Camera Interaction in Elevator Environment

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MASTER THESIS

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Abstract

This master thesis describes a product development process with the aim of developing a product concept for a surveillance camera in an elevator environment. The study is conducted on behalf of Axis Communications AB, a market leading company in network camera solutions.

The thesis includes a comprehensive background study that seeks to understand relevant parts of the elevator business to gain knowledge on how a surveillance camera could be implemented. To achieve the best understanding of the environment, user research was performed as the primarily research method. The background study revealed that the elevator business is complex and many aspects must be considered when developing a custom fit solution for the environment. The knowledge gained from the background study was used to generate solutions leading to a final product concept.

The concept development process resulted in a dome housing solution for the *AXIS FA1105* sensor unit. The housing is very small and discrete, which provides many advantages in the elevator environment. In the final concept, the sensor unit is arranged in a silicone ball, the ball is placed in two rings with a spherical inside where it can rotate freely to provide the ideal field of view. A cover ring and dome is placed over the silicone ball to protect the camera and lock the silicone ball, thereby fixating the camera angle.

Keywords: Product development, Network Surveillance Camera, Axis, Elevator, Design, Network Connection

Sammanfattning

Examensarbetets uppsats beskriver en produktutvecklingsprocess, syftet är att utveckla ett produktkoncept för en övervakningskamera i en hissmiljö. Studien är genomförd på uppdrag av Axis Communications AB, ett marknadsledare företag inom nätverksvideo.

Uppsatsen inkluderar en omfattande bakgrundsstudie, i vilken syftet är att skapa förståelse för relevanta delar av hissbranschen för att få kunskap om hur kameraövervakning kan implementeras. För att uppnå bästa möjliga förståelse för hissmiljön, valdes utförandet av användarundersökning som primär metod för insamling av data. Bakgrundsstudien påvisade komplexiteten hissbranschen, samt att många aspekter måste vägas in under utvecklingen av en lösning anpassad för den miljön. Kunskap erhållen från bakgrundsstudien tillämpades för att generera lösningar vilka ledde fram till ett slutgiltigt koncept.

Konceptutvecklingsprocessen resulterade i ett kamerahus för sensorenheten *AXIS FA1105*, utformat som en kupol. Kamerahuset är litet och diskret, vilket medför många fördelar i en hissmiljö. I det slutgiltiga konceptet arrangerades sensorenheten i en silikonboll, bollen i sig placerades emellan två ringar med en sfärisk insida där den är fri att rotera för att uppnå det optimala synfältet. En yttre täckring och kupol placeras sedan över silikonbollen för att skydda kameran och låsa bollen, därmed fixeras kamera vinkeln.

Nyckelord: Produktutveckling, Nätverksvideo, Övervakning, Axis, Hiss, Design, Nätverksanslutning

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Marie Bye Løken & Viktoria Ringdahl

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1 Introduction

This chapter introduces the master thesis and includes a presentation of the company as well as the problem description. The problem description consists of the initial brief, goals for the thesis, available resources and finally the limitations of the project.

1.1 Axis Communication

Axis Communications AB, hereafter referred to as Axis, is a global market leader in network video surveillance. They were founded in 1984 and is based at the Ideon area of Lund, Sweden. Axis offer customers a broad portfolio of video surveillance cameras and installation opportunities. Their high-quality solutions for network cameras are sold all over the world. The security business is a growing market and Axis is constantly working with innovation to meet new markets and demands.

The thesis will be conducted under the department of Extended Video Products (EVP). This is a department within Axis which develops new solutions and accessories for video surveillance that goes beyond the standard Base Video Products (BVP).

1.2 Problem description

1.2.1 **Initial brief**

Axis are continuously looking for new opportunities in the security and safety business. After requests from the market an interest in surveillance cameras for elevator environments arose. This is currently unknown territory for Axis as they have no solution optimized for video surveillance in elevators today. Axis cameras installed in elevators today does not have a design or network connection solutions adapted for this environment. They are therefore looking to expand their knowledge in the elevator video surveillance field to meet the market demand.

The thesis aims to develop means for Axis camera systems to interact with elevator environments by exploring cost effective and discrete ways of integrating the two. Interaction between camera system and elevator environment refers to mechanical interaction such as mounting and installation. It is desirable to find a concept that is applicable to most elevators and is suitable for new installations as well as the retrofit market.

The thesis will serve as a pre-study for future projects at Axis. Therefore, a comprehensive background study will be carried out before initializing the concept development phase. The thesis will investigate the best possible ways of implementing cameras in elevator environments and identify opportunities for usage which provides cost efficient solutions for customers. The chosen concept will be evaluated with the help of prototypes.

1.2.2 **Goals**

The goal of the thesis is to develop means for Axis camera systems to interact with elevator environments. Interaction refers to mechanical interaction such as mounting and installation. A study of potential camera systems will be done to identify the most suitable system in line with Axis' future projects. Furthermore, the goal is to develop an understanding of the environment and how the chosen camera system could be utilized in the most effective way both outside and inside the elevator car. Lastly, the goal is to understand the requirements in this type of installation and based on these results develop a concept of integrated solution.

1.2.3 **Resources**

Necessary equipment for the project is provided by Axis. Members of the mechanical engineering team, including supervisors provided by Axis, were involved in the product development process and members of the electric engineering team were involved in giving guidance regarding power and connection solutions as well as setting up and testing cameras. Furthermore, Axis provided access to a workshop equipped with tools and 3D printer to facilitate the making of prototypes.

1.2.4 **Initial delimitations**

In the initial stage of the project delimitations were determined in consultation with Axis. The project is primarily concerning passenger elevators with a completely enclosed car. The Axis F series, see Figure 1.1, was the initially chosen camera system and research regarding interaction is based on this system. The interaction between camera system and elevator is purely mechanical and refers to mounting and installation.

Figure 1.1 The Axis F series camera system.

2 Methodology

This chapter provides information regarding the planning of the thesis and the approach. Product development methods used during the project are presented and covered in detail.

2.1 Planning

The thesis is carried out over an estimated time frame of 20 weeks. The results are stated in this report and presented during a presentation at the end of week 20. For planning time and resources, a detailed Gantt chart was set up during the first week. The Gantt chart shows an estimated timeframe for the project activities. During the project, this timeframe was adjusted as certain activities required more or less time than first estimated. The original and adjusted Gantt chart can be found in Appendix A.

2.2 Report outline

The report is divided into four parts with underlying chapters. Part I is an extensive background study with the intention to serve as a base for future elevator related projects at Axis. It consists of external studies and user research that seeks to identify opportunities and understand the market. Part II, Analysis and selection of camera technology, provides and analysis of relevant camera systems in order to chose the one most suitable for the project. It covers both testing and selection of the preferable camera system. Part III, Concept development, accounts for the process of developing a camera housing adapted for an elevator environment. During this part, solutions are generated and tested for the chosen camera system based on identified opportunities in the background study. The outcome is a presentation of a final concept and a plan for further development. Part IV, Conclusion and Discussion, is where all parts of the project are discussed and concluded. The final part is followed by appendices relevant to the project.

2.3 Approach

The thesis is based on known methodologies for design and product development. The methods are adjusted to fit the problem description as well as available resources. The overall method follows the principles of the Double Diamond method proposed by the UK Design Council [1 pp.1-26]. Some of the activities of the Double Diamond method have been performed by following the more detailed method developed by Ulrich and Eppinger presented in Product Design and Development [2]. The next section describes the chosen methods and how they are adapted to fit the project. An illustration of the project process and combination of the two methods is shown in Appendix A.

2.3.1 **Double Diamond**

The Double Diamond method was developed by the UK Design Council in 2005. It is a simple graphic way of describing the design process. The method suggests two separate divergent stages, each followed by a convergent stage. Together they form two diamond shaped figures, see Figure 2.1. Hence, the Double Diamond method.

The method is divided into 4 phases; Discover, Define, Develop and Deliver. The basic concept is that the first divergent stage includes an extensive search for information, to gain insight into the market and product customers. This phase is then followed by a convergent stage where the information is processed to define the focus area and problem description. The next phase is again a divergent stage where concept ideas are generated. The following and last convergent stage is where the ideas are tested to find the final solution.

