alarm signal being triggered and then getting help, it is possible to trigger an auto-brake in the train in a dangerous situation. This gives the rescue service the appropriate time to rescue the injured.
The sensors of a metro line can be linked so that problems can be precisely determined and an overview of the traffic can be obtained.
The application can also be used in train stations and enables complete safety there as well.

20.6.3.6. The maximum potential use of the sensor

The sensor will use the 3D-scanning and the movement detection.
This allows the sensor to detect people and measure the distance to the sensor. In addition, different areas can be set up to see if the passengers are in a dangerous area.

Key metrics

- Send the sensor, case and the software
- Propose the installation
- Propose the maintenance service
- Propose formation on the use of the sensor, software, maintenance

20.7. Visualisation

20.7.1. Introduction

A 3D-model is always a good visual representation of how the final product should look like and helps with defining the physical properties of the actual product. In this case, the chosen production technique is 3D-printing so it was very interesting to try and 3D-print a prototype of the casing for extra strength testing. The software used for the modeling is Siemens NX 12.0 which is a collection of different software packages perfectly suited for parametric and direct solid/surface modeling.
For this project two different models were made: one model was created to be a visual representation of the final product, and the other as a base model for the parts that were 3D-printed.

20.7.2. Visual model

Figure 53

The visual model is mostly meant as an aesthetic example of the possible final casing. The shape of the casing is inspired by metro stations and their existing visuals, so the product will fit perfectly into the environment. A large part of the shape is influenced by this and the corporate identity, but some changes had to be made to make the total product 3D-printable.

A moodboard of pictures that summarise the look and the feel of a classic metro station or platform can be found below.

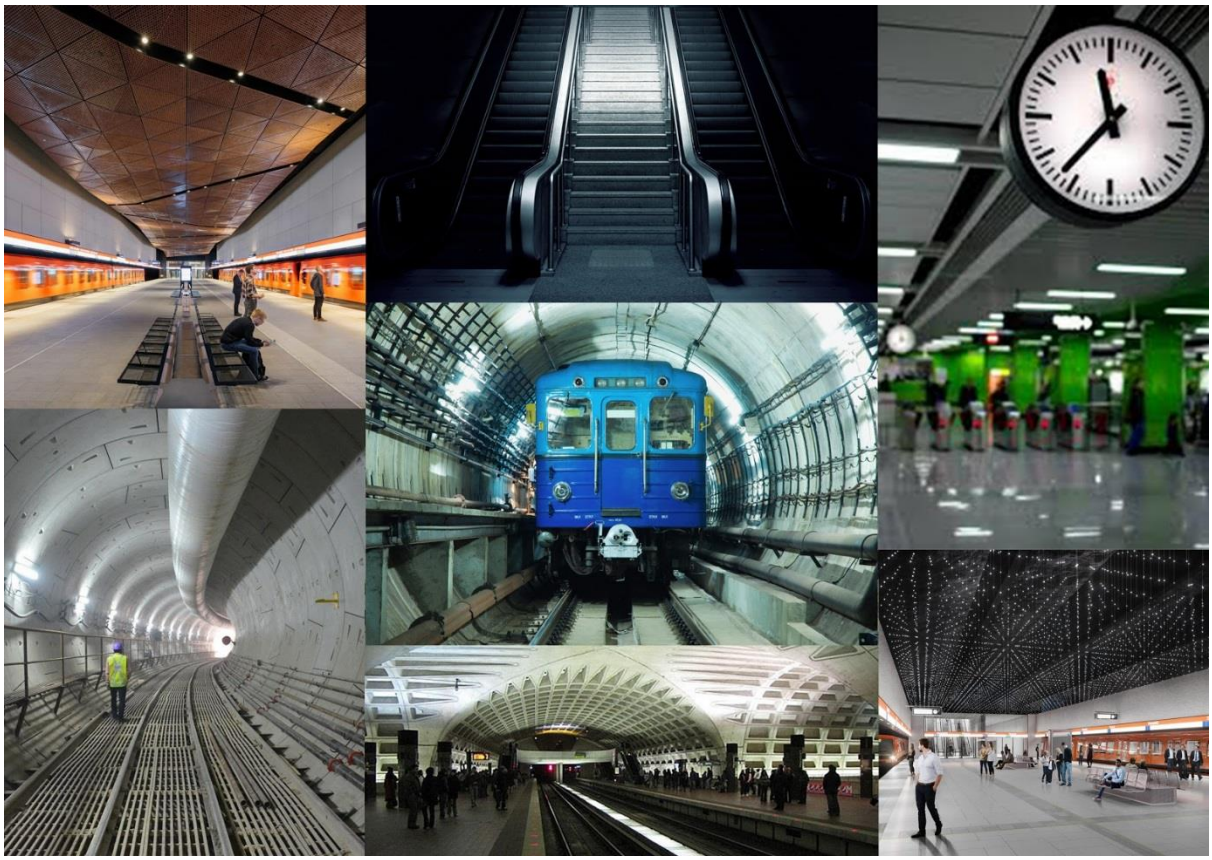


Figure 54

First, the model of the sensor was created. This way the size and the look of the other parts could be based on this model because the sensor is the heart of the product. The other two parts are the moving part and the mounting part.

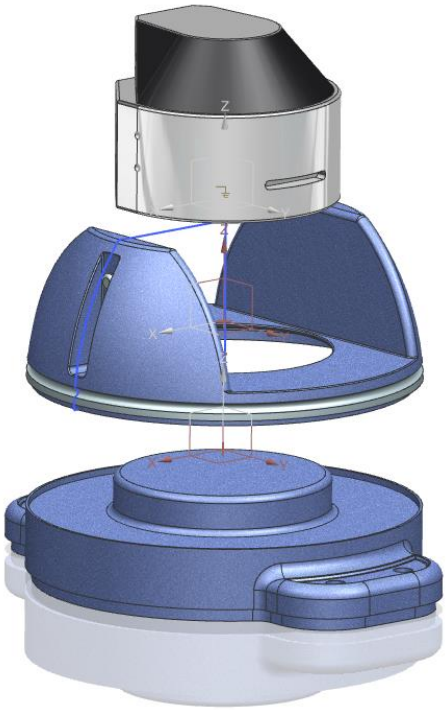


Figure 55

The chosen colours and shape were based upon the brand identity profile of the concept to make it fit within our marketing strategy. The SICK logo was added to show off the sensor we used in our concept.

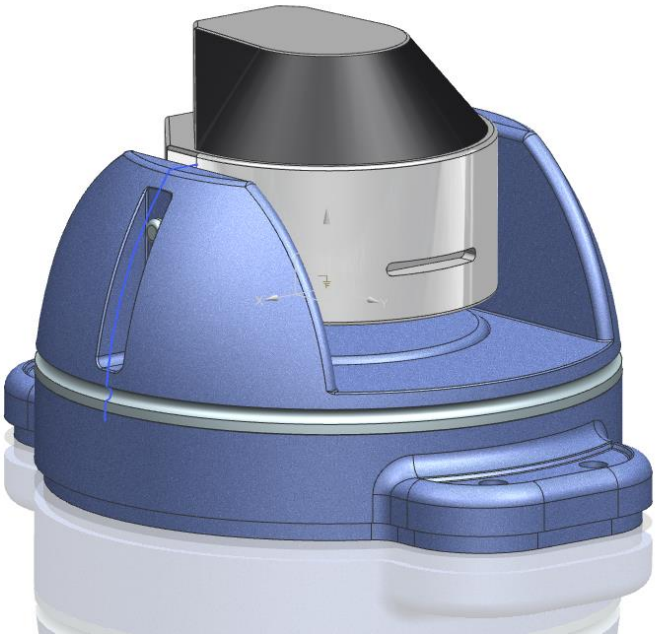


Figure 56

When the model was finished and all the materials defined, renders could be made of the final model to give the concept a photorealistic look. This improves the look and the feel of the final representation. It gives a great realistic view for stakeholders and employees.

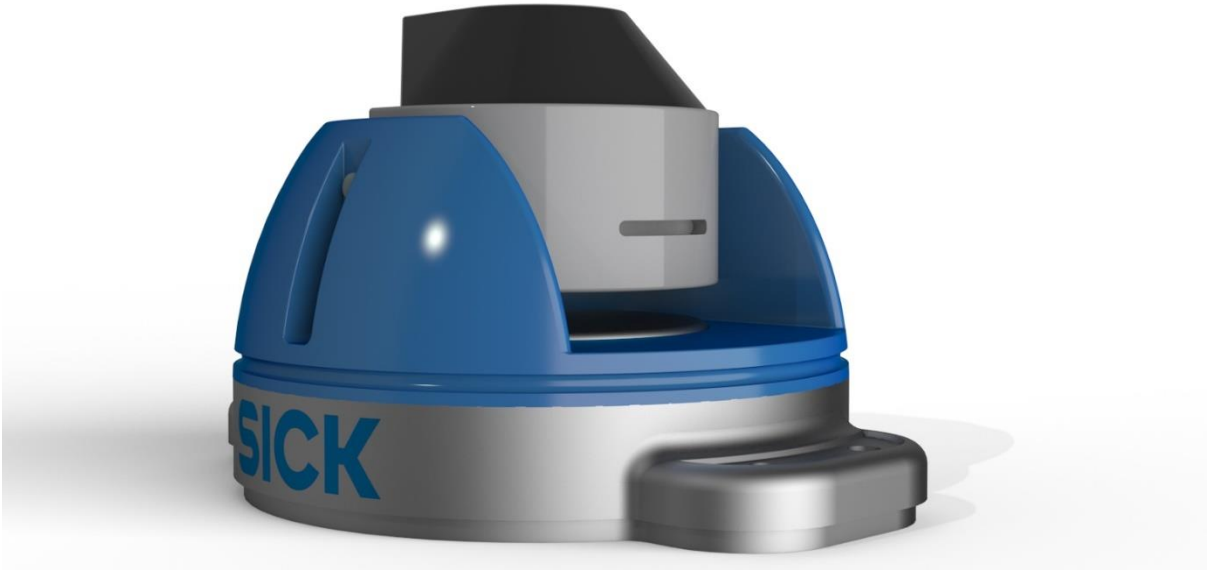


Figure 57

20.7.3. 3D-printing

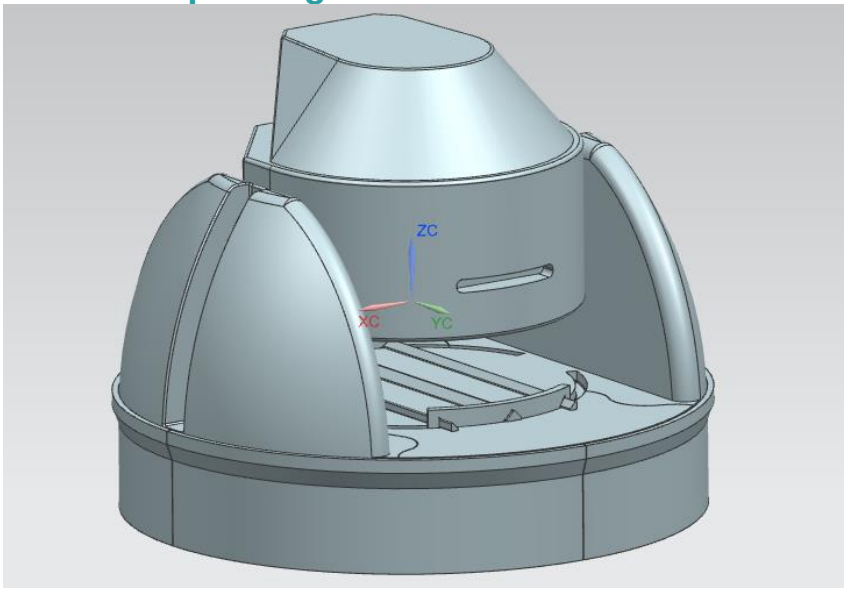


Figure 58

Finally, a real-life model could be made of the sensor casing. The chosen production technique for this product is 3D-printing so it was really interesting to try and to print the shape and some moving components. To make the visual model into a 3D-printable model, several changes had to be made. Some features were not possible to be 3D-printed so a rearrangement of the parts was necessary. The final prototype of the 3D-print has 13 parts (without the sensor).

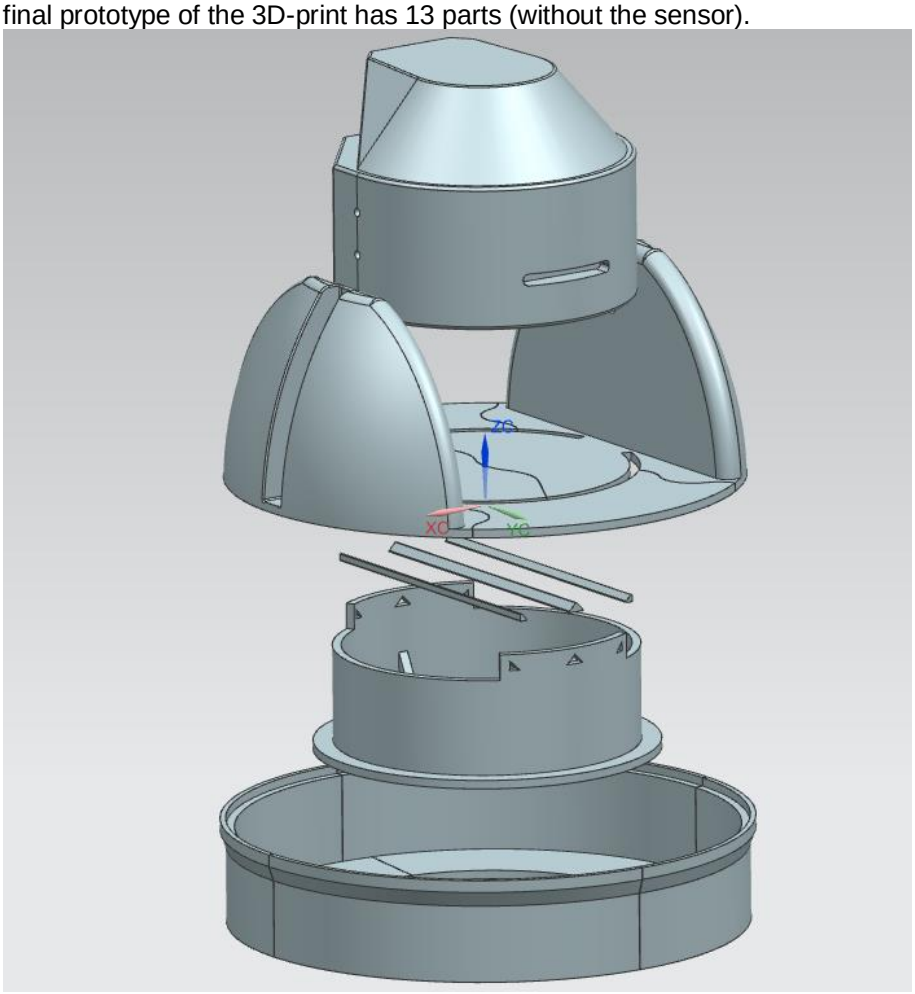


Figure 59

Pictures of one of the parts being 3D-printed can be found below.

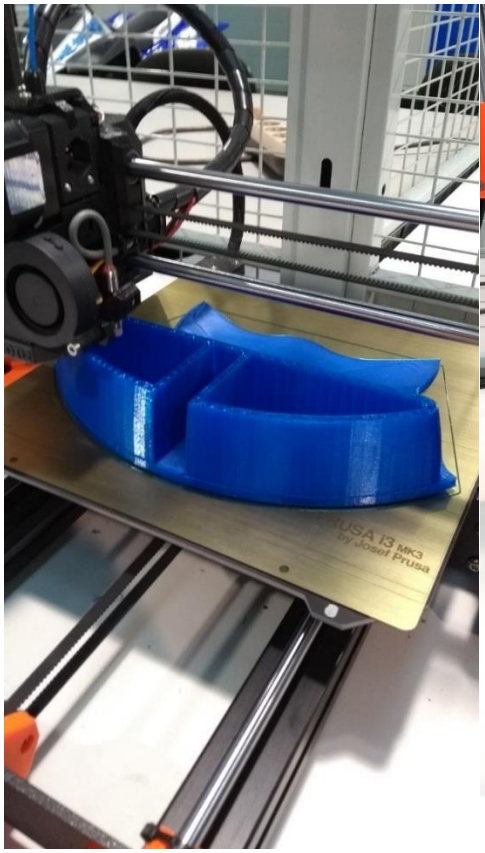


Figure 60

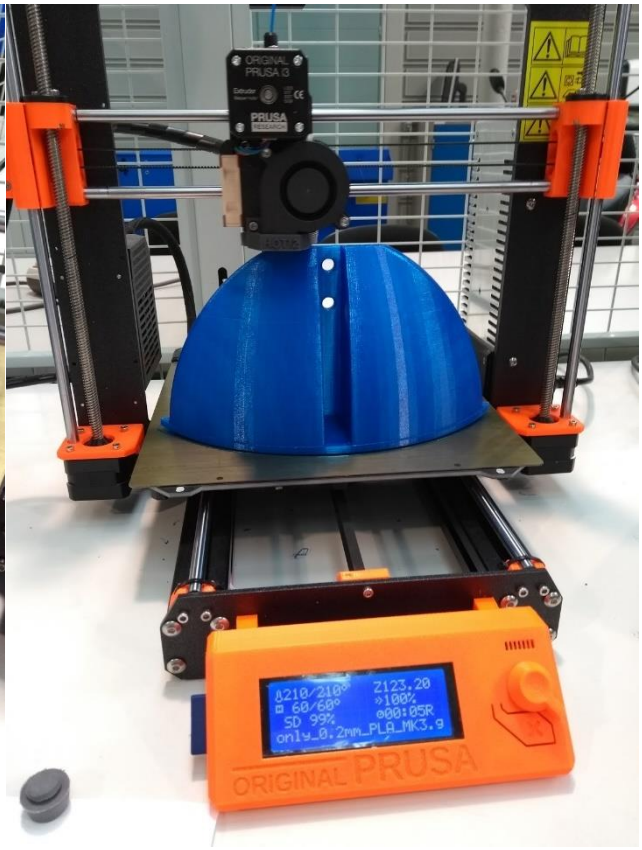


Figure 61

Because of long printing times and technical problems not all the parts could be printed yet. It is a possibility to print them later to check the model.

30. Project management

Project Management is the application of knowledge, skills, tools and techniques to project activities to meet the project requirements. By Project Management there are three things that should be identified: input → tools and techniques → output. These aspects will be explained in the following points with the order according to The PMBOK Guide – 4th Edition.

30.1. Objectives and Work Breakdown Structure

30.1.1. Project scope management

The project Scope refers to the part of the project planning that involves determining and documenting a list of specific goals, deliverables, features, functions, tasks, deadlines, and ultimately costs. In other words, it is what needs to be achieved and the work that must be done to deliver a project.

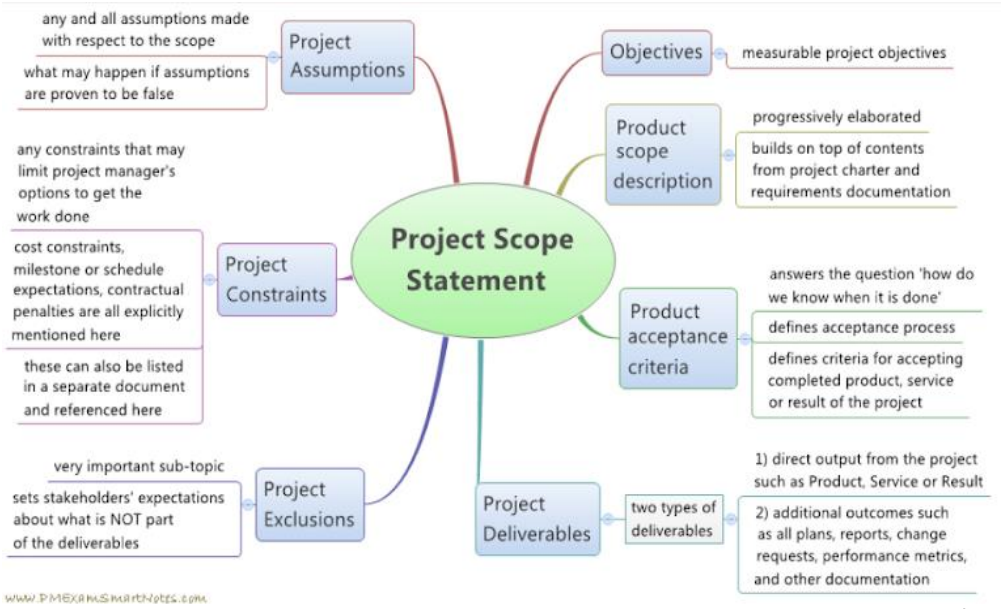


Figure 62

30.1.1.1. Objectives

- Managing a working prototype with the implemented sensor
- Final report with all the process steps
- Booklet to present the concept
- Explicative video
- 3D modelling case
- Webpage

The use of the SMART method helps the team to verify if the objectives set are suitable. This method checks each individual objective and values if it is:

- Specific and defined because it shows what the team wants to achieve
- Measurable and informative because you can figure out the amount of task completed
- Achievable thanks to the technology and the help given from NOVIA and SICK
- Realistic and fitting for the project
- Time limited because the project has a deadline

30.1.1.2. Project scope description

The scope of this project is to design a functional and innovative application for a sensor provided by SICK. The sensor will be placed in metro stations to ensure safety in metro platforms as well as improving the wellbeing of the users. Also, developing an attractive business model.

30.1.1.3. Milestones

- 5/2 - Project initiation
- 23/3 - Midterm project documentation delivery
- 26/3 - Midterm presentation
- 5/4 - Competition documentation delivery
- 18/4 - Competition results
- 7/5 - Presentation for the competition delivery
- 10/5 - Final project documentation delivery
- 14/5 - Final project presentation

30.1.1.4. Deliverables

- Midterm report
- Midterm presentation
- Sick report for the competition + video
- Sick presentation for the competition
- Final report
- Final presentation
- Website of the project
- Video of our daily work and stay in Vaasa

Exclusions, Assumptions and Acceptance criteria were stablished in the first meeting while developing the team contract. It is not necessary to go deeper in these aspects here as they will be treated in the following points.

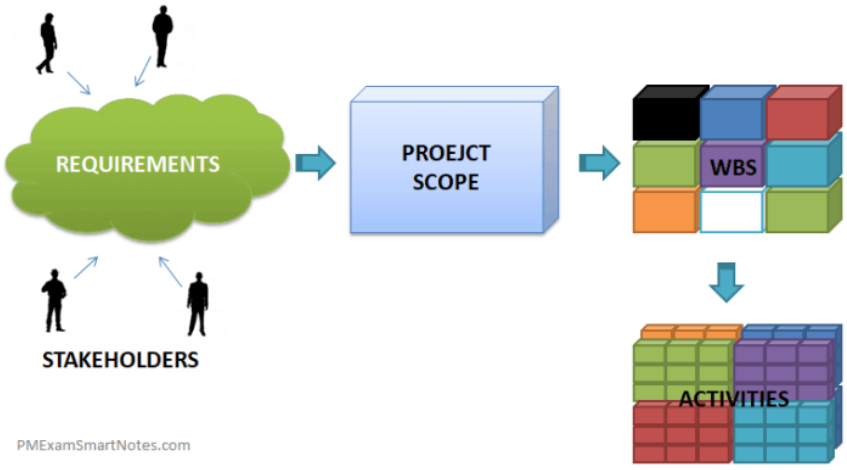


Figure 63

30.1.2. Work Breakdown Structure

By using the Work Breakdown Structure and following the steps it was possible to achieve a good product.

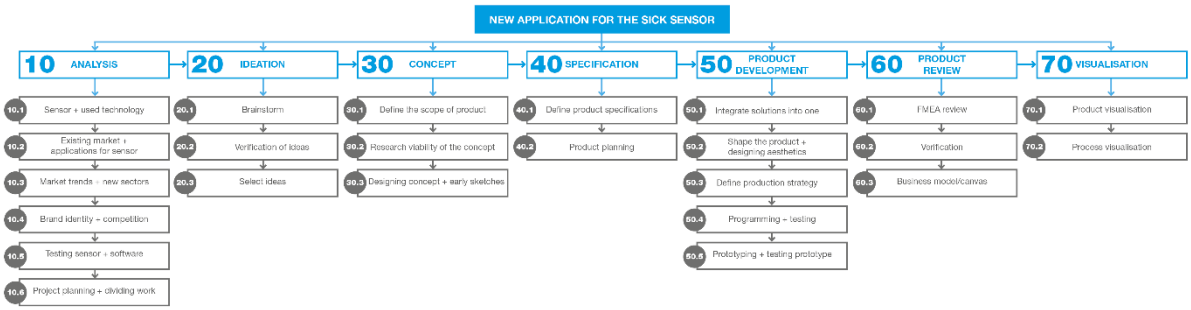


Figure 1 (in attachment)

30.2. Scheduling project

30.2.1. Sequence activities

Inputs	Tools & techniques	Outputs
Analysis	Research	Information, planning
Ideation	Mindmapping, switching/teleportation technique, group sketching	Find two good ideas
Concept	Market analysis, specifications, lean-canvas, sketches	Concept cards
Specifications	Specification list, stakeholder analysis, TOI	Define and work on tasks
Product development	Not clear yet because this is the next step	Prototype & booklet

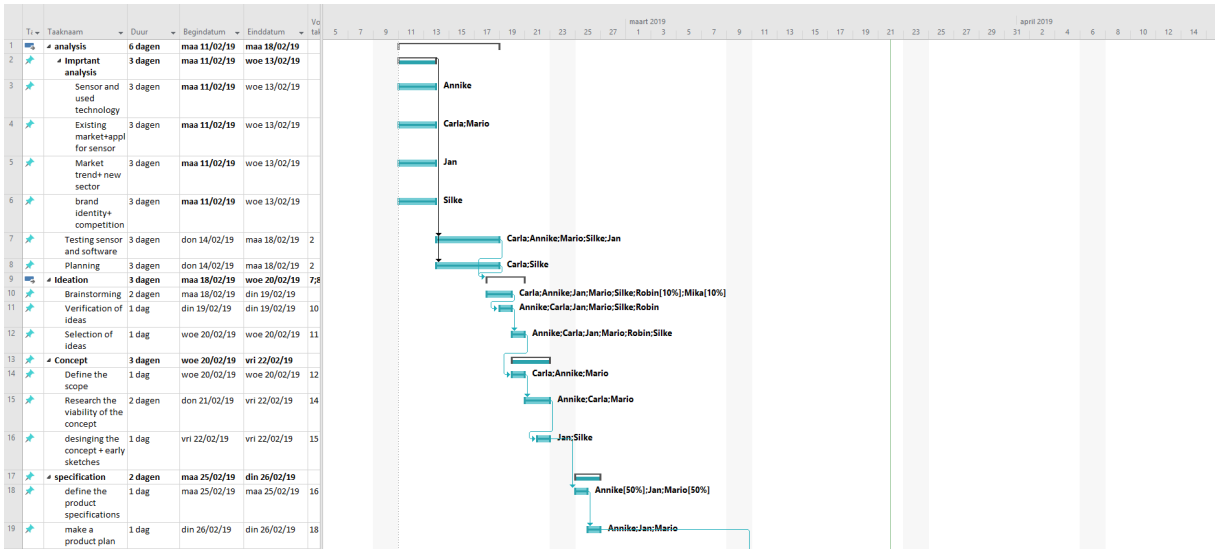


Figure 64 (in attachment)

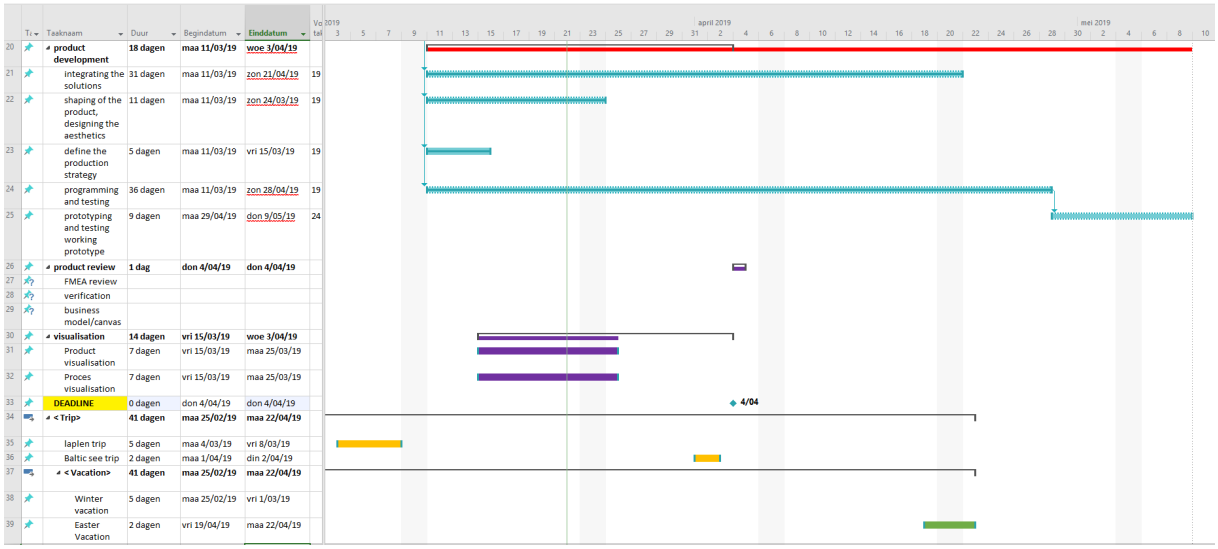


Figure 65 (in attachment)

GANTT DIAGRAM

20	product development	18 dagen	maa 11/03/19	woe 3/04/19	
21	integrating the solutions	17 dagen	maa 11/03/19	din 2/04/19	19
22	shaping of the product, designing the aesthetics	36 dagen	maa 11/03/19	maa 29/04/19	19
23	define the production strategy	36 dagen	maa 11/03/19	maa 29/04/19	19
24	programming and testing	17 dagen	maa 11/03/19	din 2/04/19	19
25	prototyping and testing working prototype	25 dagen	woe 3/04/19	din 7/05/19	24
26	product review	1 dag	zat 27/04/19	zat 27/04/19	
27	FMEA review	1 dag	woe 8/05/19	woe 8/05/19	19
28	verification	2 dagen	zat 27/04/19	maa 29/04/19	23
29	business model/canvas	1 dag	zat 4/05/19	zat 4/05/19	15
30	visualisation	14 dagen	vri 15/03/19	woe 3/04/19	
31	Product visualisation	8 dagen	zat 16/03/19	din 26/03/19	
32	Process visualisation	37 dagen	zat 23/03/19	maa 13/05/19	31
33	DEADLINE	0 dagen	don 4/04/19	don 4/04/19	

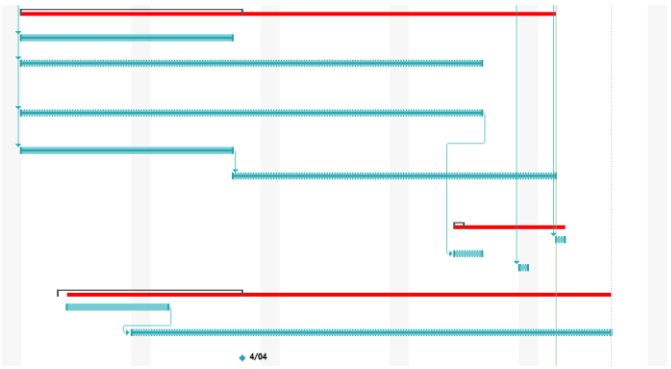


Figure 66 (in attachment)

	Work package	Activities	Time	Resources involved	Predecessors	Cost (Planed Value)
10. ANALYSIS	10.1 Sensor + used technology	1. Sensor features	3 days	Annike + sensor	-	8600
		2. Technology	3 days	Annike	-	600
	10.2 Market + Application	1. Principal Sectors	3 days	Carla/ Mario	-	600
		2.Applications	3 days	Carla/ Mario	-	600
	10.3 Market benefits + new sectors		3 days	Jan	-	600
	10.4 Brand identity + competition	1. Bran identity	3 days	Silke	-	600
		2.Sick competition	3 days	Silke	-	600
	10.5 Testing sensor + software	1. Testing features	3 days	All	10.1/10.2/ 10.3/10.4	2000
		2. features	3 days	Robin	10.1/10.2/ 10.3/10.4	1200
	10.6 Planning+ dividing	[illegible]	3 days	Carla/ Silke	10,5	800
20. IDEATION	20.1 Brainstorming	1. Mind mapping	2 days	All+ Paper +material	10,6	2050
		2. Switching personality	1 day	All	20.1.,1	600
		3. Quick Sketching	1 day	All	20.1.2	400
	20.2 Verification	1. SWOT Analysis	1 day	All	20.1.3	200
		2. Weight Criteria Method	1 day	All	20.2.1	549
	20.3 Select Ideas		1 day	All	20.2.2	448
30. CONCEPT	30.1 Define the scope of the product	1.Industrial safety	1 day	Carla/ Annike	20,3	800
		2. Metro Station	1 day	Mario/ Annike	20,3	800
	30.2 Research viability of the project	1.Industrial safety	1 day	Carla	30,1	160
		2. Metro Station	1 day	Mario	30,1	160
	30.3 Select Idea		1 day	All	30,2	280
40. SPECIFICATION	40.1 Define product Specification		1 day	Mario/ Annike/ Jan	30,3	600
	40.2. Product planning		1 day	Mario/ Annike/ Jan	40,1	600

Figure 67

50.PRODUCT DEVELOPMENT	50.1 Integrating the solutuions into one		14 days	Robine / Mario / Mika / Carla	40.2	2580
	50.2 Shaping and designing	1. Design product	7 days	Jan	40.2	7000
		2. Design midtern report	7 days	Annike / Silke	40.2	6400
	50.3 Product Strategy	1. Market feasability	3 days	Annike	40.2	1200
		2. Stakeholders analysis	4 days	Mario	40.2	1280
	50.4 Programming and testing		7 days	Robine / Mario / Mika / Carla	40.2	8400
	50.5 Prototyping and testing		7 days	All	50.4	7720
60. PRODUCT REVIEW	60.1 FMEA review	1. System analysis	6 days	Carla	50.5	3680
		2. Process analysis	8 days	Mario	60.1.1	1880
		3. Concept analysis	8 days	Annike	60.1.2	1280
	60.2 Verification	1. Ecostar	6 days	Jan	60.1.3	3200
	60.3 Business Model	1. Marketing Plan	8 days	Annike/ Mario	60.1.3	2080
		2.Final Lean Canvas	11 days	Annike/ Mario	10.2.	960
70.VISUALISATION	70.1 Product Visualisation	1. Defenitive sketches	2 days	Jan/ Silke	60.3	800
		2. 3D-modeling	5 days	Jan	70.1.1	2000
		3. Renders	2 days	Jan	70.1.2	800
	70.2 Process visualisation	1. Product Booklet	8 days	Jan / Silke	(60.1.3) / **70.1.3**	9440
		2. Final presentation	15 days	All	70.2.1	26025
		3. Poster for clear overview	5 days	All	70.2.1	8015

Figure 68

30.2.2. Estimate activity durations

Inputs	Tools & techniques	Outputs
Analysis	Expert judgment, analogous estimating	6 days
Ideation	Expert judgment, analogous estimating	3 days
Concept	Expert judgment, analogous estimating, parametric estimating	3 days
Specifications	Expert judgment, analogous estimating, parametric estimating, reserve analysis	2 days
Product development	Expert judgment, analogous estimating, parametric estimating	18 days

30.2.3. Critical Path Method (CPM)

Because every phase starts after another phase, there could be a waiting time to start with a next task. The whole project was a critical path because if it took longer for a specific phase planned, then there would be a problem.