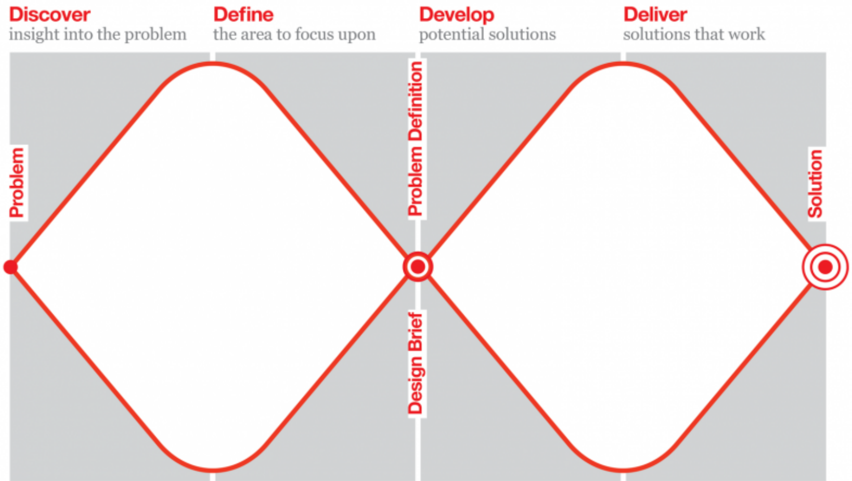


Figure 2.1 Illustration of the Double Diamond method. [1]

2.3.1.1 Discover

The first phase of the Double Diamond method is the Discover phase. The goal of this phase is to gain extensive insight into the problem. This is done through an external study, including market and user research where essential information about the market is gathered and customer needs are defined. The result of this phase is Part I Background Study. An extensive background study gives important insights about key problems, opportunities and needs that helps develop the best possible solution for the market. In addition to the extensive marketing research an internal study of Axis is done where internal resources relevant to the project are explored resulting in information presented in Part II of this report.

In the first part of the Discover phase literary research is done to gain insights on the market opportunities as well as the elevator business. The literary research is followed by interviews with people from the elevator business and from Axis as well as user research through observations of a camera installation process in an elevator. In search for information both primary and secondary research is used. Primary research is information directly from the primary source such as interviews with customers, installers or experts at Axis. Secondary research can be interviews with people who can deliver useful insight into customer needs such as marketing and sales personnel at Axis.

2.3.1.2 Define

The Define phase seeks to narrow down all the information found in the Discover phase. Findings are interpreted and aligned into needs presented in Chapter 10 *Customer Needs*. The detailed method for interpreting needs follows the concept development process of Ulrich and Eppinger presented in detail in Section *2.3.2 Ulrich and Eppinger*. The Define phase will automatically rule out certain ideas at an early stage and provide further limitations before entering the Develop phase.

2.3.1.3 Develop

The Develop phase includes iterative development and testing of concepts. The development method used for this phase will be the concept development process by Ulrich and Eppinger. This method will provide a detailed structure of important activities in the development process. Detailed information about this method is presented in Section *2.3.2 Ulrich and Eppinger*.

2.3.1.4 Deliver

The Deliver phase is where the final solution is presented. This is where the final testing and prototyping of concepts is done. From the Develop phase a large number of concepts are generated. The Deliver phase seeks to test these concepts further in order to narrow it down to a final solution. This part is also covered by the more detailed concept development method by Ulrich and Eppinger. More information about this method is presented in Section *2.3.2 Ulrich and Eppinger*.

2.3.2 **Ulrich and Eppinger**

Product Design and Development is a collection of methods used primarily to develop engineering products and is written by Ulrich and Eppinger. It covers the entire development and design process from identification of a market opportunity to the delivery of a finalized product. The product development process relevant for this project is limited to the first two phases described in the book. Phase 0; Planning and phase 1; Concept Development. See Figure 2.2. The latter will result in a detailed prototype. Subsequent steps in the process will not be undertaken.

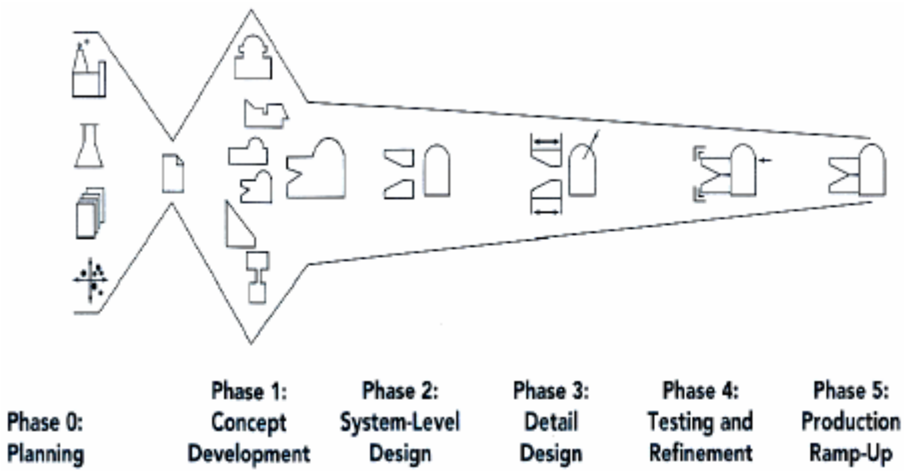


Figure 2.2 Illustration of the product development process. [2 p.14]

2.3.2.1 Planning

Prior to the concept development process, a market opportunity is identified. This phase of the project is referred to as the planning phase and results in the project Mission Statement presented in Chapter 9. An opportunity is identified when a company discovers a need which they can satisfy in a way that aligns with the corporate strategy. The planning phase has partially been done by Axis as they identified the market opportunity prior to the start of the project. The remaining part overlaps with the Discover and Define phases of the Double Diamond method. The method used when executing the planning phase is therefore the first two stages of the Double Diamond method, covered in Section *2.3.1 Double Diamond.*

2.3.2.2 Concept development

The concept development process is a front-end process divided into seven main activities, see Figure 2.3. The input for the process is the Mission Statement, also called Problem Description in the Double Diamond method. The output is a Development Plan.

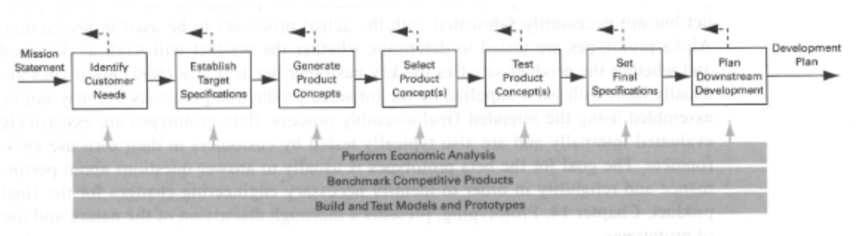


Figure 2.3 Illustrates the concept development process. [2 p.16]

2.3.2.2.1 Identify customer needs

Customer statements are identified from the initial marketing research and organized to be manageable. The statements are interpreted into customer needs and prioritized according to their importance and relevance for the project.

2.3.2.2.2 Establish target specifications

Target specifications for the final product are defined. Both ideal and marginal acceptable target values are set to provide some flexibility. The values are based on findings in the background study, including standards from Axis as well as standards for the given environment.

2.3.2.2.3 Generate product concepts

This is where all concept ideas are generated. First, the problem is divided into critical sub problems that needs to be solved. Then external search, including benchmarking, is conducted to see how problems are resolved today and internal search to explore new ideas through brainstorming. Finally, a systematic exploration of possible integrated solutions based in the results from the internal and external search is done.

2.3.2.2.4 Select product concept

One or more concepts are carefully selected to proceed onto testing. A structured method for concept selection is used to secure a high-quality result. The method for selecting is divided into two stages. The first stage is called concept screening and the second called concept scoring. Both stages are supported by a decision matrix where the team rates concepts to select the best ones. The concept selection process will be done through two iterations. During the first iteration, concepts are selected for testing and during the second the final concept is selected after testing.

In this thesis, the concept screening stage will also appear in Part II, Analysis and selection of camera technology, where possible usage of cameras is tested and selected using concept screening.

2.3.2.2.5 Test product concept

The testing of the selected concepts is done by making both digital and physical prototypes to get a visual and tactile feel for the concept. The physical prototypes are made through 3D printing as well as through purchasing additional components that are used to test certain crucial features of the concepts. The functions of the prototypes are then assessed through various tests relevant for each function.