The expectation of the project, according the schedule, was to succeed in creating a program for the application during the month of March. At the first look of the document and the first tests of the sensor, the expected program was to design the forbidden area directly on the Sick software thanks to the output. The second expectation was to work in the same time to collect data from the sensor and to determine the distance of each point.

After numerous tries with tutorials and research on Sick's application, the conclusion was that there were tools missing to reach the purpose. The first solution was that there was an output cable needed that unlocked specific tools on the software. The test with the output cable and the comparison with the project of the last years were unsatisfied.

It proved that one important document was not sent with the sensor at the beginning. The sensor uses a more complex technology than the previous one and it targets professional sectors. The sensor can communicate with telegram languages. The supervisor succeeded to find the code to dialogue with the sensor. This discovery delayed the deadline of the "project's development" phase.

Thanks to this knowledge and the help of a new IT student, the team succeed to collect the data with the software python. This was important improvement because the data could be analysed and used for the application.

A second point was to design the casing of the sensor. The casing his to follow different parameters such as allowed an upside-down position, has a mobile part to change the angle of the sensor and allowed the overview of the platform. The casing was successfully drawn on 3D-modeling software.

The critical part was to 3D-printed. The first design of the casing was too large to be printed with the tools provide by the Novia university. A second casing must be design smaller and with more easily assembly pieces. The 3D-modeling and printed was as well report later the schedule. The printed of the prototype of the casing is over the schedule because of an unexpected. The only 3D-printer that is able to print the pieces of the casing was unusable, the only one left require to cut in more pieces the model.

Current statements

The team succeed to create a program that allowed to build a prototype for the application of the sensor. In a 2D model, the program focuses on one of the 24 layer of the sensor MRS6000 and draw two zones that simulate the warning area and the forbidden area. When these areas are cross by a moving object two different alarm sound are triggered.
The prototype of the casing is still in progress without any problem. The team estimate one week of full printed to succeed to finish the prototype on time.

30.3 Human resources

Human Resource Management is responsible for identify and document roles, responsibilities, reporting, and creating a human resources management plan.

This process is very important because it defines roles and responsibilities, so each person who is involved in the project knows what role they play in which phase of the project.
There are different methods to show the responsibility in the process. One of them is the RACI-Method.

30.3.1. Develop human resources plan

	Resourcenaam	Type	Materiaallab	Initialen	Groep	Max.eenhed	Std.	Overurer	Kosten/gebr	Toenemen	Basiskalend
1	Jan	Werk		J		100%	80,00/uur	€ 0,00/uur	€ 0,00	Tijdens proje	Standaard
2	Silke	Werk		S		100%	80,00/uur	€ 0,00/uur	€ 0,00	Tijdens proje	Standaard
3	Mario	Werk		M		100%	80,00/uur	€ 0,00/uur	€ 0,00	Tijdens proje	Standaard
4	Annike	Werk		A		100%	80,00/uur	€ 0,00/uur	€ 0,00	Tijdens proje	Standaard
5	Carla	Werk		C		100%	80,00/uur	€ 0,00/uur	€ 0,00	Tijdens proje	Standaard
6	Robin	Werk		R		100%	80,00/uur	€ 0,00/uur	€ 0,00	Tijdens proje	Standaard
7	Mika	Werk		M		100%	80,00/uur	€ 0,00/uur	€ 0,00	Tijdens proje	Standaard

Figure 69

30.3.1.1. RACI-Method

The RACI-Method is a matrix that shows who is responsible for what. The following questions are answered:

- Which tasks have to be done?
- Which roles are involved?
- Who is responsible for what?

This is what RACI means in detail:
R - Responsible: Who is responsible for the execution of the task?
There is only one responsible person in each process but another person can help with the processes.
A - Accountable: who decides whether the task was performed correctly?
The “accountable” person reviews the results of the implementation and can transfer tasks to the “responsible” person.
C - Consulted: Who is asked to perform the task?
The “consulted” person is an expert or an outside person who is not directly involved in the project but who provides advice.
I - Informed: Who will be informed about the results of the task?
This person only gets information about the project process like a supervisor.

	Work Packages	Activities	Annike	Carla	Jan	Mario	Silke	Robin
10. ANALYSIS	10.1 Sensor + used technology	1. Sensor features	R	I	A	I	I	I
		2. Technology	R	I	A	I	I	I
	10.2 Market + Application	1. Principal Sectors	I	R	I	A	I	C
		2.Applications	I	A	I	R	I	C
	10.3 Market benefits + new sectors		I	I	R	A	I	I
	10.4 Brand identity + competition	1. Brand identity	I	I	I	A	R	
		2.Sick competition	I	I	A	I	R	I
	10.5 Testing sensor + software	1. Testing features	RA	RA	RA	RA	RA	RA
		2. features	I	C	I	C	I	RA
	10.6 Planning+ dividing	1. program activities	I	R	I	I	A	I
20. IDEATION	20.1 Brainstorming	1. Mind mapping	RA	RA	RA	RA	RA	
		2. switching personality method	RA	RA	RA	RA	RA	
		3. Quick Sketching	RA	RA	RA	RA	RA	
	20.2 Verification	1. SWOT Analysis	RA	RA	RA	RA	RA	
		2. Weight Criteria Method	RA	RA	RA	RA	RA	
	20.3 Select Ideas		RA	RA	RA	RA	RA	
30. CONCEPT	30.1 Define the scope of the product	1.Industrial safety	R	A	I	C	I	
		2. Metro Station	A	C	I	R	I	

Figure 70

	30.2 Research viability of the project	1.Industrial safety	C	R	I	A	I	
		2. Metro Station	C	A	I	R	I	
	30.3 Select Idea		RA	RA	RA	RA	RA	R
40. SPECIFICATION	40.1 Define product Specification		C	I	RA	C	I	
	40.2. Product planning		C	I	RA	C	I	
50. PRODUCT DEVELOPMENT	50.1 Integrating the solutions into one		I	A	I	R	I	
	50.2 Shaping and designing	1. Design product	I	A	R	I	I	
		2. Design midterm report	A	C	C	C	R	
	50.3 Product Strategy	1. Market feasibility	R	I	I	A	I	
		2. Stakeholders analysis	C	I	A	R	I	
	50.4 Programming and testing		I	A	I	R	I	C
	50.5 Prototyping and testing		RA	RA	RA	RA	RA	C
60. PRODUCT REVIEW	60.1 FMEA review	1. System analysis	I	R	I	A	I	C
		2. Process analysis	I	I	A	R	I	
		3. Concept analysis	R	I	I	I	A	
	60.2 Verification	1. Butterfly model	I	I	R	I	A	
		2. Hexagon model	I	I	A	I	R	
		3. Structural Verification	I	R	I	A	I	
		4. Ergonomic verification	A	I	I	R	I	
		5. Usability verification	I	A	R	I	I	
		6. Ecological verification	R	I	A	C	I	

Figure 71

30.3.2. Acquire project team

30.3.2.1. Belbin test

30.3.2.1.1. Summary of team roles

Roles	Annike	Mario	Silke	Jan	Carla
Primary	Resource/ Investigator	Evaluator/ Monitor	Completer Finisher	Teamworker	Plant
Secondary	Evaluator or Monitor	Plant or Coordinator		Evaluator	Monitor

Annike: resource/investigator -> explore new ideas and possibilities

Strengths	Weaknesses	Team role compatibility	Optimum working environment
Has a lot of energy at the beginning Works well with others Is a good networker Is a good communicator	Loses energy after the first flush Is not comfortable with large changes during the project	Shaper Completer finisher	Hight productivity = work with others

Mario: evaluator/monitor -> provide a logic eye

Strengths	Weaknesses	Team role compatibility	Optimum working environment
Is sober, strategic discerning Sees all options and judges accurately	Lacks to make decisions Has difficulties to inspire people Can be overcritical Can have friction with Plant or Investigator	Shaper Coordinator	Hight productivity = strategy's situation

Silke: completer / finisher -> correct mistake, ensure that important details are not overlooked

Strengths	Weaknesses	Team role compatibility	Optimum working environment
Tries to reach the highest standards Is accurate Catches mistakes	Struggles to finish off Struggles to keep deadlines Is anxious	Shaper Plant Resource / Investigator	Hight productivity = environment that improves concentration and where they are given adequate time

Jan: teamworker -> cares for individuals and the team, promote harmony

Strengths	Weaknesses	Team role compatibility	Optimum working environment
Is a good listener Good at resolving social problems Is diplomatic, sensitive and supports others	Avoids conflict and tense situations Lacks to make decisions Is hesitant	Shaper Coordinator	Hight productivity = positive and peaceful environment

Carla: plant -> prime source of innovation and ideas

Strengths	Weaknesses	Team role compatibility	Optimum working environment
Is creative and inventive Can tackle complex problems in a new way	Is not aware of what is going on elsewhere in the team Does not communicate with people who do not share the same idea Plant's ideas can be radical and lack practicalities	Coordinator Monitor/Evaluator Implementer	Hight productivity = Space and time to think

30.3.2.1.2. Team Meeting

Most enjoyable/ agreeable meeting:
- Positive and peaceful environment
- Free to speak and share ideas
- Possibility to be flexible

Most efficiently/ professional meeting:
- Quiet and exclusive area
- Meeting has to be prepared
- Everybody must be informed how the project is and what they have to do
- Everybody has to know the schedule and dead lines

How the team do a "feedback":
- Note taken by the secretary during meeting needs to be shared with the other team member
- The recap of the meeting has to expose clearly the progress of task,
- What people have done and what they have to do next,
- The issue that the team or a team member face of and how they fix or not it,
- The news ideas, the new due date for the next meeting

30.3.2.1.3. About team roles

Roles that the team miss:

The role of the shaper is missing in the team. According to team role compatibility, the shaper appears many times in different profiles. The shaper can ensure that the due dates will be respected and push the team to challenge themselves.

Roles that we did not want:

The coordinator appears to be the role that the team does not need because it is over controlling.

30.4. Develop project team

Mika's Monkeys - Lidar project

Team contract from 4th of February until 31th of May

Values

1. **Respect**
   Everyone has the right to speak freely without judgement. If you have a problem or didn't get a task, just tell how you're feeling and communicate clear about everything. Everyone also has the right to share their ideas and everyone must listen.
2. **Teamwork**
   We must be on the same level and facing the same way so that everything is clear, and we can make the best of it. Make a clear agenda, to do lists and appointments.
3. **Enjoyment**
   Everyone must do something that he/she likes, and we should use everybody's strengths to become the best results. We must be flexible so that the appointments fit for everyone.

Meetings

You can find the meetings in the agenda. Everyone must come to the meeting at the right time and place like described in the agenda. If you're a little late for a good reason you've to contact the group as soon as possible. The tasks will be distributed at the meetings.

Files

We'll be using Google drive for our documents. In the end everything that we did has to be on the Google drive.

Punishments

- When you're three times late you must cook dinner for everyone in the group
- If you're late or absent without a good reason one time, then you must bring snacks for the whole group
- If you miss two deadlines or more, you must rewrite the logbook

Names	Signatures
Annike Prehn	
Carla Laborde	
Jan Van de Ven	
Mario Montero Garrido	
Robin Snellman	
Silke Debie	

Figure 72

30.5. Project cost management

30.5.1. Planification of cost management

The monetary units of the cost management plan are established to be the euro (€). The metric units to define the amount of material will be used in the international metric system. The volume will constitute an exception: the litre (L) could be replaced by the cubic meter (m^3).

The control of cost management will be carried out by a methodology of periodic cost reports. The date will coincide with the deadlines of periods that will be established in the cost baseline. A report must be submitted per work package which is made by the person responsible for it. In addition, the responsible one has to specify if additional costs were needed.

30.5.2. Cost estimations

The different techniques to estimate the cost were put into practice. The bottom-up method will be used according to the WBS and the activities scheduled in the purpose to estimate the cost for each activity. The cost of one activity was not easy to estimate if problems appear. Therefore, other tools as the 3-value method and expert advice were used to solve these problems.

Moreover, a law of rounding is established to the nearest hundred without decimals to facilitate the interpretation and reading of the figures. On the other hand, those responsible for the project will ensure that the costs estimated have a range of acceptability of 15%.

30.5.3. Budget and cost calculation

The planed value (PV) chart distributes the cost of each activity in the schedule depending on the week in which the activity will be developed. The second chart concerns the earned value (EV) and shows the amount of the task that is currently completed in percentage. The last chart presents the actual cost (AC), which means the real cost of the activities at the time they are finished.

Furthermore, the management reserve is determined as 10% of the total cost of the project to avoid unplanned changes of scope. Contingency reserves of each main work package are determined as 7% of the cost of the pack with the purpose of mitigating possible identified risks. Both reserves follow the rule of rounding to the nearest hundred.

Below there is a summary table of costs per activity and period in addition to the cost baseline.