2.3.2.2.6 Set final specifications

Final specifications of the chosen concept are set based on the target specifications and results of the final concept.

2.3.2.2.7 Plan further development

A further development plan is set up based on both the limitations and the results of the concept testing. This part presents the activities that need to be completed before a final concept is ready for production.

PART I
Background study

3 External study

This chapter provides information regarding the external market. The chapter covers market opportunities, a market study of the elevator and of cameras in elevators as well as user research.

3.1 Market opportunities

Market opportunities covers all trends and forecasts in the market relevant for video surveillance in elevators. This study covers both the elevator and the surveillance business as they are equally important to the project.

3.1.1 **Increasing demand for network surveillance**

The security market is growing fast and there is an increased demand for video surveillance. According to Axis the IHS Video Surveillance Intelligence Service estimates that the worldwide market for video surveillance is expected to grow 6% annually for the next 5 years and the market for *network* videos will expect an annual growth of 12% in the same period [3 p.12]. The US is a big market for Axis. According to Axis sales representatives for the North American region, the market for video surveillance is growing exponentially. The general perception on video surveillance is changing due to the increase of shooting episodes in places such as schools and concert venues. The market is now seeking full coverage video surveillance of all spaces to be able to locate both criminals as well as victims, to keep people safe.

3.1.2 **Internet of things**

Internet of things (IoT) is a word commonly used to describe how all digital devices will be connected to each other and able to communicate. The Compound Annual Growth Rate of the IoT market is expected to be at least 20% from 2015 to 2020, according to BCG [4]. The exponential technological growth creates an interesting future where the interaction between humans and technology will continue to evolve. IoT creates a demand for network connected devices and changes the behavior of people who will be able to control several devices through one device, instead of handling separate digital devices. The technology development opens up the market for smart homes and buildings that are managed by technology to improve everything from personal experiences to energy efficiency. What this means for a video surveillance company like Axis is that their network connected products will likely only become more popular in the years to come, which is in line with the previous presented trends. An additional effect from the increasing IoT market is that the demand for full service solutions will possibly increase. According to Axis sales representatives for the North American region, there is for instance an increased interest of possibilities for two-way communication through microphones and speakers integrated in the security camera systems. For Axis, development of integrated solutions or modular systems can be a way to meet this potential demand.

3.1.3 **Competitors**

Axis is a big player in the network video surveillance business. The biggest competition on the market is according to Axis the Chinese giant Hikvision which has an enormous product portfolio and are, like most Asian companies, a quick copycat of new technologies and product offerings. Hikvision is big in Asia but as for now, Axis has a stable market position in the western parts of the world.

3.1.4 **Increased demand for mobility**

3.1.4.1 Urbanization

All over the world countries are experiencing an exponentially increasing urbanization. People are moving from more rural areas and into the big cities. Half of the world's population lives in cities and according to the UNFPA by 2030, 5 billion people will be living in cities [5]. To house the growing population and businesses, new buildings are rising in high speed. The urbanization and growing number of densely populated cities sets a new demand for mobility and people flow, where elevators play an important role. The elevator and escalator market is expected to grow from USD 88,78 billion in 2015 to USD 125,22 billion by 2021 [6]. Building smart, energy efficient and resource efficient is crucial for a sustainable growth in the cities. Elevators will play an important part for efficiency and mobility in urbanized areas.

3.1.4.2 Aging society

Our society is aging, meaning people are getting older and older. According to the United Nations Department of Economics and Social Affairs by 2050 more than 20% of the population in the world will be over 60 years old and the population of older people is growing even faster in urban than rural areas [7]. An aging society will be a big social change for the world and societies need to adapt to the growing older population. This means for instance facilitate living at home for a longer time than before. Elevators will be essential to meet the need of this aging society.

3.1.5 **Possible market segments**

The demand for increased video surveillance covers a broad variety of businesses. Possible market segments for surveillance in elevators can cover everything from banking to residential buildings, hotels to public spaces. All of these areas normally house several elevators to provide mobility. Today many of these elevators remain a blind spot in otherwise highly monitored areas.

3.1.5.1 New installation and retrofit market

There are many more existing elevators on the market than new installations. Installing an elevator is a comprehensive performance, a big investment and takes at least 2 weeks to perform. Installation of completely new elevators are therefore mostly reserved for the new building segment of the market.

An elevator can last for decades if service and maintenance is performed on a regular basis. Because of the comprehensive and expensive installation process and the long lifetime of existing elevators, it is more common to perform modernization of elevators than to install new ones. In other words, there is a vast retrofit market for elevators that is by all means larger than the new installation market. It is therefore important to keep in mind that surveillance solutions should be adapted for both old and new elevators to cover the entire market.

3.1.6 **Legal aspects of surveillance in elevators**

Most countries have specific laws regarding video surveillance due to personal integrity of their citizens. These laws and regulation plays an important role for the market size of Axis products. The laws differ quite a lot within the EU countries as well as the US. According to Axis, Sweden is one of the countries in the world with the strictest video surveillance laws. It is very hard to get permission to install cameras in what is considered a public space while installing a camera in a private space is ok as long as the video surveillance is announced. According to Datainspektionen, permission for surveillance in public spaces should only be given when the interests for surveillance overrules individual's interest of not being surveilled [8]. In the US on the other hand, setting up cameras in public spaces are no problem while installing cameras in private spaces is much more regulated. Once you go out in public you are considered a public person that want to be seen and there is no need for announcing surveillance. The elevator is a special space that can be considered both private and public and the laws for video surveillance has to be taken into consideration when estimating the market opportunities.

3.2 The elevator environment

The market study of elevators covers all important background knowledge that was collected in order to understand the elevator environment and how video surveillance can be implemented. Important parts of this study are to identify power and connection possibilities, as well as standard designs for elevators and restrictions for installing devices inside and outside of the elevator car. Another important part of this study is to get an overview of the stakeholders in the elevator business. Information provided in the market study of elevators was gathered through research and interviews, both personal and through e-mail, with elevator manufacturers Kone, ThyssenKrupp, Otis and Schindler. E-mail interviews with elevator manufacturers ca be found in Appendix D.

3.2.1 **General mechanics of elevators**

The major elevator manufacturers that serve a big international market are Otis, ThyssenKrupp, Schindler and Kone [9 p.9]. Most elevators are electrically propelled, cables and sheaves are used together with a counterweight to hoist the elevator car.

Figure 3.1 below illustrates the different components of a cable elevator. The motor, normally placed on the top ceiling of the shaft, drives the pulleys and hoists the elevator. A control unit is placed next to the motor to which the travelling cable is connected. The travelling cable supplies the elevator car with power and information. [10] The elevator car and travelling cable are covered in detail in the subsequent chapters.

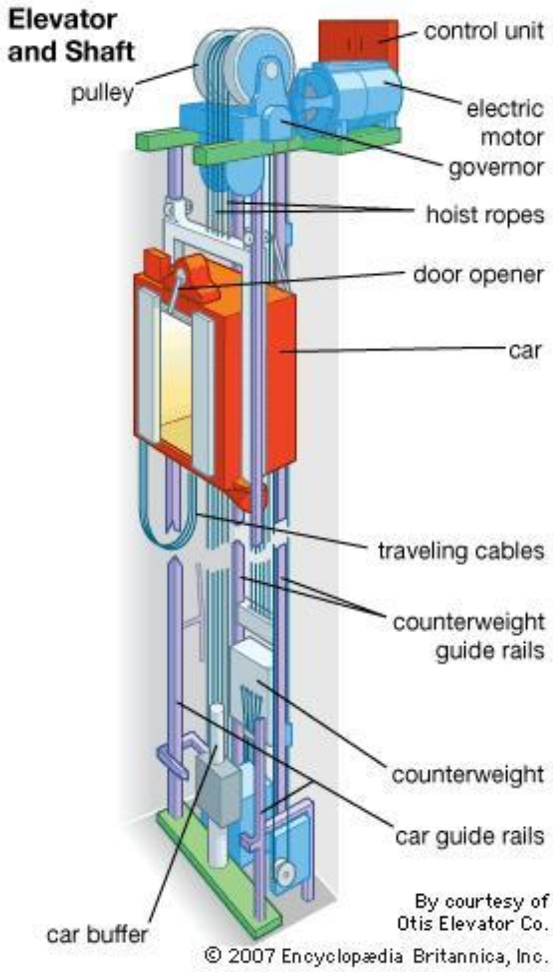


Figure 3.1 Diagram of components of cable elevator and shaft.

3.2.1.1 Elevator travelling cable

All cable elevators have a travelling cable that follows the car from bottom to top. The cable is either flat or round and consists of several wires. It is through these wires that power is supplied to the elevator car as well as information transmitted to and from the control unit. In other words, the travelling cable is the information link between the control unit and the car. In an elevator where the control unit is situated on the top of the shaft, the cables bend in a u-shape when the elevator is on the top level and unfolds as the car descends. All additional cables follow the same path as the travelling cable and has to be customized to withstand the bending movement when following the car up and down the shaft.

Wires from the travelling cable are used for operating the car, the car doors, lights, fans and other functions. See Figure 3.2. The dimension of the wires is what restricts the level of information that can be transmitted through them. The wires in the travelling cable are often 0.7-1 mm in diameter. There are fewer wires in the travelling cable of an old elevator than there are in new elevators. Therefore, there is a greater chance of having available wires to connect new accessories to in newer elevators where the travelling cable is equipped with a total of 20-30 wires.

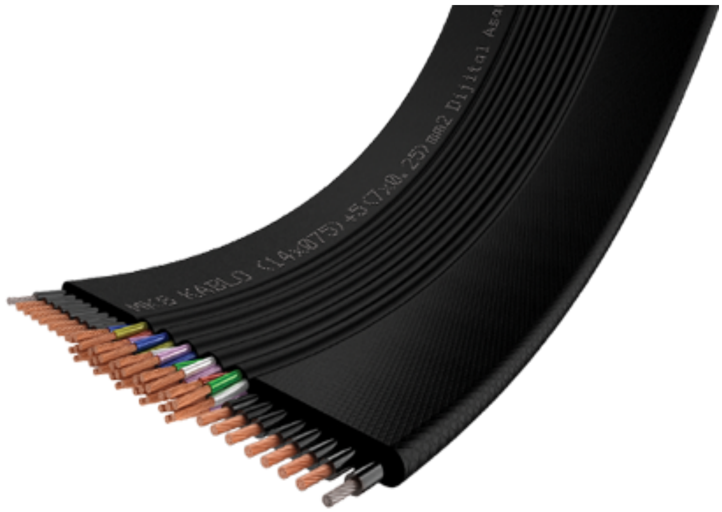


Figure 3.2 Illustration of the wires in the travelling cable. [11]

3.2.1.2 Elevator car

The car itself is constructed and installed by an elevator company. The interior design of the car can be provided by either the elevator company or by numerous interior design firms. There is no official standard design that must be followed when constructing an elevator car or when installing the interior of the car. As long as the consumer is willing to pay for it, elevators can be designed in any form and with any material desired.

However, there are some general things that can be assumed about the elevator car. For instance, walls are often built with steel, sheet metal or wood. The interior is often glued to the walls. The thickness of the walls varies depending on material. Steel walls or walls of sheet metal are a couple of millimeters thick and walls made of wood usually around 25 millimeters.

The ceiling inside the elevator car is often flat. The interior can be mounted directly onto the ceiling. However, it is also common to install an inner ceiling. In those cases, there is often a 50-70 mm gap between the ceiling and inner ceiling. There is no official standard or classification that must be followed for components placed in the gap. Lights are often installed in the inner ceiling; the gap is used to fit the housing and electronic wires. Drilling holes in the ceiling or walls in order to install a camera is allowed as long as it does not damage components or electrical wiring behind or above. Research conducted throughout the thesis shows that components can be placed so parts extend to the outside of the car wall or inner ceiling. However, they must not get in the way of moving parts in the shaft when the car is in operation.

3.2.1.3 Power connection in elevators

Elevators normally have a 230V power supply accessible on the elevator roof. For instance, it is used for lights in the elevator car or for power points on the outside of the car. All elevators are equipped with emergency lighting. If for some reason the power is cut of, the elevator will still be lit up.

3.2.2 **Operation, service and maintenance of elevators**

The elevator business has many stakeholders that participate in the operation, service and maintenance of the elevators. The elevator is a complicated machine where safety for the passengers is a key factor. The industry has developed into a complex business involving manufacturing, installation, design, maintenance and service of elevators.

For maintaining the safety standards and secure the elevators performance, inspections have to be made to control the elevator. In Sweden, all elevators should be inspected by a third party of certified inspectors for elevators. These inspections will detect whether the elevator needs maintenance or if components should be replaced; to maintain the required level of safety. The inspection must be performed once a year for the elevator to be certified for operation.

For most elevators there is a service contract established between the owner of the building and an elevator company. The service contract gives the company all rights to perform service and maintenance of the elevator and the elevator shaft within the period of the contract. Activities that requires the elevator to be stopped, like performing installations or electrical work on the outside of the elevator car or in the elevator shaft, the company holding the service contract has to be present to perform the stop and the start sequence of the elevator. To hold a contract, the company needs to be certified as elevator mechanics. The first years after a new installation of an elevator it is common that the elevator company providing and installing the elevator holds the service contract as well. When the contract expires any certified elevator service provider can take over the contract.

When performing activities and work inside the elevator car the rules are less strict than when operation outside the car in the elevator shaft, as long as these activities does not require the elevator to be stopped. Anyone can for instance perform minor renovations of the interior design of the car. Today there are numerous companies specializing in design and renovation of elevator cars. They do not necessarily have any connection to the elevator manufacturer or elevator company holding the service contract. In other words, installations that are possible to perform inside the elevator car without the need for stopping the elevator car is preferable from a cost perspective, as it requires less involved parties.

3.2.3 **Elevator interior design**

Since the design of the elevator depends on the consumer, not much can be said about the shape or size of the car. The shape of the car can be round, octagon, square or rectangular. The corner angles are therefore not always 90-degrees. Even if they are, it is common to round of the corners using some kind of strip or corner profile. If a strip is placed covering the corner where the side walls meet, the gap between the walls can be wider. This is done so that interior design firms and elevator manufacturers can have higher tolerances on their interior decoration. There are also numerous elevators with visible gaps in the corners between the sidewalls. Examples of different elevator designs are shown in Appendix C.

There can also be a gap between walls and the inner ceiling. Furthermore, the ceiling is often equipped with lights, these can either be spotlights distributed over the ceiling or an integrated light panel.

As previously stated, elevators are often custom made to fit the buyer's demands. Therefore, materials used for the ceiling or walls differ from one elevator to the next. Glass, metal or wood is often used when building the elevator as described in Section *3.2.1.2 Elevator car.* Building an elevator with glass walls is a common way of designing so that a passenger feels less trapped and safer in the company of other passengers. Since other people are able to see into the elevator it is also harder for vandals to get away undetected. However, cameras are generally not to be placed on glass walls for aesthetic purposes.

3.3 Market study of cameras in elevators

The market study of cameras in elevators focuses more specifically on video surveillance in elevators. The study seeks to understand why video surveillance is important in such an environment as well as exploring existing solutions for video surveillance. An important part of the study is analyzing possibilities for network connection in elevator cars, as this is crucial in order for the network cameras to work.

3.3.1 **Reasons for surveillance in elevators**

Based on information provided by employees at Axis, the reason for implementing a video surveillance system varies depending on what the purpose for surveillance is. A reason can be to facilitate in police investigations by being able to account for a sequence of events. Elevators has been viewed as a surveillance blind spot in buildings and a safe hiding place for criminals because of the lack of video coverage. It is common for criminal activity to also take place in the elevator due to the same reason.

However, the main reasons for installing surveillance cameras in elevators are to prevent vandalism and make people feel safe. Installing cameras in elevators can help prevent vandalism of the car as the fear of being identified and caught discourages vandals. In turn, this leads to a decrease in maintenance costs. An elevator is a small, confined space where many people can feel trapped and claustrophobic. There is no way of escaping if you are trapped in an elevator with people you feel unsafe around. Knowing there is a surveillance camera in the elevator can provide some comfort and feeling of safety. At the same time, a surveillance camera in such an environment can make people feel watched. Unfortunately, this negative aspect results in a high rate of vandalism of the camera itself.