PV

			February				March				April				May			
Management reserves: 13519 €			1	2	3	4	5	6	7	8	9	10	11	12	13	14	TOTAL	Contingency reserves
Expert input			3600	1080	720	360		960	2520	960	240	960	960	960	240	720	14280	
10. ANALYSIS	10.1 Sensor + used technology	1. Sensor features		3600													3600	1100
		2. Technology		600													600	
	10.2 Market + Application	1. Principal Sectors		600													600	
		2.Applications		600													600	
	10.3 Market benefits + new sectors			600													600	
	10.4 Brand identity + competition	1. Brain identity		600													600	
		2.Sick competition		600													600	
	10.5 Testing sensor + software	1. Testing features			2000												2000	
		2. Features			1200												1200	
	10.6 Planning + dividing	1.Program activities			800												800	
20. IDEATION	20.1 Brainstorming	1. Mind mapping			2050												2050	300
		2. Switching personality method			600												600	
		3. Quick Sketching			400												400	
	20.2 Verification	1. SWOT Analysis			200												200	
		2. Weight Criteria Method			549												549	
	20.3 Select ideas				448												448	
30. CONCEPT	30.1 Define the scope of the product	1.Industrial safety			800												800	200
		2. Metro Station			800												800	
	30.2 Research ulability of the project	1.Industrial safety			160												160	
		2. Metro Station			160												160	
	30.3 Select idea				280												280	
40. SPECIFICATION	40.1 Define product Specification					600											600	200
	40.2 Product planning					600											600	
50. PRODUCT DEVELOPMENT	50.1 Integrating the solutions into one							1140	1440								2580	2400
	5.2 Shaping and designing	1. Design product							3500	3500							7000	
		2. Design midterm report						400	3000	3000							6400	
	50.3 Product Strategy	1. Market feasability						600	600								1200	
		2. Stakeholders analysis						600	680								1280	
	50.4 Programming and testing							3000	4000	1400							8400	
	50.5 Prototyping and testing									4000	3720						7720	
60. PRODUCT REVIEW	60.1 FMEA review	1. System analysis									80	3600					3680	900
		2. Process analysis									80	1200	600				1880	
		3. Concept analysis									80	600	600				1280	
	60.2 Verification	1.Ecostar													3200		3200	
		1.Marketing Plan												1280	800		2080	
	60.3 Business Model	2.Final Lean Canvas													960		960	
70. VISUALISATION	70.1 Product Visualisation	1. Detemine sketches												800			800	3300
		2. 3D-modeling												800	1200		2000	
		3. Renders													800		800	
	70.2 Process visualisation	1. Product Booklet									6020			2400	1020		9440	
		2. Final presentation												6000	10000	10025	26025	
		3. Poster for clear out review														8015	8015	
TOTAL			3600	13280	11167	1560	0	6700	15740	12860	10220	6360	2160	12240	18220	18760	132867	
ACUMULATION PV			3600	16880	28047	29607	29607	36307	52047	64907	75127	81487	83647	95887	114107	132867	265734	

Figure 73

AC

				February				March				April				May	
			1	2	3	4	5	6	7	8	9	10	11	12	13	14
Acumulative	Expert input until week		3600	4680	5400	5760	5760	6720	9240	10200	10440	11400	12360	13320	13560	14280
Expert input			3600	1080	720	360		960	2520	960	240	960	960	960	240	720
10. ANALYSIS	10.1 Sensor+ used technology	1. Sensor features		100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
		2. Technology		100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
	10.2 Market + Application	1. Principal Sectors		100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
		2.Applications		100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
	10.3 Market benefits + new sectors			100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
	10.4 Brand identity + competition	1. Brand identity		100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
		2.Slick competition		100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
	10.5 Testing sensor + software	1. Testing features			100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
		2. Features			100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
	10.6 Planning+ clustring	1.Program activities			80%	80%	80%	100%	100%	100%	100%	100%	100%	100%	100%	100%
20. IDEATION	20.1 Brainstorming	1. Mind mapping			100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
		2. Switching personality method			100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
		3. Quick Sketching			100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
	20.2 Verification	1. SWOT Analysis			100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
		2. Weight Criteria Method			100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
	20.3 Select ideas				100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
30. CONCEPT	30.1 Define the scope of the product	1.Industrial safety			100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
		2. Metro Station			100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
	30.2 Research viability of the project	1.Industrial safety			100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
		2. Metro Station			100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
	30.3 Select idea				100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
40. SPECIFICATION	40.1 Define product Specification					100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
	40.2 Product planning					100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
50. PRODUCT DEVELOPMENT	50.1 Integrating the solutions into one							35%	100%	100%	100%	100%	100%	100%	100%	100%
	5.2 Shaping and designing	1. Design product							15%	75%	75%	100%	100%	100%	100%	100%
		2. Design midterm report						20%	80%	100%	100%	100%	100%	100%	100%	100%
	50.3 Product Strategy	1. Market feasability						40%	100%	100%	100%	100%	100%	100%	100%	100%
		2. Stakeholders analysis						70%	100%	100%	100%	100%	100%	100%	100%	100%
	50.4 Programming and testing							5%	15%	25%	25%	30%	75%	100%	100%	100%
	50.5 Prototyping and testing									16%	16%	16%	60%	80%	100%	100%
60. PRODUCT REVIEW	60.1 FMEA review	1. System analysis									20%	100%	100%	100%	100%	100%
		2. Process analysis										70%	100%	100%	100%	100%
		3. Concept analysis									10%	60%	100%	100%	100%	100%
	60.2 Verification	1.Ecostar													100%	100%
	60.3 Business Model	1.Marketing Plan												70%	100%	100%
		2.Final Lean Canvas													100%	100%
70. VISUALISATION	70.1 Product Visualisation	1. Detailed sketches												50%	50%	100%
		2. 3D-modeling												40%	100%	100%
		3. Renders													50%	100%
	70.2 Process visualisation	1. Product Booklet									50%	50%	50%	80%	100%	100%
		2. Final presentation												70%	50%	100%
		3. Poster for clear overview													100%	100%
	ACUMULATION EV		3600	16830	27837	29447	29447	34545	45577	54052.2	55616.2	59626.2	77159	105468.5	130365.75	132397

Figure 74

EV

			February					March			April			May				
			1	2	3	4	5	6	7	8	9	10	11	12	13	14	TOTAL	Contingency reserves
Expert input			3600	1080	720	360		960	2520	960	240	960	960	960	240	720	14280	
10. ANALYSIS	10.1 Sensor + used technology	1. Sensor features		8600													8600	1200
		2. Technology		600													600	
	10.2 Market + Application	1. Principal Sectors		600													600	
		2.Applications		600													600	
	10.3 Market benefits + new sectors			600													600	
	10.4 Brand identity + competition	1. Brain identity		600													600	
		2.Slick competition		600													600	
	10.5 Testing sensor + software	1. Testing features			2000												2000	
		2. Features			1200												1200	
	10.6 Planning + dividing	1.Program activities			800			400									1200	
20. IDEATION	20.1 Brainstorming	1. Mind mapping			1650												1650	300
		2. Switching personality method			600												600	
		3. Quick Sketching			400												400	
	20.2 Verification	1. SWOT Analysis			200												200	
		2. Weight Criteria Method			549												549	
	20.3 Select ideas				448												448	
30.CONCEPT	30.1 Define the scope of the product	1.Industrial safety			520												520	100
		2. Metro Station			520												520	
	30.2 Research viability of the project	1.Industrial safety			80												80	
		2. Metro Station			80												80	
	30.3 Select idea				100												100	
40. SPECIFICATION	40.1 Define product Specification					600											600	100
	40.2 Product planning					600											600	
50. PRODUCT DEVELOPMENT	50.1 Integrating the solutions into one							1140	1440								2580	3500
	5.2 Shaping and designing	1. Design product							3500	3500							7000	
		2. Design midterm report						1000	3500	12000							16500	
	50.3 Product Strategy	1. Market feasability						800	600								1400	
		2. Stakeholders analysis						600	760								1360	
	50.4 Programming and testing							4200	9800	4200							18000	
	50.5 Prototyping and testing									3000							3000	
60. PRODUCT REVIEW	60.1 FMEA review	1. System analysis									80	3600					3680	900
		2. Process analysis									80	1200	600				1880	
		3. Concept analysis									80	600	600				1280	
	60.2 Verification	1.Ecostar													3200		3200	
	60.3 Business Model	1.Marketing Plan												1280	600		1880	
		2.Final Lean Canvas													1280		1280	
70. VISUALISATION	70.1 Product Visualisation	1. Define the sketches												800	800	80	1680	3500
		2. 3D-modeling												1280	1280		2560	
		3. Renders													800	880	1680	
	70.2 Process visualisation	1. Product Booklet									6020			2400	1020		9440	
		2. Final presentation												6000	10000	10025	26025	
		3. Poster for clear outcome													8015		8015	
TOTAL			3600	13280	9867	1960	0	9100	21920	23660	6500	6360	2160	12720	27235	11705	133387	
ACUMULATION AC			3600	16880	26747	28307	28307	37407	59327	82987	89487	95847	98007	110727	137962	149667	283054	

Figure 75

Figure 76

30.5.4. Earned value analysis

The earned value analysis is a project management tool that is used to measure the project progress. It compares the actual work completed at any time to the original budget and schedule. It forecasts the final budget, schedule and the analysis of the path to get there. The analysis gives the essential early warning signal when the situation is going awry.

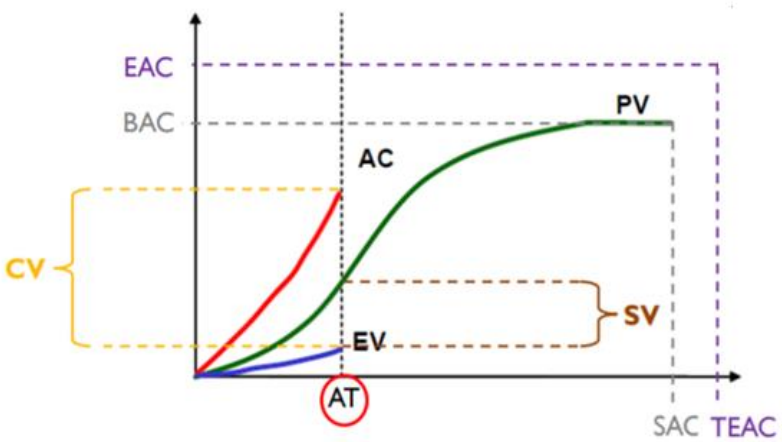


Figure 77

Comparing the values of the different curves it is possible to determine an index which helps to understand the situation of the project better.

- A positive CV means the project is under budget
- A negative SV means the project is behind the schedule
- CPI and SPI are the same as CV and SV but in percentage terms
- EAC and TEAC are estimation for budget and time at the end of the project if unplanned facts continue happening

Earned Value Analysis	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Cost Variance (CV)	0 €	0 €	1,140 €	1,140 €	1,140 €	-2,861 €	-13,750 €	-28,895 €	-29,571 €	-26,221 €	-20,848 €	-5,259 €	-7,596 €	-16,800 €
Schedule Variance (SV)	0 €	0 €	-160 €	-160 €	-160 €	-1,761 €	-6,470 €	-10,815 €	-15,211 €	-11,861 €	-6,488 €	9,582 €	16,259 €	0 €
Cost Performance Index (CPI)	1.00	1.00	1.04	1.04	1.04	0.92	0.77	0.65	0.67	0.73	0.79	0.95	0.94	0.89
Schedule Peerformance Index (SPI)	1.00	1.00	0.99	0.99	0.99	0.95	0.88	0.83	0.80	0.85	0.92	1.10	1.14	1.00
Estimate at Completion (EAC):	132,867 €	132,867 €	127,435 €	127,723 €	127,723 €	143,871 €	172,951 €	203,841 €	198,442 €	182,904 €	168,767 €	139,492 €	140,609 €	149,667 €
Estimate Time at Completion (TEAC) weeks	14.0	14.0	14.1	14.1	14.1	14.7	16.0	16.8	17.6	16.4	15.2	12.7	12.3	14.0

Figure 78 (in attachment)

The analysis of this method for the report at week 8 shows that the project is over budget and under schedule. The main problem starts in week 6 when the programming task is planned to be developed. Even with the help of an Informatics Engineer student, the programming of the forbidden areas with the sensor did not succeed. Extra working hours and the forthcoming arrival of expert help are being scheduled to get back on path.

After the incorporation of an expert programmer to the team the programming task was developed in the scheduled days. The product review and the visualisation were finished earlier and with less cost than planned and we succeeded in finishing all the activities in 14 weeks. The final budget of the project is more than expected due to our problems with the programming task. With the effort of all the team members we got back on path.

30.6. Project communication management

30.6.1. Team communication

The communications management plan describes how project communications will be planned, structured, implemented and monitored to achieve their effectiveness and efficiency. The team have used Trello, e-mail and What´s app as the main tools for distance communication. At least there is one weekly meeting between the team members.

It has been decided to describe this plan through a summary table that includes what will be communicated, the reason, between whom it will be carried out, the appropriate method, the person responsible for the communication and when and how often.

What will be communicated?	Why?	Between who?	Best method	Resp.	When? And frequency
WBS	To know the Project scope	Team members and the supervisor	Formal written document	Supervisor	At the beginning and in each update
Problems	To avoid possible deviation in project planning	Team members and the supervisor	Informal writing (e-mail)	All those responsible for each area of the project	Whenever it happens
Progress reports	Measure and verify the current situation of the scope	Team members and the supervisor (not always)	Verbal Formal (meeting)	Supervisor/ team leader	Weekly
Suggestions	Promote communications and team work	Team members	Informal writing (email, Trello, what´s app)	Team members	At any time during the project
Expert help in project Management	Advice and corrections in the project management task	Team members and Roger	Formal email or face to face meeting	Team members	Whenever expert help is needed

Expert help in academic writing	Advice and corrections in the report	Team membes and Hanna.	Formal email or face to face meeting	Team members	Whenever expert help is needed and the day of the exam
Expert help in Eco design	Advice and corrections about the materials used in our prototype	Team members and Karine	Formal email or face to face meeting	Team members	Whenever expert help is needed
Sick Finland	To participate in the competition	Responsible of getting the ideas, supervisor and team members	Formal written report about the application of the sensor	Supervisor	Before the deadline of the competition
Holidays	To plan the activities and the meetings	Team members	Informal text (what´s app, Trello) + update google calendar	Team members	At least one week before the departure

The following chart contains essential information about important people with whom the team should stay in contact or at least take into account while developing our project.

Name and occupation	Contact	Deliverable information	Deliverable method
Mika Billing (Project supervisor)	Email: mika.billing@vamk.fi Phone: +358 40 591 2854	Project status	Meeting or email
Roger Nylund (EPS coordinator)	Email: roger.nylund@novia.fi	Doubts about project management tasks	Meeting or email
Karine Van Doorssealaer (Eco design teacher)	Karine.vandoorssealaer@uantwerpen.be	Doubts about the materials used in our idea	Meeting (during her stay in Finland) or email
Hanna Latva (English teacher)	Email: juha.liinamaa@sick.fi Phone: +358 (0)9 2515 800	Doubts about academic writing	Meeting or email
Juha Liinamaa (Sales engineer SICK)	Email: juha.liinamaa@sick.fi Phone: +358 (0)9 2515 800	Information about how to use the sensor MRS6000	Phone call and email

30.6.2. Stakeholders

30.6.2.1. Stakeholders analysis

A stakeholder analysis is a process of systematically collecting and analysing qualitative information to determine whose interests should be considered when developing a new project.

30.6.2.2. Identify and understand the stakeholders

	Concerns	Initial position	Wanted position	Strategy for support
1. Customer	Safety No delays Increment users	NEUTRAL	IN FAVOR	Periodic information Product guarantee Stay in contact
2. Users	Comfort Safety No delays	NEUTRAL/ IN FAVOR	IN FAVOR	Periodic information Product guarantee Stay in contact
3. Public administrations	State grants Security Reliability Accidents	AGAINST	IN FAVOR	Prestige compared to other countries Advertising and logos Become the safest rail city Weekly reports
4. Workers	Easy to use Reliability Effective	NEUTRAL	IN FAVOR	Guarantee Formative courses
5. Suppliers	Prices Reliability Abidance	NEUTRAL	IN FAVOR	Regular payment Advertising Long-term contracts
6. SICK	Use all sensor features Sales Material integrity	NEUTRAL	IN FAVOR	New market Advertising Future improvements/new areas
7. Advertising Companies	Prices Reliability of the information Waste money	NEUTRAL	IN FAVOR	Trial month Surveys and research of the efficiency
8. Competing companies in the sector	Sales Replacement Technology	AGAINST	NEUTRAL	Complementary tools New Possible projects in common
9. Health services, police and firefighters	Unknown product Reliability of the system Stop-service Warning system	NEUTRAL	IN FAVOR	Description of our product and how it works Access to data Direct warning signals Provide the information about the best door access to deal with the problem Annual reports
10. Small business inside train stations	Unknown product Flow of travellers Busiest hours	NEUTRAL	IN FAVOR	Possibility to predict busiest days and hours Warning alarms Advertising

11. SICK **Shareholders**	Share value Dividends Prosperity of the Product	NEUTRAL	IN FAVOR	Regular reports Viability analysis Market survey
12. Community	New employment opportunities Contribution to the community Facilities Replacement of renewable resources Social investments and donations Relationships with the community Public health, safety and protection Conservation of materials and energy Environmental assessment in projects	NEUTRAL	IN FAVOR	New post needed Environmentally friendly policies Public information Environmentally friendly policies Public information Environmentally friendly policies Public information

The company is part of a system with multiple stakeholders in its good march because they benefit from it. The shareholders have a central role in the timeshare that requires responsibility of the good governance of the company. The rest of the groups from a part of the network of necessary collaborators. Therefore, the managers must meet the expectations of the stakeholders. This is important in companies that face of rapid changes in structures of the market, customer needs, technologies and the values of the society such as SICK.

The first step to develop is the identification of the stakeholders. It means to figure out every person or organization that is involved or can be affected by the scope of the project. The concerns and the initial position of every stakeholder have to be known in order to choose the right strategy to manage them and achieve the final position. The main point is to place the stakeholders in the IN-FAVOR position, but it can be difficult in some occasions.

30.6.2.3. Stakeholders prioritisation

The next step is to prioritise the stakeholders. This step is important to know which are the most relevant to focus on them. The POWER-INTEREST matrix will be used to classify the stakeholders. The strategy that has to be applied will change according to the position of the stakeholder on the matrix.

The matrix focusses on giving the needed attention to the people with the most influence and their interests because they set the guidelines of the real economic progress of organisations.