Elevators are equipped with emergency buttons which establishes audio contact between passengers inside the elevator and the outside. According to sales engineers at Axis, video from a camera inside the elevator can be used as a tool in emergency situations in addition to the audio system. Furthermore, a camera with a view of the entire car can facilitate maintenance as it can detect the reason for why an elevator for instance is at a standstill or why it malfunctioned.

3.3.2 **Issues with video surveillance in elevators**

In the elevator environment, several factors need to be taken into account when implementing video surveillance. Vandalism of cameras in elevators is more frequent than in other spaces as cameras are installed within people’s reach, which normally can be avoided in other spaces.

A challenge due to the confined space is the field of view and potential trade-offs between eliminating blind spots and achieving facial recognition of passengers. For instance, a corner mount camera can miss the area directly beneath the camera. Whereas a dome placed in the center of the ceiling may remove all blind spots but mainly record the top of people's heads. If the license for video surveillance only covers the elevator car, the camera cannot be place so that the field of view covers the outside of the elevator when for instance the doors are open or the elevator car walls are made partly of glass. The small elevator space also poses as a challenge regarding perception of personal space. Is the elevator considered a private sphere where a camera can be intrusive? Furthermore, the mobile environment itself poses yet a challenge when it comes to connection opportunities, these are covered in Section *3.3.3.2 Common network connection solutions*.

3.3.3 **Benchmark of video camera solutions for elevators**

3.3.3.1 Common elevator camera solutions

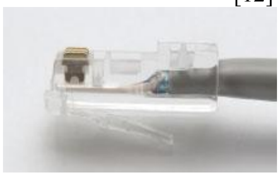
According to Axis sales engineers, analog cameras are commonly used as surveillance cameras in elevators today. In addition to analog cameras there are quite a few low price digital camera solutions used in elevators. These cameras only store video on a local memory card and does not require any network connection to the elevator car. Digital solutions like these are not able to provide a live feed of video and can only be used to see incidents that already occurred. The range of network cameras developed to fit in elevator environments are limited and the access to network connection adds an extra concern. Network connection solutions are covered in detail in the next chapter.

The most common camera housings specialized to fit in elevators are corner mounts; where the camera housing is shaped to fit in a corner where two walls and the ceiling meet. The most commonly used materials for camera housings in elevators seems to be stainless steel. For a more detailed benchmark of surveillance camera mounts for elevators, see Appendix B. Some companies specialize in providing camera housings customized for elevators, built to fit existing network cameras, like Wren Solutions, see second row in Table B.1. Elevator cameras are often quite discrete and the camera is safely placed inside a housing with not many protruding parts.

3.3.3.2 Common network connection solutions

In order to install a network camera in an elevator a network connection must be provided. The possibilities of network connection in an elevator depends on how old the elevator is and if the camera installation is performed together with the installation of the elevator or at a later stage. According to interviewed elevator technicians, elevators installed today can often come with a network cable, which is the most reliable solution for network connection. In new elevators, the cable is either included in the travelling cable or placed adjacent to it. If the elevator company does not have the network cable as a standard it is possible to include a cable when installing the elevator, for an insignificant extra cost. In other words, if the buyer of a new elevator desires network in the elevator the company providing the elevator will install a solution. However, few elevators are new installations and adding a network connection to an already existing elevator poses a greater challenge and cost. Different solutions for network connections are presented in Table 3.1 below.

Table 3.1 Examples of network connections in elevators

Type	*How it works*	*Example*
Network cable	Signals transmitted through a network cable type cat5, cat6 etc. The network cable has to be added to the elevator system either during installation of the elevator or afterwards. The cable needs to be able to withstand severe bending in the shaft. It is also important that the cable is shielded so that the signals are not disturbed by the high voltage electronics in the elevator shaft. The cost of this solution varies depending on when the cable is installed and the number of floors of the building. The picture to the right shows a network cable and a RJ45 connector.	 [12]  [13]
Wi-Fi	Signal transmitted wirelessly from the camera through Wi-Fi. A router can be placed near the camera or in the elevator shaft to improve the signal. The cost of the solution shown on the right is US$945 [14].	
Laser transmitter	Signals from the camera is transmitted through a laser. A transmitter is placed under the elevator car and connected to the camera. The receiver is placed at the bottom of the elevator shaft. The cost of a laser transmitter solution is US$650 [15].	 [16]
PoE over Coax	Signals are transmitted through Ethernet over Coax converters that allows network signals to be sent through a coaxial cable. This solution requires that a coaxial cable is already installed in the elevator. If an elevator already has an analogue camera this could be the case. One adapter is placed in the control unit and the other on the elevator car connecting the camera's network cable to the Coaxial cable. An estimated cost for two converters is around US$469.	 [17]

2 wire to PoE	Signal are transmitted through the travelling cable. One converter is placed on each end of the travelling cable where one serves as a “slave” and the other “master”. The converter has a transfer length to up to 220m. The converter requires two free wires in the travelling cable in order to make the connection. Any wire will do and they do not need to be shielded or twisted. [18] Cost of two converters are estimated to around US$370 [19].	

As previously stated, the most reliable solution for network connection is through a network cable since it is a direct connection to network. The signal does not need to be converted back and forth before reaching the control room which would be the case if another connection option was chosen. A network cable also provides the safest network signal. In existing elevators cables can be added to the shaft. Adding a network cable is rather easy for buildings with only 3-5 floors. The taller the building is, the harder and more expensive it will be to install. Even though this is the most efficient solution, there is a problematic with adding network cables to existing elevators. After talking to several camera installers this seems to be a very expensive solution because it is a rather time consuming and complicated activity that can only be performed with the involvement of the elevator company with the service contract, since turning the elevator off during installation is a necessity.

Wireless solutions eliminate the complicated process of adding cables. On the other hand, a wireless solution will not send as secure signals as a network cable because of disruptions to the signals. Axis do not provide wireless solutions to their cameras since this is not a secure enough solution. The Wi-Fi signals can be easily interrupted by the extensive amount of electronics inside the elevator shaft as well as by materials like steel and concrete which is difficult for the signal to pass through. It is also challenging to maintain a good Wi-Fi signal throughout the entire shaft.

The laser transmitter, where data is transmitted through a laser, also allows for wireless transmission of signals from the elevator car. However, the performance of the laser is weakened over time due to the challenging environment of the elevator shaft. Dust and dirt is accumulated in the shaft which can disrupt the signal.

The final network connection solutions presented are the Coax and 2 wire converters connecting to already existing cables. The converters transmit data and power over ethernet (PoE) from the control unit through the cable and onto the elevator car roof. These solutions require two converters. One placed in the control unit and one at the elevator roof. It is a relatively cheap solution compared to adding a network cable, as long as the required cables are already installed. A converter connected to the travelling cable requires two available wires in the cable. According to elevator technicians most elevators, except very old ones, have at least two free wires in the existing travelling cable. A converter connected to a coaxial cable can be used in the cases where a coaxial cable is installed in the shaft. Unlike a travelling cable, a coaxial cable is not a standard cable for any elevator. However, it might be previously installed in the elevator if analog cameras have been used. The transmitted signals can experience some disturbance and is not as good as a network cable.

3.3.3.3 Preferable network connections

The connection for network and power to the elevator car is, as previously presented, a complex challenge. The different solutions for network connection presented in the study vary a lot in quality, simplicity as well as in cost. A direct connection through a cable is by far the most reliable and secure way to connect network cameras. In new elevator installations, this is the best alternative for network connection.

A network cable is also a good option for buildings with relatively few floors. The time for installation is short and there are relatively cheap products on the market that is both shield and rotation proof. Shielded cables are resistant to electrical interference and rotation proofing is a requirement for cables in the elevator shaft. For high rising buildings, the 2N 2-wire converter could be a better solution as it provides a secure connection for up to 220 meters. The background study reveals that the only cabling that can be considered standard in an elevator is the travelling cable. The 2-wire converter is the only connection solution that offers a connection using only the existing cabling.

4 Stakeholder study

This chapter presents results from the user research. The user research was done through interviews and observations. Observations and assumptions regarding user behavior and vandalism are based on the teams own experience, conversations with elevator installers, Axis customers and employees as well as representatives from the faculty of engineering at LTH.

4.1 Installation of camera in elevator

A team from Axis, including the authors of this report, participated in the installation of an Axis camera in an elevator at Rådhuset subway station in Stockholm. The installation process was observed and documented, see Appendix G for pictures. Involved installers and elevator technicians were interviewed on site.