Figure 79

The matrix POWER_INTEREST is presented below:

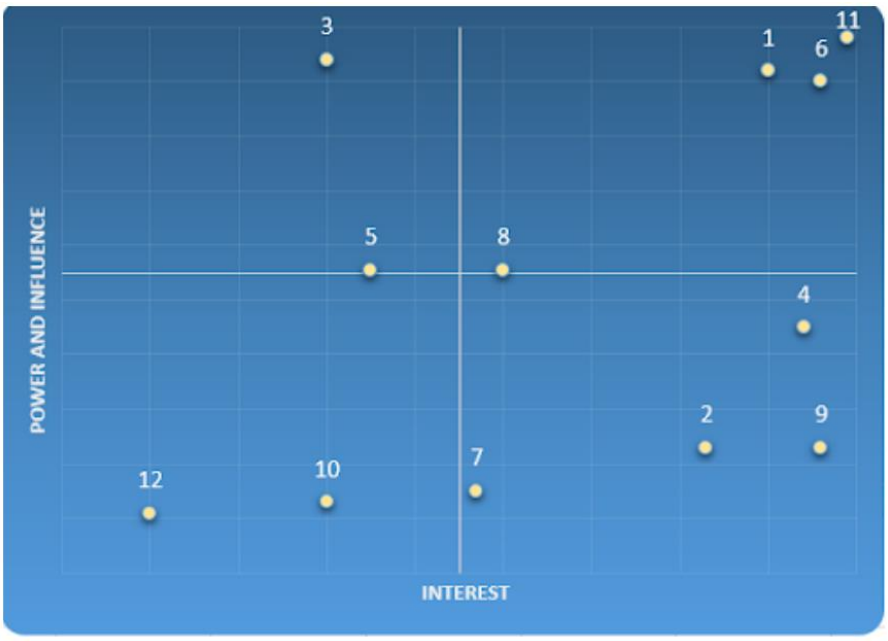


Figure 80

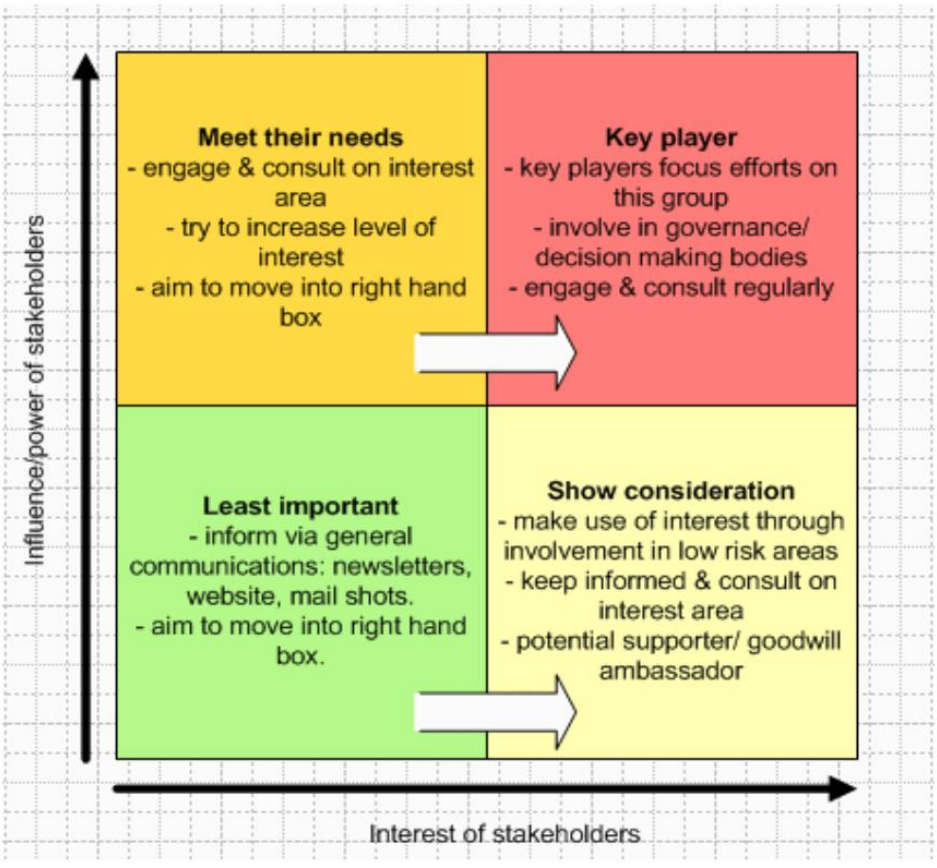


Figure 81

30.7. Project quality management

The quality management must be carried out in the most detailed way to guarantee the satisfaction of the clients and the users. The first step is the planification which means identify requirements/standards for the project, the product, and its deliverables. Subsequently it is necessary to set metrics to measure quality in order to review and evaluate each activity that can modify the scope, time, cost, risks or resources.

On the other hand, considering that some of the requirements cannot be measured, because they simply consist of the realisation or not of a process or product, a Verification Sheet (YES / NO) is added for them.

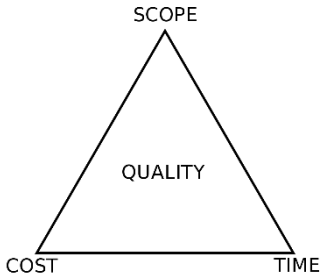


Figure 82

The team members attend weekly meetings where time is expended to develop quality improvements and to ensure that integrated change control is used. The continuous improvement is one of the team objectives and PDCA cycle *(W. Edwards Deming, 1950)* is used during all the project management.

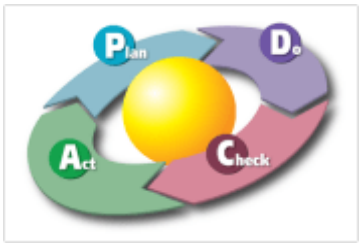


Figure 83

Quality planning must take into consideration the commitment between costs and benefits. The main benefit of fulfilling the quality requirements is decrease the rework which means, higher productivity, lower costs for claims and greater satisfaction of the stakeholders. Cost of quality is considered as an investment to prevent future cost for poor quality.

If a Non-Conformity is detected, the project director (Mika Billing) will be informed in the shortest possible time to obtain the authorisation of the latter and, thus, correct it within a maximum period of 15 days with an extra budget determined by the Director. After the correction process, preventive measures will be determined and implemented, ensuring that it does not reappear.

Below there is a table of the quality requirements of the activities, and subsequently, a verification sheet.

Requirements	Metric	Quality requirements
Reliability of the information searched	Hours of research	At least 15 hours of research per person
Work division	Working hours	Everyone works the same amount of hours with a variation of 5% allowed
Use different techniques of brainstorming	Number of techniques	At least 2 diffrent techniques
Extend development of the switching personality technique	Number of characters	At least 3 characters per person
Select the most scored ideas	Number	Choose the most scored 2 ideas or 3 if the score between them is very similar
Key functions of the product	Aim of the functions	At least one function must be environmentally friendly or ensure industrial safety
Questionnaires	Number of answers	Every team member must ask at least 10 people
Cost	€	Determine a specific business strategy
List of things we still need to develop	Number of list	At least every two weeks one list should be made
Testing the working prototype	Number of test	At least 3 different successful test in different places
List of materials	Number of materials	Upgrade the list every week and ensure that everything arrives before it is needed
Verification	% Aims fulfilled	The percentage of aims fulfilled must be higher than 80%
Meetings	Number of meetings	At least 2 a week between team members and at least once every two weeks with the supervisor
Presentation	Number of trainings	At least one full performance of the final presentation with all the team members

Necessary steps to be developed	Accomplished? YES/NO
Has the manual of the sensor been read by all the team members?	**YES**
Has everyone read the analysis part of each member?	**YES**
Have the roles of the team members been selected?	**YES**
Has everyone done a previous brainstorming before the brainstorming meeting?	**YES**
Is everyone happy and willing to work for the selected idea?	**YES**
Is the application and its scope approved by the supervisor?	**YES**
Have we checked if there are any problems in the first concept testing and early prototype?	**YES**
Do the early sketches match with the first idea?	**YES**
Do we have a final product that matches with our first aims?	**YES**
Is everyone available for the competition day?	**YES**
Is every change made in the project approved and carry out as planned in change management?	**YES**
Have we checked if our programming knowledge is enough to do the prototype?	**YES**
Is expert help needed?	**YES**
Do we have all the materials needed for the prototype?	**YES**
Do we have everything needed for the presentation in Helsinki?	**YES**
Have we thought about different techniques to make an unusual final presentation?	**YES**

30.8. Project risk management

The risks of the project have to be identified in the early phases of the project. These steps will open the possibility of adding, modifying or eliminating risks during the development of the project at specific and predefined moments. The identification of risks will follow an approach based on the WBS that allows to discover the risk that may appear in the Work Breakdown Structure.
The identification, the management and the control of risks is due to the responsible person for each task who must be responsible for taking care of it. The contingency reserves already mentioned in the management of costs are intended for the control, the prevention and the materialization of those risks. Exceptionally, these reserves may be exceeded with the authorisation of the project director.
The first identification of possible risks has been done by the team: the result of this step is a list with all the risks.

30.8.1. Definition of possible risks

This is a list of risks that could take place during the project:

- Unclear objectives
- Early deadlines
- Bad work distribution
- Unclear tasks
- Poor scheduling
- Discrepancies between team members
- Team member is on a trip
- Sickness or injuries
- Choose the wrong idea (motivation)
- Get extra components on time
- Lack of programming knowledge
- Communication problems
- Language barriers
- Lost information or damaged files
- Denied access to certain resources
- Winning the competition (positive)

30.8.2. Risk assessment matrix

The purpose is to obtain a quick and simple view of the importance of the risks. A risk assessment matrix has been developed considering the likelihood of the risk and the severity of the consequences.

Importance = Likelihood x Consequences

		Likelihood				
		1 Rare	2 Unlikely	3 Possible	4 Likely	5 Almost Certain
Consequences	5 Catastrophic	5 Moderate	10 High	15 Extreme	20 Extreme	25 Extreme
	4 Major	4 Moderate	8 High	12 High	16 Extreme	20 Extreme
	3 Moderate	3 Low	6 Moderate	9 High	12 High	15 Extreme
	2 Minor	2 Low	2 Moderate	6 Moderate	8 High	10 High
	1 Negligible	1 Low	2 Low	3 Low	4 Moderate	5 Moderate

Figure 84

		Likelihood				
		1 Rare	2 Unlikely	3 Possible	4 Likely	5 Almost Certain
Consequences	5 Catastrophic	Lose information or damaged files		Unclear objectives		
	4 Major		Poor scheduling Choose the wrong idea (motivation)	Bad work distribution		Early deadline Lack of programming knowledge
	3 Moderate	Discrepancies between team members	Get extra components on time Communication problems	Winning the competition		
	2 Minor	Language barriers	Denied access to certain resources	Unclear task		
	1 Negligible	Sickness or injuries		Team member on a trip		

Figure 85

Risk level	LOW	MODERATE	HIGH	EXTREME
	ACCEPTABLE OK TO PROCEED	AS LOW AS REASONABLY PRACTICABLE TAKE MITIGATION EFFORTS	GENERALLY UNACCEPTABLE SEEK SUPPORT	INTOLERABLE IMMEDIATE MESURES HAVE TO BE TAKEN HOLD

Figure 86

After classifying the risks, it is of utmost importance to choose the right action to treat them. A proactive way of acting is going to be the main answer to all the risks in the purpose to avoid their materialisation. On the other hand, if it happens, a reactive answer will be set up.
If the impact is negative the answer can be avoided, transferred, mitigated or accepted depending on the risk level. If the impact is positive, the options are exploited, shared, improved or ignored.

30.8.3. Analysis of the risks

Based on the evaluation of the risk, the study of the causes and the solutions of the risks are classified into three different levels of importance: moderate, high or extreme.

RISK	Early deadline	RISK Level	Extreme
Causes	Taking part in Sick competition 2019 leads to finish the project earlier than expected		
Solution	Better scheduling and try to avoid delays		

RISK	Unclear objectives	RISK Level	Extreme
Causes	Misunderstanding of the subject between the group members, not clear information about which tasks should be develop.		
Solution	Determine the objectives at the beginning of the project while the scope is defined and the tasks that should be developed are discussed Select only the most wanted task for all the group members		

RISK	Lack of programming knowledge	RISK Level	Extreme
Causes	None of the team members is specialized in programming task		
Solution	Help from local students with programming skills		

RISK	Poor scheduling	RISK Level	High
Causes	Inaccurate understanding of the project and its scope		
Solution	Develop a WBS in detail and schedule all the activities in the time given with a Gantt chart		

RISK	Bad work distribution	RISK Level	High
Causes	Inaccurate understanding of the tasks planned and the amount of work they entail Bad comunication		
Solution	Knowing the background of each member and stablish a daily communication with the rest of the group Willingness to learn about other subjects and ask for a review of the WBS to the supervisor		

RISK	Choose the wrong idea (lack of motivation)	RISK Level	High
Causes	Rush to choose an idea too quickly due to lack of time Lack of passion and interest		
Solution	Take our time in choosing the idea and develop good techniques of brainstorming It has to be sure that all the team members agree with the chosen idea		

RISK	Winning the competition (positive risk)	RISK Level	High
Causes	Developing a good report with the application for the sensor		
Solution	The report and the presentation should be done before the final deadline Therefore, there is more time to improve it		

RISK	Unclear tasks	RISK Level	Moderate
Causes	Misunderstanding of the task, undefined goals		
Solution	Good explanations of the given task and good communication between members to clear the ideas if it is needed		

RISK	Lose information or damaged files	RISK Level	Moderate
Causes	Human errors		
Solution	Try always to save the work done in the team's Drive file. Be careful		

RISK	Communication problems	RISK Level	Moderate
Causes	Team members have uncommon set of expectations in terms of what has to be delivered and when They do not keep the rest informed about what is going on or do not know what the state of the project is		
Solution	Weekly meetings explaining how far the project is. Daily communication by What´s app Create status report list with all the necessary information of the scope, the risks, the changes, the milestones… Develop a list with what and when it is needed		

RISK	Denied to certain resources	RISK Level	Moderate
Causes	Not having permissions or licenses		
Solution	Use alternative solutions to get similar results		

30.9. Project change management

In the change management the changes of structures, processes and behaviours of a project where made. Group members would rather stick to already existing things because they have a fear of changing something. The situation sometimes gets even worse when no change is happening.
Various rules must be adhered to and they become a very important tool.

During weekly meetings, possible changes were discussed. In addition, reviews were made on the individual tasks of each team member. As a result, no sudden changes were made that affect the entire team disapproves of.

The integrated control of changes is a process that is carried out from the beginning of the project until its completion. It consists of the review of all the change requests presented (whether to take preventive, corrective or defect repairs). Also, approving these requests and manage changes to deliverables, project documents and project management plans. Finally, communicate the decisions made. A flowchart that easily summaries the integrated change control is:

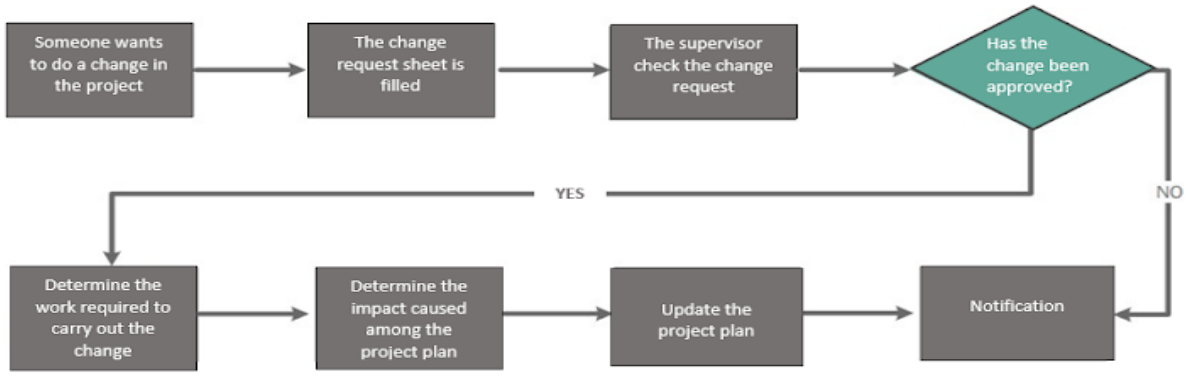


Figure 87 (in attachment)

The change request sheet that must be filled in the project is as follows.

CHANGE REQUEST SHEET		
PROJECT (Name; Identifier):		
CHANGE APPLICANT Name: Surname: ID:	Date: Request number:	
REQUESTED CHANGE:		
CHANGE REASON:		
ADVANTAGES	DISADVANTAGES	
ESTIMATED INVESTMENT IN THE CHANGE:	APPLICANT SIGNATURE:	
UPDATE OF PROJECT PLAN		
REVIEWED BY: RESPONSIBILITY:	DATE: NUMBER OF APPLICATION:	
CHANGE APPORVED?	YES	NO
REASON FOR DECISION:		
CHANGE INVESTMENT:	REVISER SIGNATURE:	PROJECT DIRECTOR SIGNATURE:

30.9.1. Magical triangle

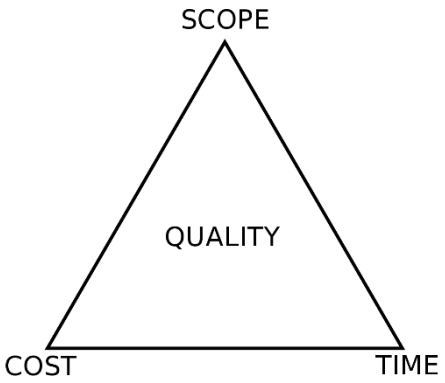


Figure 82

There are various changes in a project, but the biggest factors are changes in money, time and complexity.
These must be defined and prioritized before the project starts.