SL has an extensive surveillance camera system installed throughout their public transport system in Stockholm, including many elevators. According to Axis, SL is one of their biggest clients in the Northern European market. SL reports that out of all cameras installed in their elevators 60% are vandalized. Lighters, chap sticks and stickers are frequently used to obstruct the camera view or to destroy the dome.

The aim of the installation was to change an existing Axis camera, *AXIS M3014-R*, for a new one, *AXIS M3044-V*, due to security upgrades performed on metro stations in Stockholm. Participating in the installation process were two camera installers and one supervisor from a company selling and installing Axis surveillance cameras as well as one elevator technician from the company holding the service contract for the elevator.

The elevator technician was only there to operate the elevator which in this case involved stopping the elevator before the installation and starting it again after the installation was complete. The elevator technician had no other task to perform during the installation process. The camera installers performed all electrical work involving cables on top of the elevator car roof and the installation of the new camera inside the elevator car. The installation took about 1.5 hours, an additional hour was spent on connecting the installed camera to the network, in order to verify the cameras function and get pictures from the camera in order to optimize the focus and field of view. This is due to the fact that when the *AXIS M3044-V* camera is mounted in the corner of an elevator it is hard to access the RJ45 connection that is placed on the back of the camera. This is an extra RJ45 connection placed on the camera with the purpose of easy and direct connection for use during installations. When this is not accessible the installers have to find other ways of connecting to the camera or as a final solution take down the camera again to get access to the RJ45 connection at the back.

The network connection used in this installation was a converter solution, using wires from the travelling cable, previously installed by the camera installation company. As the elevator was quite old this was the cheapest solution. Installing a network cable would have amounted to about ten times the cost according to the camera installation company. Although, the converter solution is not ideal since the signal performance is not always as good as it would have been for a network cable.

The camera was installed in the ceiling, close to the inner left corner of the elevator facing the elevator doors. The installed camera has a horizontal field of view of 82°, a vertical field of view of 44° and it was installed in corridor format to optimize the view of the elevator car. A corridor format refers to a 90° rotation of an installed camera, the horizontal field of view then becomes the vertical and vice versa. This can be preferable in smaller spaces since the camera view then covers more of the space. The elevator car had a deep format with room for 13 persons. According to the camera installers as well as the representatives from SL, the corridor format was a suitable format for the elevator and provided a more than sufficient view of the elevator car. Both parties pointed out that a too wide field of view can become problematic, due to the restrictions of filming outside of areas with permission. For instance, through car walls made out of glass or through an open elevator door. Camera installers have been known to mask the field of view of the camera to avoid breaking rules. Furthermore, too much view of the walls could be distracting and make it more difficult to identify situations occurring in the elevator.

4.2 Elevator technicians

Elevator technicians from different companies were interviewed to get an understanding of their profession as well as to gain insights relevant to camera installation. Personal interviews were done with three different technicians; Kone, Axis, and SL. Three additional elevator technicians were interviewed through e-mail conversations, see Appendix D. Some of the answers were ambiguous, in those cases further investigation was made in order to completely understand the elevator environment, the result of this investigation and the interviews are presented below.

Elevator technicians are certified to operate elevators and normally work for the company that holds the service contract for the elevator. They are the ones who are allowed to operate the elevator car and are in charge of turning it on and off during installation. After interviewing elevator technicians several important findings of operations in elevators were discovered.

For third party devices installed in the elevator, there is plenty of room for placing components on top of the elevator roof. This is not considered a complicated procedure according to elevator technicians. Although, it is preferable that third party devices are installed on the outside of the elevator shaft, if possible. This way, the presence of an elevator technicians would not be necessary if the device need service, since there is no need to stop the elevator. An example is the Axis access relay for elevators where the I/O can be placed on the wall outside of the elevator shaft, the access relay is covered in detail in Section *6.6 Other Axis products related to elevators*. The access relay can then be accessed at all time.

If devices are to be installed inside the elevator car, the elevator technician can prepare the installation by pulling cables from the travelling cable or from other connected devices on the elevator roof to the inside of the car.

The elevator technicians and manufacturers were questioned about the potential usage of cameras outside the elevator car. Examples of cameras used in the elevator shaft for maintenance purposes were brought up for discussion. Examples included; cameras monitoring parts of the mechanics that usually requires service, other components of interest or cameras placed to detect faulty wires and cables without the physical presence of a person in the elevator shaft. However, this was of no interest to either technicians or manufacturers. Firstly, the shaft is dark and dusty. It would be hard to detect anything without the use of a camera with infrared light (IR). Adding IR to the camera for this purpose would be too costly. Secondly, the service contract of the elevator covers regular maintenance. Substituting these visits with the recordings from a surveillance camera could result in loss of money for the company with the contract, as the need for maintenance visits might become rarer. Furthermore, elevator accessories are not a profitable segment for elevator manufacturing companies, the use of third party accessories is therefore irrelevant to them. Therefore, video surveillance of the elevator shaft was not considered beneficial for either the elevator manufacturers, technicians or the buyers.

4.3 Camera installers

Camera installers are in charge of delivering the complete surveillance solution. They install cameras for customers in a variety of spaces, one being elevators. The installers usually have certifications allowing them to perform electrical work in elevators. However, they are not certified to operate elevator itself.

Three camera installers were interviewed during the installation of an Axis camera in an elevator at Råduset metro station in Stockholm. The three installers all have extensive experience in installing cameras in elevator environments. After observing the installation and interviewing the installers several important findings were discovered.

Camera installers are responsible for providing a connection to network if a solution is not already in place. In these cases, they choose to implement the most suitable solution based on price and performance. Furthermore, it is their responsibility to coordinate with the elevator technicians in order to carry out the installation. The camera installation itself often requires working outside the elevator car, for instance on top of the roof. This part of the installation must be performed in the presence of an elevator technician. Installation solutions that limits the downtime of the elevator or eliminates the need of an elevator technician is preferable, because it would save time and resources.

In elevators, cameras are often installed in the ceiling. The reason is twofold; most of the electronics are placed on the roof of the car and the ceiling is often flat. It is hard for camera installers to foresee what materials the ceiling consists of since this can vary from case to case. However, the ceiling in modern elevators is often made of steel plates. The process of installing a camera in the ceiling requires a somewhat awkward position for the installer. Therefore, it is preferable that the installation process is fast and unnecessary activities eliminated. Installations which requires drilling holes larger than 25 mm can be problematic in elevators made out of thick materials since it is both difficult and time consuming. It is rare to mounting cameras on the elevator walls. According to the interviewed camera installers this is partly because mounting the camera on the ceiling has become the business standard. However, it is possible as long as the walls are not made of glass or other materials that are difficult to handle.

4.4 Buyers

To identify the buyers' perspective of the camera installation process mostly secondary interviews, with personnel at Axis with great market experience were performed.

When installing cameras in elevators the one making the decision varies with each project. The owner of the building, the security manager or an architect can all be involved in the final decision. In order to design a product that sells, these are important stakeholders to take into account. The architects might have strict demands for design, security managers want devices that provide quality surveillance whilst for the owner of the building the cost is an important factor.

Architect designs the entire building down to the smallest detail. Everything is cautiously thought through and designed to communicate a certain expression. Architects do not want a surveillance camera to interfere with the rest of the interior of the building or elevator. A design with an aesthetic that complements the interior is of importance.

Security managers are in charge of the overall security. Their main job is to provide a secure environment. Their top priority is the quality and field of view of the surveillance. A robust design that can withstand vandalism is important for security managers as well as other features that gives high quality surveillance.

The building owners are responsible for the building and is the ones who has the final say in installations of surveillance in the buildings. They are the ones paying for the surveillance installations. Therefore, price is naturally an important factor, in addition to the quality of the video surveillance.

4.5 User behavior

To be able to develop a good design it is important to have knowledge of the human behavior and interaction in the specific environment, answering the question: How does a person usually behave when using an elevator?

When entering an elevator most people firstly look down to check that the gap between the floor and the elevator is not too big. Then they turn towards the control panel to push the floor button. The most common position to take after entering the elevator is to stand facing the doors. During the ride people tend to keep an eye on the passing floors displayed on a small screen either above the control panel or above the doors.