1. The parameter time is the project duration and includes project start and end as well as all appointments to be kept structuring the project.
2. The cost parameter refers to the existing budget that is set at the start of the project.
3. The performance of a project are the goals that must be met by stakeholder consultation

If one of the three parameters changes, this has a direct effect on the other two parameters.
Since project goals still have to be achieved, changes in one parameter must be compensated for by the other two variables. This leads to a change of all three parameters.

The most common change in the project was the time.
Due to difficulties in programming more time was needed for these tasks and therefore less time for other tasks.
As a result of this the goals needed to be redefined and some were deleted.
The costs did not rise because the working hours have not changed.
In the project was an increase in time, but a decline in the defined goals, which the triangle was compensated again.

30.9.2. Change control log

The changes were recorded in a change log that shows the main information about the changes.
The change control log helps to get an overview of the changes, from which they were made and for what reason.
During the project, the changes were confirmed there.

Request Number	Schedule Number	Change Type	Describtion of Change	Requested By	Date of Request	Expected Response Date	Priority	Status	Comments
Each change has his own number	Which number of the project plan is it?	Which type of change is it?	What ist the change about	Who initiaded the change request				Is the change open, closed or pending? Approved, denied or deferred	This describes the status or provide any useful information or the describtion of the change.
1	10.6	Time	Program activits	Mario	18.02.	08.03.	H	Approved	The programming takes more time than expected. That means we'll not be on time with the pramming and prototype.
2	50.2	Time	Design Product	Jan	15.03.	12.04.	M	Approved	The programm to design the case is new and it more time is needed.
3	50.2	Time	Design Midterm Report	Silke	15.03.	29.03.	H	Approved	Not every part of for the midterm report is ready.
4	50.4	Time	Programming and testing	Mario	21.03.	01.05.	H	Approved	The programming is still difficult. Another expert is highly recommended.
5	50.5	Time	Prototype and testing	Mario	02.04.	03.05.	H	Approved	The main focus is on the programming but it'll take more time.
6	50.5	Design	3D-Printing of the case	Jan	29.03.	04.05.	M	Approved	For the competition and the final presentation it is nice to see a 3D-printed prototye of the case.

Figure 88

30.10. Project marketing management

30.10.1. Strategic marketing

After the complete development of the product it is necessary to set up a marketing strategy. This strategy begins with an analysis of the entire metro market of the entire world.

30.10.1.1. Analyse of the world

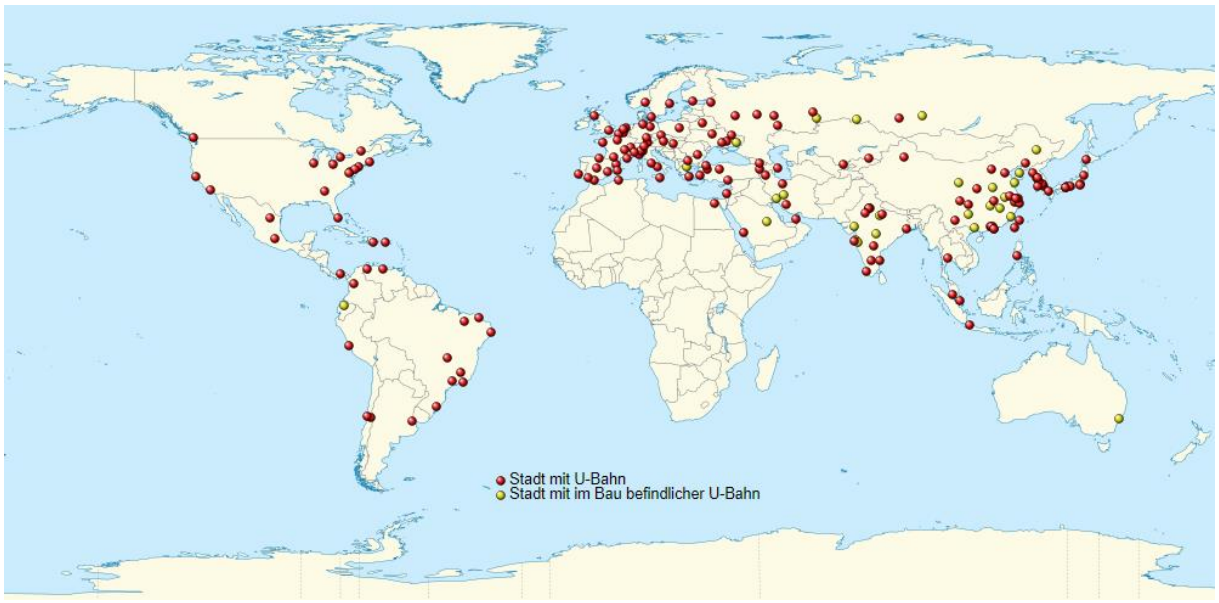


Figure 89

The analysis of the market for metro station in the world has shown that there are around 192 metro lines in the world:

Africa	2
Asia	95
Europe	57
Central America	1
North America	20
South America	17

After further research it turned out that SICK is mainly based in Europe and so Europe is the best place to start the marketing strategy.

30.10.1.2. Analyse Europe

In Europe there are 57 metro lines and others are already under construction or planned.
Since a sensor costs about 8.000 € it is first intended to use it in countries with small metro lines and little stations.

Country	Number of metro lines	Kilometer	Stations	Passengers per day
Scandinavia				
Finland	1	21	16	173.973
Denmark	1	20	22	142.466
Sweden	1	108	100	898.630
Norway	1	86	101	258.630
West Europe				
Switzerland	1	6	27	73.698
Portugal	1	44	56	405.479
Belgium	1	56	59	63.014
Czech Republic	1	65	61	1.600.000
Austria	2	1.363	113	1.205.480
Netherlands	2	121	120	640.000
Italy	7	220	272	650.257
Great Britain	3	423	309	4.984.950
Germany	4	397	410	3.740.138
France	6	351	489	5.794.679
Spain	7	704	697	5.557.534
East Europe				
Poland	1	29	28	384.658
Belarus	1	37	28	900.000
Bulgaria	1	40	34	450.000
Hungary	1	38	52	800.000
Romania	1	69	53	490.740
Greek	1	80	60	500.000
Ukraine	4	113	88	2.102.055
Turkey	3	97	92	1.816.438
Russia	5	503	331	6.532.877

After analysing every European country, it is the best option to start the marketing in the country's with less than 100 stations.
Scandinavia has only 4 metro lines that means it is the best place for a market entry in the beginning.

30.10.1.3. Near market strategy

The near market strategy is a mix of the waterfall and sprinkler strategy.
In the waterfall strategy the market entry takes place successively. For determining the order in which the countries are serve different criteria's such as intensity of competition, market risks, etc. can be used. The markets that are tapped first are most similar to home market.
The sprinkler strategy takes place in foreign markets at the same time.
However, this strategy is associated with high investment costs and a relatively high risk but market shares can be secured quickly.

In the first two years, the focus will be on cooperating with the metro stations and concluding maintenance contracts in Scandinavia metro stations on of the sensors in the metro stations. After 2 years, the sensor will be used in all stations and will ensure safety there.

Two years after the market entry the search for cooperation's with the west of Europe will begin. The installation in western Europe should be finished after 4 years since the beginning.

The last 2 years of the near market strategy will take place in east Europe.

After 6 years the smallest metro lines in Europe will be equipped with the security system and it will be continued with the big metro stations in western Europe and eastern Europe.
In the first section, about 707 stations were covered with the new security system. This means that only the sales of the sensor will result in about 5.656.000 €.

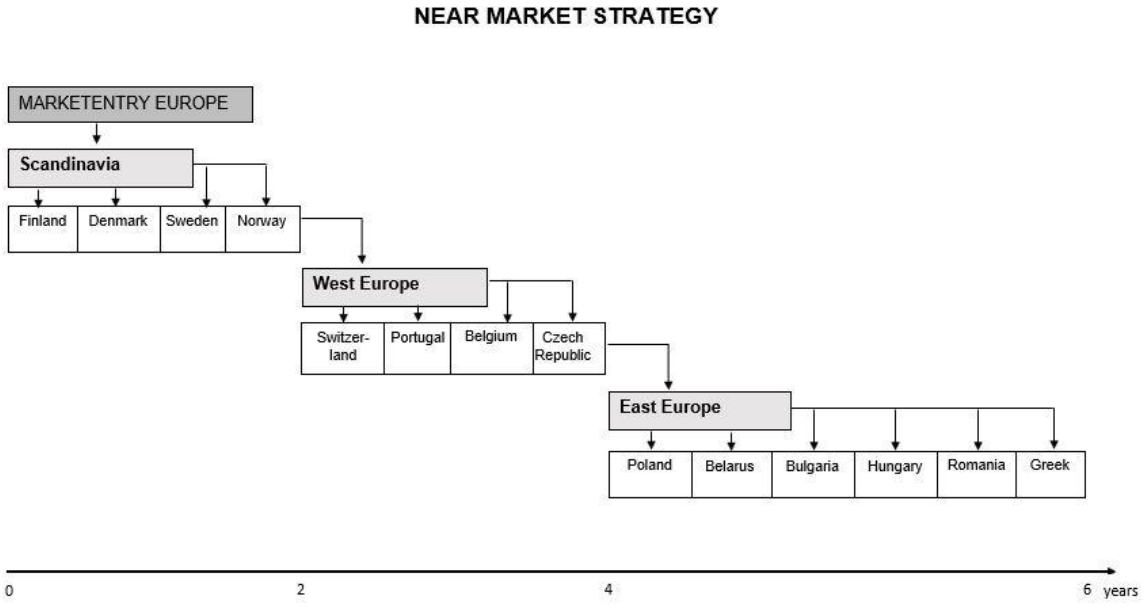


Figure 90

30.10.1.4. Marketing strategy Finland

30.10.1.4.1. Analyses

The first thing to do was to analyse all the metro stations in Finland to know how much different kinds of stations there are.
Every station was analysed by how many tracks the stations have, if they are underground or on the ground and if there are objects between the tracks on the waiting platform.
After analysation the stations where divided into 4 different groups.

Group 1 "Benches, beverage- and snack machines, billboards"

Station	Underground	Tracks	What is in between?
Matinkylä	Yes	2	Benches, beverage- and snack machines, billboards
Niittykumpu	Yes	2	Benches, beverage- and snack machines, billboards
Aalto university	Yes	2	Benches, beverage- and snack machines, billboards
Keilaniemi	Yes	2	Benches, beverage- and snack machines, billboards
Hakaniemi	Yes	2	Benches, beverage- and snack machines, billboards
Kontula	No	2	Benches, beverage- and snack machines, billboards
Siilitie	No	2	Benches

The first group has only the basic elements of metro platforms like benches, beverage- and snack machines and billboards.

Group 2 “Columns”

Station	Underground	Tracks	What is in between?
Urheilupuisto	Yes	2	11 columns and benches
Tapiola	Yes	2	3 columns and benches
Koivusaari	Yes	2	6 columns and benches
Lauttasaari	Yes	2	6 columns and benches
Kulosaari	No	2	14 columns and benches
Herttoniemi	Yes	2	28 columns and benches
Itäkeskus	Yes	3	12 columns and benches
Puotila	Yes	2	21 columns and benches
Rastila	No	2	20 columns and benches
Vuosaari	No	2	6 columns and benches
Myllypuro	No	2	21 columns and benches
Mellunmäki	No	2	24 columns and benches

The second group is the largest group and also the most problematical one.
Many columns are very wide and numerous. A complete control of the station is only possible with many sensors or sensors in the middle of the platforms not in the corners. For the last possibility the sensor has to be far away to be able to use his full angle and that is not possible in underground metro stations. Most of the columns are in the middle of the stations and that’s not a big problem for the safety program because the warning areas are next to the tracks. It is only a problem for the passenger flow analysis.

Group 3 “Big areas“

Station	Underground	Tracks	What is in between?
Ruoholahti	Yes	2	Continuous area in the middle. The end areas are free
Kamppi	Yes	2	2 big buildings in the middle with a way between that
Central railway station	Yes	2	2 big buildings in the middle with a way between that
University of Helsinki	Yes	2	Continuous area in the middle. The end areas are free
Sörnäinen	Yes	2	Continuous area in the middle. The end areas are free

The third group is the best for the developed safety precaution. There is a continuous area in the middle just the warning areas are free and have only benches.
Only 2 stations have a way between the continuous area. This route can’t be covered with the planned installation of the sensors in opposite corners of the railway station. This is not a big problem only for the passenger flow analysis.

Group 4 “Tracks lie side by side”

Station	Underground	Tracks	What is in between
Kalasatama	No	2	No platform in the middle instead outside. Tracks lie side by side

The fourth group consists of only one metro station. The warning areas are covered easily and completely.
One sensor can be enough in this metro station, if the trains do not come at the same time but offset.

30.10.1.5. Conclusion of strategic marketing

Through the analysis the following order resulted, in which the stations receive the sensors first:

1. Group 4 is the easiest to develop the sensor because it is only one station and one sensor can be enough. Also, there is nothing in the middle like columns, etc.
2. Group 3 is good to develop the sensor because there is a building in the middle of the station where nothing can happen. There are only 2 stations which can be difficult but only for the passenger flow analysis.
3. Group 1 is a bit difficult because there are a lot of benches, machines and billboards in the middle where the sensor cannot see through. This problem is not that difficult for the warning areas but for the passenger flow analysis.
4. Group 2 is the last group where the sensor will be developed because the stations have a lot columns which are really big and the sensor cannot see through this.

30.10.2. Operational Marketing

30.10.2.1. Marketing Strategy

The marketing strategies to be implemented by SICK will take into account the target audience to which our product is directed: metro stations. Our idea involves a different business model. The sensor will not be sold, it will be rented as well as the software that makes it work.

For the formulation of the marketing strategy we use the extended Ansoff matrix. Our company will follow a strategy of partial diversification: it is the effect of developing completely new products for new markets or distributions of modified products for new target groups.

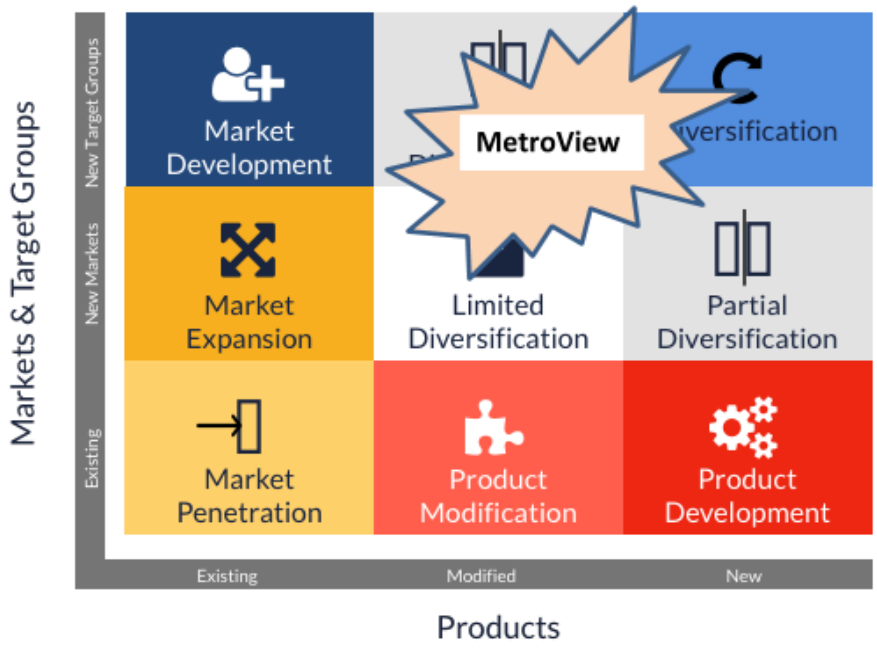


Figure 91

Our company with the new Metroview product will follow a differentiation strategy unlike to the products offered by the competition. The collected data from the sensor allows the owners to provide more safety in the station, to adapt the platform to better suit the needs of the passengers and to control the flow of the crowd across the metro network. Furthermore, the sensor scans the platform and it is programmed to count the number of passengers who are waiting. The LiDAR technology can pinpoint the location of each passenger that will provide information about the most and the least popular spots where people are standing and how they move around the station. The goal is to adapt the platform and increase the comfort of passengers by adding benches, vending machines and other features. This will allow more dispersion of the crowd along the platform and make the station more adapted to their needs. The Metroview product would be more effective if it is rented as an interconnected network of sensors in different metro stations. Gathering data of the full network of metro stations would make possible to predict the most crowded hours or days and put more trains to ensure the passenger flow and the wellbeing of the users.