4.6 Vandalism

An important factor as to why cameras in elevators are vandalized, opposed to other cameras, is of course that they are placed within reach. The camera is an easy target that stands out from the rest of the elevator interior and can simply be a victim of boredom. Another reason is that vandals and criminals do not want to be watched. The elevator environment is a confined space, signalizing a resemblance to a private space rather than a public. Surveillance in such an area can be experienced as threatening and as an intrusion to one's personal space. The enclosed elevators space itself also facilitates vandalism because no one can see what is happening inside it.

According to SL, the most common ways of vandalizing surveillance cameras in elevators is either to use lighters to burn the dome or to put gum or chopstick on the dome to block the view. Larger domes placed in the middle of the elevator roof can be easily gripped by hands. They have therefore been known to be used as hoisting tool, where people grip the dome and lift their bodies up for fun.

To prevent vandalism, the design of the camera plays a key role. Designing it to communicate in a way that prevents both vandalism and negative feelings of being watched is preferred. This can be achieved through design solutions that interact with people in a positive way through screens, speakers and microphones or simply through the physical design of a camera housing.

5 Conclusion of background study

This chapter concludes the background study by highlighting important findings. It covers the complex elevator environment and insights regarding design for human interaction.

The results of the background study show a need for a good solution for network video surveillance in elevators. The demand for network video solutions is increasing. Elevators stands for a complicated part of the network video surveillance market, the complex environment requires thought through solutions that are optimized to fit both the retrofit and new installations market. It will be beneficial for Axis' portfolio to develop a custom solution for network video surveillance inside the elevator car. The study reveals that there is no use for video surveillance outside of the elevator car or in the elevator shaft. Several important findings for further concept development have been discovered throughout background study, these are concluded below.

5.1 Complex environment

The background study reveals that there is no standard interior design for elevators. Materials, design and size differ from elevator to elevator. It will therefore be important to design a flexible solution that can fit most elevator environment.

As discovered in the background study there are many stakeholders to keep in mind when operating in the elevator environment. This makes the installation process of a camera more complex than regular camera installation and can possibly become very costly. It is important that the complex environment of the elevator is taken into account in the concept development phase of the project, in order to deliver a cost-efficient solution that fits the elevator environment.

Furthermore, elevators are a challenging environment for supplying cost-efficient and quality network connection solutions. This has to be taken into consideration when developing a customized solution for this environment.

5.2 Design for human interaction

The background study reveals that there is a huge problem with vandalism in elevators. The cameras are often within reach, opposed to cameras in regular environments. A design that not only withstands vandalism but also prevents it is beneficial.

Elevators are often considered a somewhat private space for passengers. When integrating video surveillance solutions in such an environment there is a possibility of creating a feeling of intrusion on private space. There is a fine line between feeling watched and feeling safe. In further development, it is important to listen to customer needs and develop a good design based on human interaction.

PART II
Analysis and selection of camera technology

6 Axis portfolio of interest

This chapter accounts for the internal study of Axis' products relevant to the project. The chapter presents two modular camera systems and provides information about products that are developed for environments similar that of elevators.

6.1 AXIS F network camera series

The F series is part of Axis modular camera range. It enables up to four sensor units to be connected to one main unit, with a single IP address.

The F series consists of sensor units and a main unit, as shown previously in Figure 1.1 and again in Figure 6.1 below to provide context. The modular camera system is designed for discrete video and audio surveillance and can be installed in tight spaces. The main unit is equipped with either one or four channels allowing for up to four sensor units to be connected via cables. The sensor units, or camera heads, consists of lens and image sensor.

By separating the camera lens, sensor unit, from the processor, main unit, the sensor units can be made very small which allows for easy and discrete installation of surveillance cameras in areas such as retail or ATMs.

Figure 6.1 The components of the Axis F series.

In addition to the traditional F series sensor units, other devices such as speakers or screens can be connected to the main unit, allowing speakers and screens to be connected to network and controlled from one location. The big variety in devices that are compatible with the F series main units gives a wide range of opportunities and allows for custom solutions. [20]

6.1.1 **Main units**

Axis offers three types of main units. *AXIS F34* with 4-channel connection, *AXIS F41* with 1-channel connection and *AXIS F44 Dual Audio Input* with 4-channel connection. To these main units nine different types of sensors units can be connected. The main units are supplied with powered by a network cable connected to the PoE outlet. The different main units are presented in Figure 6.2 below.

Figure 6.2 The main units in the F series. Order from left to right: AXIS F34, AXIS F41 and AXIS Dual Audio Input.

6.1.2 **Sensor units**

Properties of sensor units differ and the choice of which ones are most suited is therefore dependent on the situation. Five of the F series sensor units are deemed suitable for an elevator environment, these are presented in Table 6.1 below. Units are attached to a pre-mounted cable of 3 or 12 m [21]. The minimum bend radius of the cables are 18mm [22]. A name of a camera ending with -E means that the camera is approved for outdoor use. The length of the sensor units are around that of 6 cm.

Table 6.1 The different sensor units in the Axis F series.

Sensor unit	*Lens*	*Horizontal angle of view*	*Vertical angle of view*	*Comment*
AXIS F1005-E 	Standard	113° in 1080p	62° in 1080p	
AXIS F1015 	Varifocal	52°-105° in 1080p	30°-57° in 1080p	The lens allows an operator to zoom in on the video without losing focus.
AXIS F1025 	Pinhole	92° in 1080p	45° in 1080p	The sensor unit can easily be hidden or integrated in a panel. Used in ATMs.
AXIS F1035-E 	Fisheye	194° in 1080p	113° in 1080p	Known for its large video coverage with a somewhat distorted picture.
AXIS F4005-E 	Standard	110° in 1080p	62° in 1080p	A dome with a built in standard lens.

6.2 AXIS FA network camera series

The FA series can be considered as the next generation F series. Like the F series it is a modular camera series with a main unit and several sensor unit alternatives ranging from standard and, varifocal to pinhole lens. See Figure 6.3. Other than improved sensor units, the main difference from the F series is how the cables are attached to the sensor units. Whereas the sensor units in the F series have a pre-mounted cable that connects to the main unit, the cables in the FA series are not mounted on the sensor units. The unit attaches to the cable via a USB-outlet which in turn connects to the main unit. [23]

Figure 6.3 Components of the Axis FA series.

6.2.1 **Main unit**

The 4-channel *AXIS FA54 main unit* could be seen as an updated and more powerful version of the F series main units and is able to support HDMI. Power is not supplied via PoE but though a separate power cable.

6.2.2 **Sensor units**

There are three sensor units compatible to the FA54 main unit, these are presented in Table 6.2 below. Cables connecting the sensor unit to the main unit are 8 m long and can withstand bending up to a minimum radius of 18mm [24].

Table 6.2 The different sensor units of the Axis FA series.

Sensor unit	*Lens*	*Horizontal angle of view*	*Vertical angle of view*	*Comment*
AXIS FA1105 	Standard	111° in 1080p	62° in 1080p	
AXIS FA4115 	Varifocal	53°-99° in 1080p	30°-53° in 1080p	A dome with a built in varifocal lens, allowing an operator to zoom in on the video without losing focus.
AXIS FA1125 	Pinhole	91° in 1080p	45° in 1080p	The sensor unit can easily be hidden or integrated in a panel.

6.3 AXIS P39 network camera series

The P39 series and the F series, which are installed aboard busses and in other public transport, stores the surveillance video on a SD-card on a main unit [25]. The video can then be requested by the surveillance system and sent via a Wi-Fi dock when the bus passes an area where the Wi-Fi signal is strong enough. The P39 series is presented in Figure 6.4.

Figure 6.4 Network cameras in the Axis P39 series. Order from left to right: AXIS P3904-R, AXIS P3905-R, AXIS P3905-RE and AXIS P3915-R.

6.4 AXIS M30 network camera series

Cameras from the Axis M-series are installed in elevators in the subway system in Stockholm. Previously it was the *AXIS M3014-E*, it is now replaced with the *AXIS M3044-V*. See Figure 6.5. A camera name ending with -V means that the camera is vandal resistant. A main prioritized feature when choosing suitable cameras for these elevators was vandal resistance. The network camera in the subway elevator is a dome camera and is placed in the elevator ceiling, near a corner and connected to network via the travelling cable through a 2-wire converter solution with one data/PoE converter placed on the elevator roof and one in the control room. There is also an ongoing project at Axis for the M30 camera series where they are looking into developing a solution adapted for elevators.