Metroview will position itself in the market as a product that offers safety, integrated solutions, innovation and respect for the environment.

30.10.2.2. Marketing mix

30.10.2.2.1. Product Strategy

As far as product decisions are concerned, marketing's service employs different tools called matrix. In this case, we have opted for the Growth Matrix-Market Share, deployed by the North American consultancy Boston Consulting Group (BCG). This matrix is designed to help with long-term strategic planning. It strives for business growth opportunities by reviewing its portfolio of products and deciding where to invest, dismiss or develop products. It is also known as the Growth/Share Matrix.

SICK has a product line that, at the time of the project's launch, could be considered as a question mark, due to it is a new product in his Introduction phase in the Product Life Cycle (P.L.C.). In addition, it is characterised by its high financial needs - essential to expand its market share- and by generating a low cash flow. The objective is to achieve, through various marketing-mix actions, the category of star products, defined by high growth and a significant participation. Question mark products also need the investment of large monetary flows but generate liquidity.

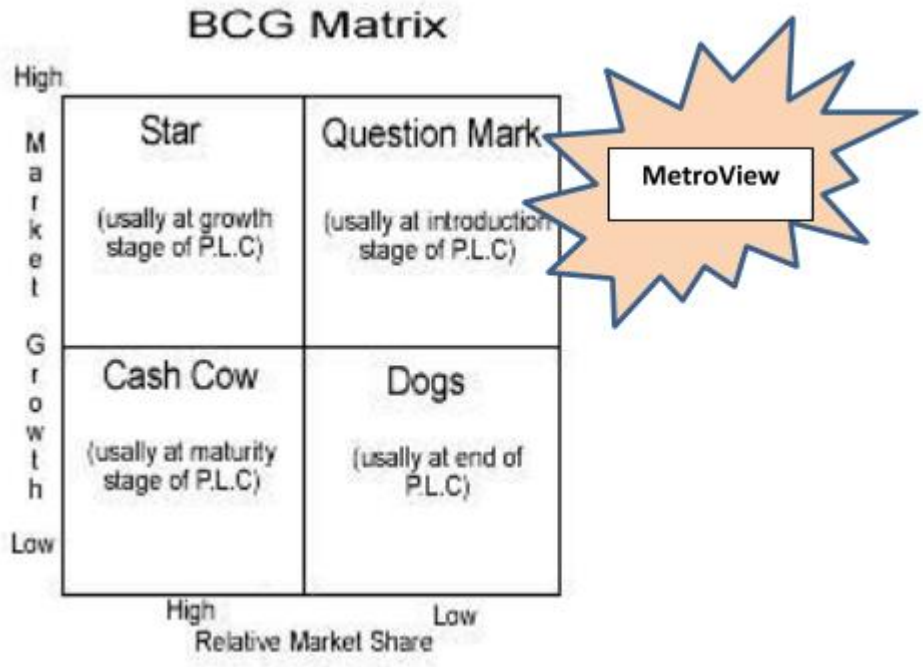


Figure 92

Sensor Brand

Name	Metroview
Origin	Metro + View (control of metro stations)

Extended Product:
Guarantees and services:
- 5 years guarantee, both for parts and software update.
- Technical service and maintenance.

Financing:
- Discounts depending on the payment method

30.10.2.2.2. Price Strategy

Pricing can be done using an internal, external or both approach at the same time. The internal is based on costs and the external on the analysis of competition and demand.
The technology, that will include SICK in the production of Metroview, is of the highest level hence the production will be expensive. To the extent, the company is positioning as the creator of a sensor that provides an integrated solution for metro stations. This will lead us to determine a medium / high sale price in the market.
On the other hand, if we consider the competition, the market offers hardly any options for this type of solution. Finally, it is very interesting to consider the demand perspective in the pricing process. It would be interesting to conduct a survey of our potential customers to determine the range of prices that would willing to pay.

Cost for the metro station

	when	persons	Responsible	hours	cost	total
Analyse of the station	beginning	1	Engineer	2	80,00 €	160,00 €
Installation	beginning	2	Programmer	40	150,00 €	12 000,00 €
printing cases	beginning	1	Engineer	25	80,00 €	2 000,00 €
maintenance	every 3 years	1	Programmer	8	150,00 €	1 200,00 €
Material 3D-Printing				**kilo**	**cost**	**total**
PLA Ingeo 3D860	beginning			2	32,00 €	64,00 €
total beginning						14 224,00 €
every 3 years						1 200,00 €

Figure 93

Cost for our project

	when	persons	Responsible	hours	cost	total
Analyse of the station	beginning	1	Engineer	2	50,00 €	100,00 €
Installation	beginning	2	Programmer	40	120,00 €	9 600,00 €
printing case	beginning	1	Engineer	25	50,00 €	1 250,00 €
maintenance	every 3 years	1	Programmer	8	120,00 €	960,00 €
Material 3D-Printing	**when**	**sensors**		**kilo per sensor**	**cost per kilo**	**total**
PLA Ingeo 3D860	beginning	2		2	32,00 €	128,00 €
total beginning						11 078,00 €
every 3 years						960,00 €

Figure 94

Total profit

Profit per station	1 station	3 146,00 €
Total Profit for all stations	707 stations	2 224 222,00 €
Total Profit	6 years	370 703,67 €

Figure 95

30.10.2.2.3. Sales Channels

In order to be able to market the product, it is necessary to set various channels in which the sales department will operate:

- Add on industrial revue
- Demonstration on industrial show
- Direct way to the government
- Website. The product will be sold B2B
- Maintenance contracts
- Specific events for railway companies and global tech events

The most important sales channel is the maintenance contract. So, it is regulated that the sensor will be updated every 3 years and the program will be paid annually. In addition, a reduction of the price can be determined here when the costumer wants to buy many products.

30.10.2.2.4. Communication strategy

- Communication through internet and social networks (Web and youtube channel)
- Direct marketing (Sales Force)
- Fairs
- Promotions in specialised magasines
- For the presentation of our sensor we will carry out big events (like Apple or Tesla). We will make a staging in style.

30.10.2.3. Conclusion of the operational marketing

Following a **partial diversification** in marketing strategy, Metroview places itself as a new product that wants to make its own path in the existing market. It is a product identified as a **question mark** which means that a lot of investment is needed at the beginning to be known. However, an appropriate renting price, a correct sales channels and an effective communication strategy will lead the Metroview to top sales in future market.

40. Conclusion

Introduction

To be able to draw the right conclusions it is important to remember the mission of the project:
"Design an original and innovative application using the MRS6000 LiDAR sensor that fits in the existing market and uses the maximum potential of the technology."
Now we are able to conclude if we reached the goals set out by the project, if we reached the goals set by ourselves and evaluate the steps we took to reach these goals.

Process

A technology-driven design project starts with an analysis of the technology which is followed by a lengthy brainstorming phase. The concept was found by using the correct methods at the right time thanks to the strong project management. Because our main goals were to strictly follow the schedule and explore all the possible aspects of the product we were able to find the perfect idea for an application in a short time. This provided the team with a lot of motivation to go through with the project and develop the final product.
After the ideation and concept phase, the team faced a difficult situation. To define the safety areas on the platform it was necessary to collect and extract all the data generated by the sensor and communicate with it. Because no team members were skilled in programming or had any experience with this kind of sensor, this activity slowed down the progress of the project. Despite this issue, the team kept working hard on the programming and with the help of Harry, another international student and programming expert, the team succeeded in communicating with the sensor and defining the areas. Eventually we reached the goals we set for ourselves and had no problem finishing all the tasks before the deadline.

Product

The final product is intended to be used inside a metro station. There are a lot of opportunities for using the sensor in this environment and we chose passenger safety and passenger flow control as our main priorities. By detecting obstacles on the train tracks or in proximity to the tracks the system will provide more safety on the platform, and by counting the passenger and gathering data about the passenger flow the metro station can be better adapted to the needs of the passengers. It fit perfectly into the deliverables for the SICK innovation competition and also raised some awareness for the circular economy principle.

Project

During the four months of this EPS project, our team learned a considerable amount about the different aspects of project management and working with people from different fields. Since the start of the semester every team member has been very invested in the project and everyone performed really well during each step of the product development process. Through the course of this project the team developed many new skills such as project, time and cost management, programming with LiDAR sensors, 3D modeling and printing and researching material resources. Every team member enjoyed working on the product because of the competition and this made us perform even better. The honorable mention (4t place) in the SICK innovation competition was a big surprise but it gave us recognition for the work we did.
Doing an EPS is an amazing opportunity which allowed us to not only learn from the project but also from each other. We learned to work together with people from different cultures, different backgrounds and different fields. This made us more comfortable in a multi-cultural environment which is a strong value for future careers. The EPS experience has enriched us and made us grow individually on a personal and an intellectual level. Mika's Monkeys will forever cherish this opportunity and remember it as an amazing experience.


SICK
Sensor Intelligence.
KUNNIAMAININTA
METRON ODOTUS-


KUNNIAMAININTA
METRON ODOTUSALUEEN
VALVONTA
SICK
1000
EUROA

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60. Attachment

Figure 1

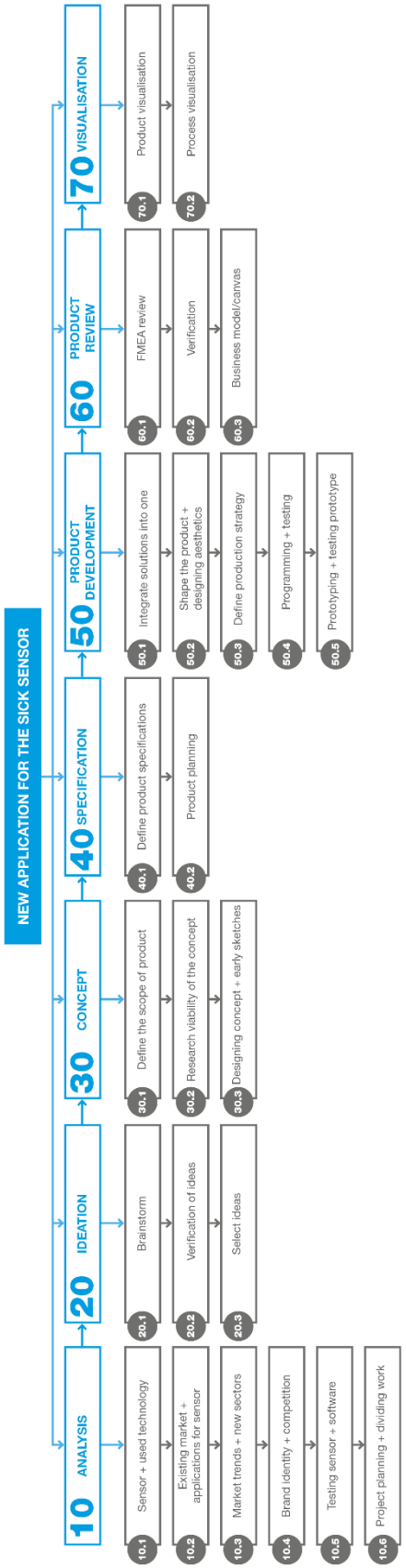
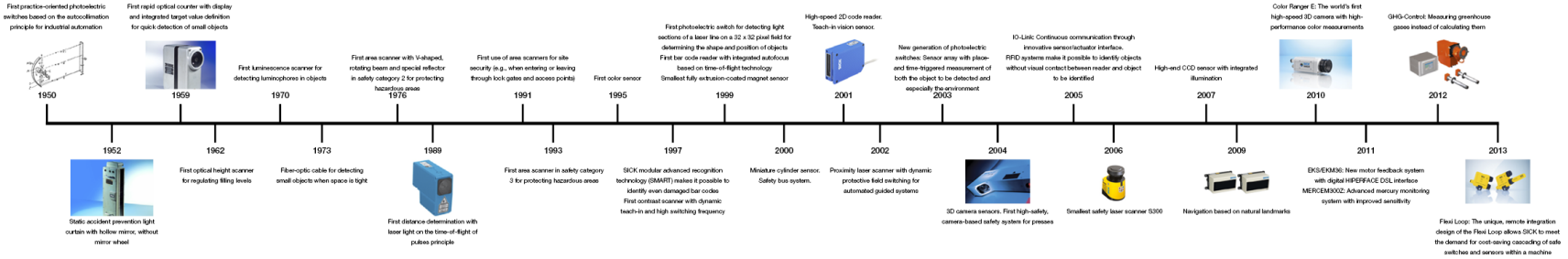


Figure 10

TIMELINE: Technological milestones



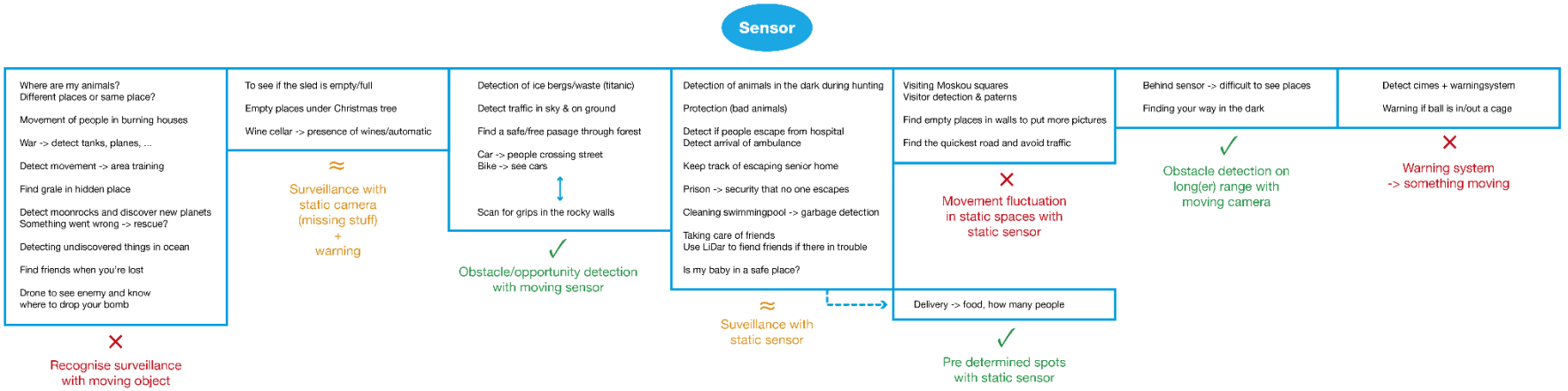

Sensor
Where are my animals?
Different places or same place?
Movement of people in burning houses
War -> detect tanks, planes, ...
Detect movement -> area training
Find grale in hidden place
Detect moonrocks and discover new planets
Something went wrong -> rescue?
Detecting undiscovered things in ocean
Find friends when you're lost
Drone to see enemy and know
where to drop your bomb
Recognise surveillance
with moving object
To see if the sled is empty/full
Empty places under Christmas tree
Wine cellar -> presence of wines/automatic
Surveillance with
static camera
(missing stuff)
+
warning
Detection of ice bergs/waste (titanic)
Detect traffic in sky & on ground
Find a safe/free pasage through forest
Car -> people crossing street
Bike -> see cars
Scan for grips in the rocky walls
Obstacle/opportunity detection
with moving sensor
Detection of animals in the dark during hunting
Protection (bad animals)
Detect if people escape from hospital
Detect arrival of ambulance
Keep track of escaping senior home
Prison -> security that no one escapes
Cleaning swimmingpool -> garbage detection
Taking care of friends
Use LiDar to fiend friends if there in trouble
Is my baby in a safe place?
Suveillance with
static sensor
Visiting Moskou squares
Visitor detection & paterns
Find empty places in walls to put more pictures
Find the quickest road and avoid traffic
Movement fluctuation
in static spaces with
static sensor
Delivery -> food, how many people
Pre determined spots
with static sensor
Behind sensor -> difficult to see places
Finding your way in the dark
Obstacle detection on
long(er) range with
moving camera
Detect cimes + warningsystem
Warning if ball is in/out a cage
Warning system
-> something moving

Figure 15

	Ta	Taaknaam	Duur	Begindatum	Einddatum	Vo tak
1		**analysis**	**6 dagen**	**maa 11/02/19**	**maa 18/02/19**	
2		**Imprtant analysis**	**3 dagen**	**maa 11/02/19**	**woe 13/02/19**	
3		Sensor and used technology	3 dagen	**maa 11/02/19**	woe 13/02/19	
4		Existing market+appl for sensor	3 dagen	**maa 11/02/19**	woe 13/02/19	
5		Market trend+ new sector	3 dagen	**maa 11/02/19**	woe 13/02/19	
6		brand identity+ competition	3 dagen	**maa 11/02/19**	woe 13/02/19	
7		Testing sensor and software	3 dagen	don 14/02/19	maa 18/02/19	2
8		Planning	3 dagen	don 14/02/19	maa 18/02/19	2
9		**Ideation**	**3 dagen**	**maa 18/02/19**	**woe 20/02/19**	**7;8**
10		Brainstorming	2 dagen	maa 18/02/19	din 19/02/19	
11		Verification of ideas	1 dag	din 19/02/19	din 19/02/19	10
12		Selection of ideas	1 dag	woe 20/02/19	woe 20/02/19	11
13		**Concept**	**3 dagen**	**woe 20/02/19**	**vri 22/02/19**	
14		Define the scope	1 dag	woe 20/02/19	woe 20/02/19	12
15		Research the viability of the concept	2 dagen	don 21/02/19	vri 22/02/19	14
16		desinging the concept + early sketches	1 dag	vri 22/02/19	vri 22/02/19	15
17		**specification**	**2 dagen**	**maa 25/02/19**	**din 26/02/19**	
18		define the product specifications	1 dag	maa 25/02/19	maa 25/02/19	16
19		make a product plan	1 dag	din 26/02/19	din 26/02/19	18

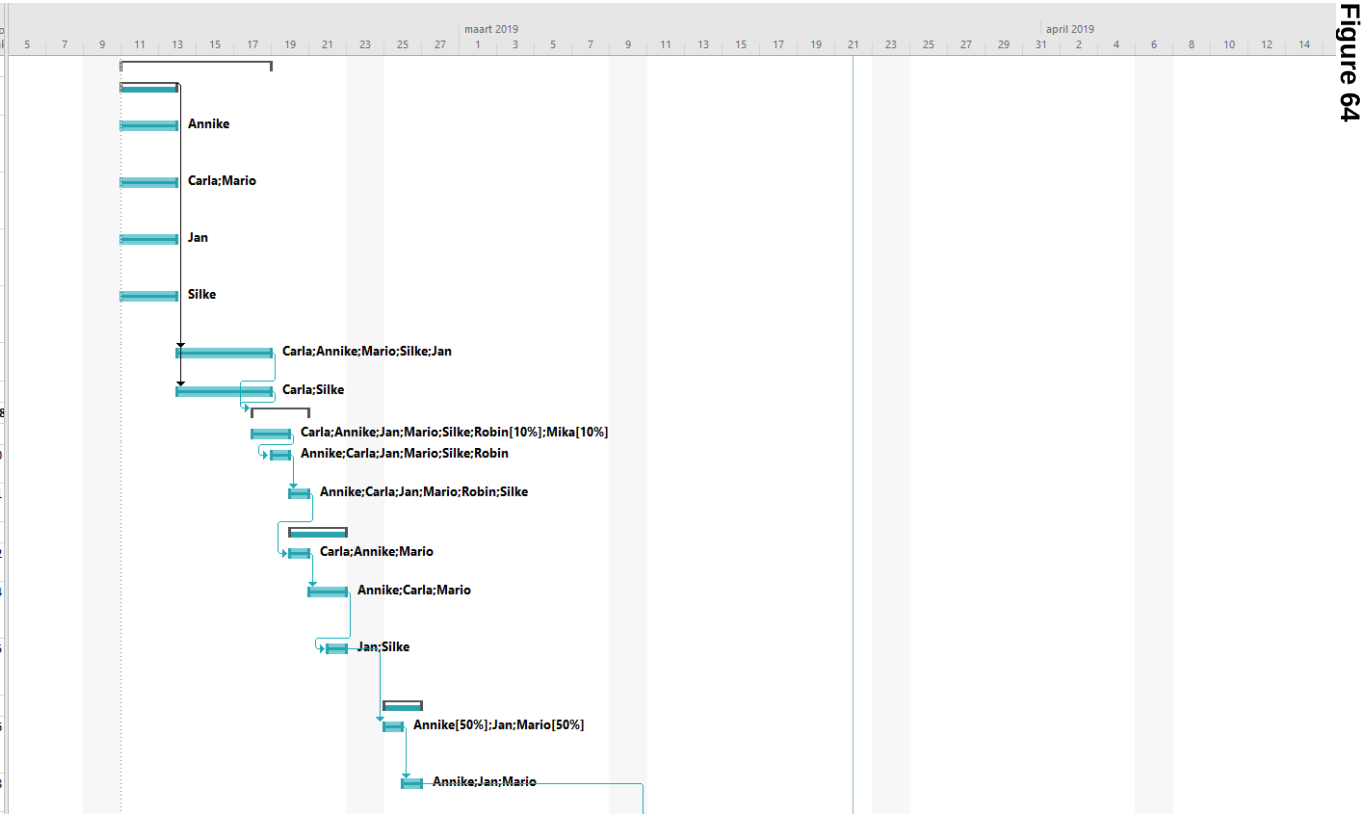


Figure 64

Figure 65

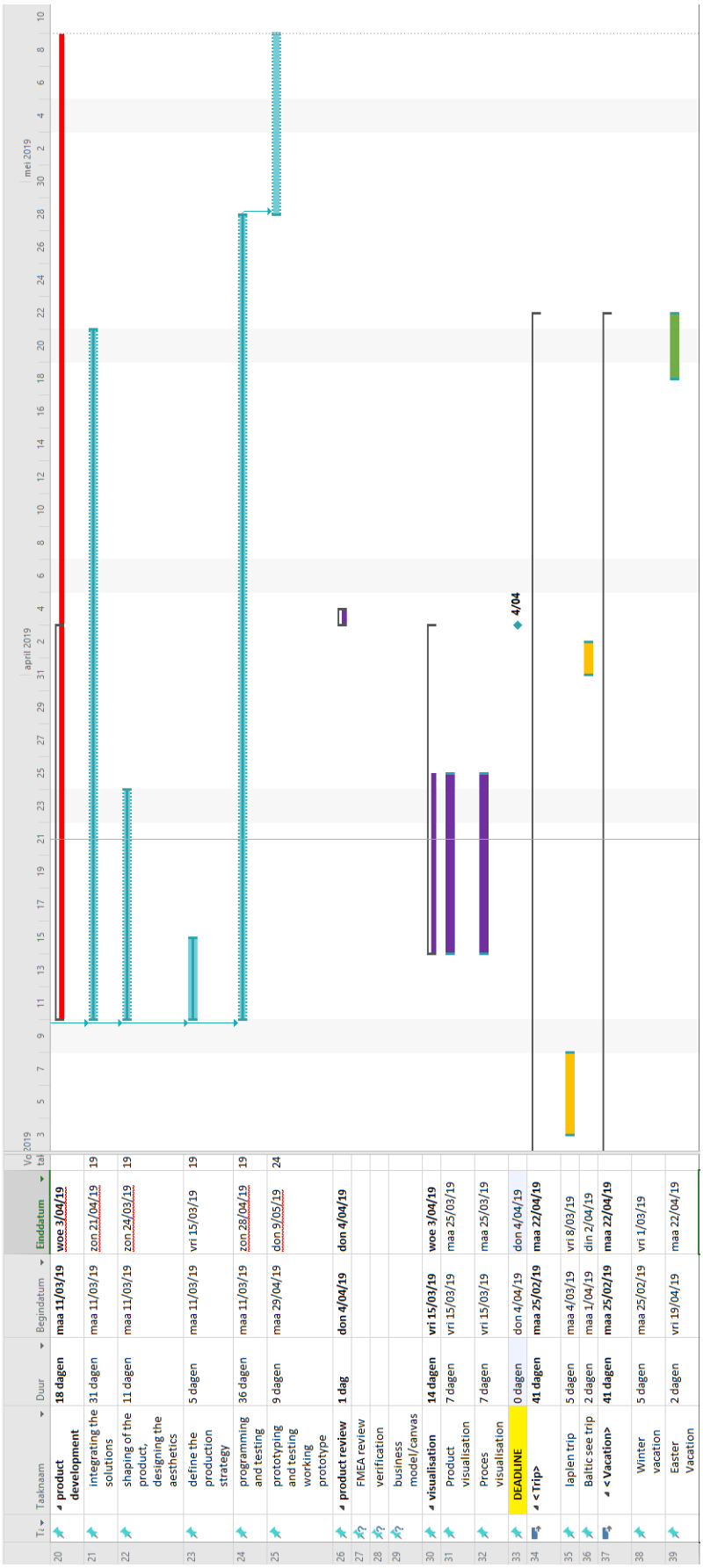
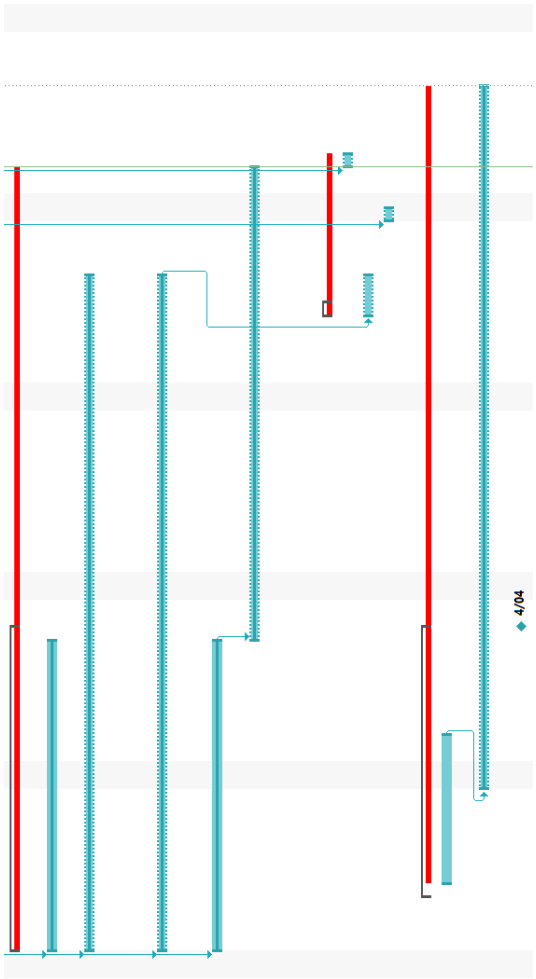

Ti
Taaknaam
Duur
Begindatum
Einddatum
Vo 2019
tal
april 2019
mei 2019
4/04
20 product development 18 dagen maa 11/03/19 woe 3/04/19
21 integrating the solutions 31 dagen maa 11/03/19 zon 21/04/19 19
22 shaping of the product, designing the aesthetics 11 dagen maa 11/03/19 zon 24/03/19 19
23 define the production strategy 5 dagen maa 11/03/19 vri 15/03/19 19
24 programming and testing 36 dagen maa 11/03/19 zon 28/04/19 19
25 prototyping and testing working prototype 9 dagen maa 29/04/19 don 9/05/19 24
26 product review 1 dag don 4/04/19 don 4/04/19
27 FMEA review
28 verification
29 business model/canvas
30 visualisation 14 dagen vri 15/03/19 woe 3/04/19
31 Product visualisation 7 dagen vri 15/03/19 maa 25/03/19
32 Proces visualisation 7 dagen vri 15/03/19 maa 25/03/19
33 DEADLINE 0 dagen don 4/04/19 don 4/04/19
34 < Trip> 41 dagen maa 25/02/19 maa 22/04/19
35 lapland trip 5 dagen maa 4/03/19 vri 8/03/19
36 Baltic see trip 2 dagen maa 1/04/19 din 2/04/19
37 < Vacation> 41 dagen maa 25/02/19 maa 22/04/19
38 Winter vacation 5 dagen maa 25/02/19 vri 1/03/19
39 Easter Vacation 2 dagen vri 19/04/19 maa 22/04/19

Figure 66



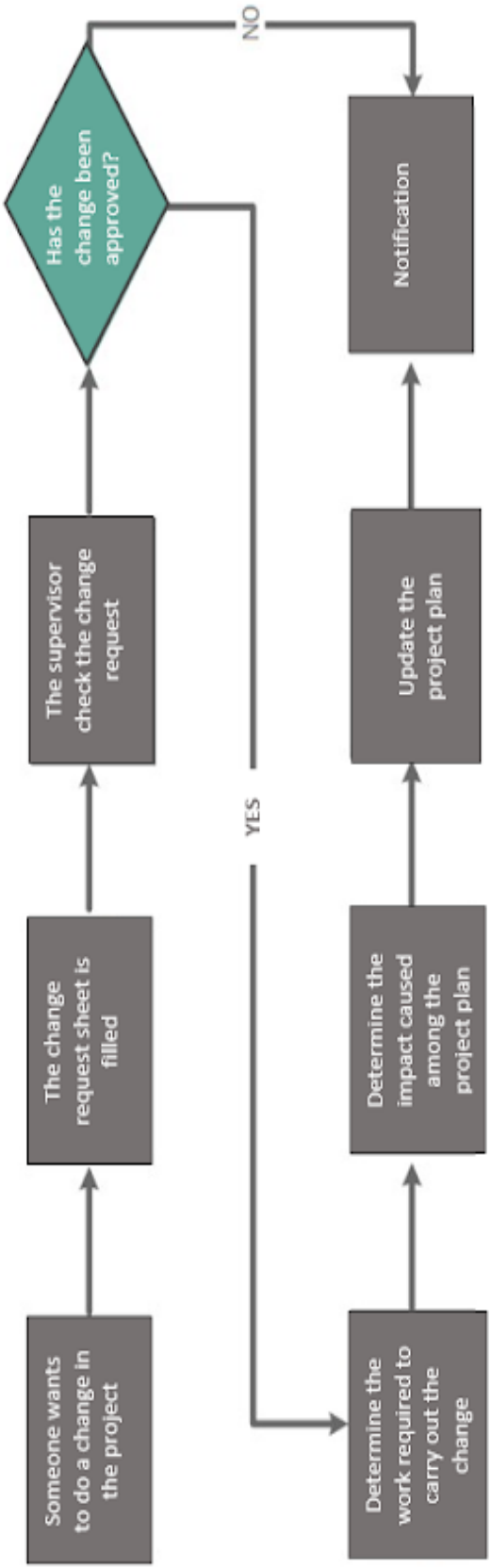
20					
21	product development	18 dagen	maa 11/03/19	woe 3/04/19	
22	integrating the solutions	17 dagen	maa 11/03/19	din 2/04/19	19
23	shaping of the product, designing the aesthetics	36 dagen	maa 11/03/19	maa 29/04/19	19
24	define the production strategy	36 dagen	maa 11/03/19	maa 29/04/19	19
25	programming and testing	17 dagen	maa 11/03/19	din 2/04/19	19
26	prototyping and testing working prototype	25 dagen	woe 3/04/19	din 7/05/19	24
27	product review	1 dag	zat 27/04/19	zat 27/04/19	
28	FMEA review	1 dag	woe 8/05/19	woe 8/05/19	19
29	verification	2 dagen	zat 27/04/19	maa 29/04/19	23
30	business model/canvas	1 dag	zat 4/05/19	zat 4/05/19	15
31	visualisation	14 dagen	vri 15/03/19	woe 3/04/19	
32	Product visualisation	8 dagen	zat 16/03/19	din 26/03/19	
33	Process visualisation	37 dagen	zat 23/03/19	maa 13/05/19	31
	DEADLINE	0 dagen	don 4/04/19	don 4/04/19	

GANTT-DIAGRAM

Earned Value Analysis	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Cost Variance (CV)	0 €	0 €	1,140 €	1,140 €	1,140 €	-2,861 €	-13,750 €	-28,895 €	-29,571 €	-26,221 €	-20,848 €	-5,259 €	-7,596 €	-16,800 €
Schedule Variance (SV)	0 €	0 €	-160 €	-160 €	-160 €	-1,761 €	-6,470 €	-10,815 €	-15,211 €	-11,861 €	-6,488 €	9,582 €	16,259 €	0 €
Cost Performance Index (CPI)	1.00	1.00	1.04	1.04	1.04	0.92	0.77	0.65	0.67	0.73	0.79	0.95	0.94	0.89
Schedule Peerformance Index (SPI)	1.00	1.00	0.99	0.99	0.99	0.95	0.88	0.83	0.80	0.85	0.92	1.10	1.14	1.00
Estimate at Completion (EAC):	132,867 €	132,867 €	127,435 €	127,723 €	127,723 €	143,871 €	172,951 €	203,841 €	198,442 €	182,904 €	168,767 €	139,492 €	140,609 €	149,667 €
Estimate Time at Completion (TEAC) weeks	14.0	14.0	14.1	14.1	14.1	14.7	16.0	16.8	17.6	16.4	15.2	12.7	12.3	14.0

Figure 78

Figure 87


Someone wants to do a change in the project
The change request sheet is filled
The supervisor check the change request
Has the change been approved?
NO
YES
Notification
Update the project plan
Determine the impact caused among the project plan
Determine the work required to carry out the change

Website:
https://silkedebie4.wixsite.com/metroview?fbclid=IwAR2PSkjk7ZdPY6z416Htn23WcoGRIwlhE3bhUGC5OBsPkMlJRKHQ0xyHOPY

Video:
https://www.youtube.com/watch?v=i2N5lzpbe8Q&fbclid=IwAR02TAjoyM1weJv1rPp-6LWuc6eOtYOr8wYAsvXtpA_iJQB2bC-ReP_G6EE