Figure 6.5 The AXIS M3044-V network camera. [26]

6.5 AXIS Q8414-LVS network camera

The *AXIS Q8414-LVS* is a camera designed for prison environments, where the letters L and S stand for LED illumination and Stainless steel. The camera is big and extremely robust. [27] The material of the housing is stainless steel and the mount is designed to be securely placed in a corner, similar to the existing elevator camera solutions presented in section *3.3.3.1 Common Elevator Camera Solutions.* However, the size of the *Q8414* is not suitable for a small elevator environment. Figure 6.6 shows the *AXIS Q8414-LVS.*

Figure 6.6 The AXIS Q4814-LVS network camera.

6.6 Other Axis products related to elevators

6.6.1 **Access relay**

There are not only network cameras in Axis' portfolio but also a variety of access control devices. One of these devices is a solution developed for elevators that can control people's access to certain floors [29]. The device consists of a relay that is placed behind the floor control panel in the elevator car and a I/O device placed in the control room at the top of the shaft. What the device does is allow or deny access to floors by the use of the input/output signal. Because the I/O could be placed in the control room and not in the elevator there is no need for network connection to the elevator car.

7 Preferable camera series

In this chapter, the ideal camera series for further development is discussed based on the findings from the background study.

In order to achieve the thesis goal of designing a mechanical interaction of a camera in an elevator environment, one camera has to be selected for further development of a product solution. Before selecting one camera a camera series has to be selected for further testing. As presented earlier, the modular Axis F series was initially chosen as the primary focus for the project. Although, the internal study reveals additional Axis camera series that could be suitable for an elevator solution. In this chapter, the preferable camera series is established. The decision is made partially based on findings from the background study but also through dialogue with Axis, to fit their current and future projects.

The Axis F series is a modular series that can provide a variety of custom made solutions for customers. Because of the big variety in elevator design, as well as many custom elevator solutions a modular camera series can be beneficial. The ability to connect several sensor units to the same main unit opens up from possibilities of quality surveillance in all types of elevators no matter shape or size. Even speakers, microphones and screens can be connected to the same main unit which will open up from the possibility for providing a full surveillance- and communication solution for elevators. In addition to the F series the background study presents the next generation modular series, the FA series. Both the F and FA series are interesting camera systems to examine further.

Furthermore, the cameras in the F and FA series are relatively small and discrete which is a great advantage in small elevator spaces. The background study states the importance of a good design adapted for human interaction. The small size and modular solution will allow for both a flexible and a discrete design. The possibility of completely hidden surveillance in the modular F- and FA series is also interesting for the elevator environment and its' challenges.

Due to the extensive problems of vandalism in elevators it is beneficial that the modular series allows for change of only the sensor unit if the camera becomes a victim of vandalism. This results in easier and cheaper replacements of cameras.

As for the disadvantage with the modular camera series, some features are not ideal for the elevator environment and has to be taken into consideration. The main unit box of the modular camera series has to be placed somewhere inside or outside of the elevator car. If the elevator has an inner ceiling the main unit can be placed there, if the design enables it to. However, the safest solution is placing the main unit on top of the elevator car. This means that an elevator technician has to be involved in the installation. On the other hand, any camera installation would require network and power connection from the elevator roof. This would also require the elevator to be stopped by an elevator technician. The main unit would, in case it is placed on the elevator car roof, most likely have to be protected against dust. For instance, it could be place in a dust- and waterproof box, see Figure G.1 in appendix G. This could be considered as extra work for the installer. However, according to camera installers interviewed during the user research the placement and protection of this box is an insignificant part of the installation process as it only accounts for a small part of it.

The results of the background study indicate that a modular camera series is a good option for an elevator environment, despite some challenges with placement of the main unit. A modular camera series can provide a flexible solution with a discrete design adaptable for a variety of elevator designs. Both the F and the FA series are relevant options for further development and testing.

8 Testing of Camera Sensor Units

In this chapter, the different camera sensor units in the chosen F and FA series are tested in order to determine which would be ideal to use in an elevator. The sensor unit chosen for further development is selected based on the test results.

8.1 Background

The Axis F and FA series have, as described earlier in Table 6.1 and Table 6.2, several different sensor units. The difference between the sensor units are that the different models have different optical field of view as well as design, functionalities and accessories for mounting. Before going into the concept development phase, the ideal use of sensor units needs to be identified. The testing is conducted by test filming with the different sensor units in an elevator and an analysis of the taken pictures. All pictures from the testing can be found in Appendix E.

8.2 Method

Sensor units from the F and FA series were tested in an elevator to identify both the field of view as well as ideal placement. The available FA series sensor units all have an equivalent sensor unit from the F series that has the exact same angle of view[1]. Therefore, the test was only performed with the sensor units from the F series as they were accessible during the test period. The assessed sensor units and their angle of view are presented in Table 8.1 below.

Different sensor units were combined to get the optimal field of view based on results from the background study. The test was carried out in two steps to get

[1] The field of view stated in the specifications of the sensor units at Axis' website differ some +/-5 from one series to another because of factors like different test parameters internally. In theory they are the exact same.

qualitative results. The sensor units were tested in an elevator at Axis to simulate what an actual camera installation would record. The elevator is an Otis Gen2, the car can hold 13 people or a maximum weight of 1000kg. It has a depth, width and height of 210 cm, 110 cm and 220 cm. Pictures were captured from various positions for later comparison and evaluation of the different sensor units and their placement.

Table 8.1 The specifications of the different sensor units.

Camera	*Lens*	*Horizontal angle of view*	*Vertical angle of view*
AXIS F1005-E ***AXIS FA1105***	Standard	113°	62°
AXIS F1015 ***AXIS FA4115***	Varifocal	52°-105°	30°-57°
AXIS F1025 ***AXIS FA1125***	Pinhole	92°	45°
AXIS 1035-E	Fisheye	194°	113°
AXIS F4005-E	Standard	110°	62°

The purpose of the first test was to establish which of the presented sensor units from the F and FA series were suitable in an elevator environment. The test was performed based on two predetermined criteria: how well the camera is suited for facial recognition and how well the picture covers the entire car. Cameras were held up at different heights, from different positions and in different angles inside the elevator to investigate suitability of the sensor units.

The second test was a systematic testing of sensor units and their positions to get comparable results for establishing the ideal use of the sensor units. All sensor units were placed on the same predetermined positions shown in Figure 8.1 to facilitate the process of comparison. These positions were decided based on the result of the first test as well as Section *4.5 User behavior* All cameras except for *AXIS F1025* and *FA1125*, the pinhole lenses, were held at ceiling height. Pictures from the pinhole camera were taken from a lower height based on discoveries from the first test.

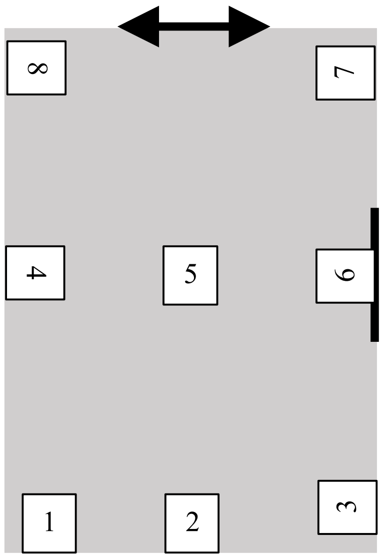


Figure 8.1 Illustrates the positioning of the cameras in the test. The arrow at the top represents the elevator door and the black line on the right the control panel.

8.3 Results after testing of camera sensor units

8.3.1 **Test 1 – Suitable sensor units**

The sensor units were tested and evaluated according to the criteria; possible facial recognition and possible field of view of entire car. The results are presented in Table 8.2 below.

The main findings from the first test was that the regular camera format of 16:9 gives pretty poor field of view of the elevator. Although if the camera is rotated 90 degrees, filming in what is called a corridor format instead of landscape format, the picture covers more or less the entire elevator car. In theory, the 90 degrees' rotation means that for instance the *AXIS FA1105* sensor unit now gets a horizontal angle of view of 62° and vertical angle of view of 110°. This view would cover most of the car in all similar, deep elevators. Pictures from the test can be found in Table E.1 in Appendix E.

In order to achieve both ideal field of view as well as quality facial recognition two sensor units are needed. The most suitable lens for facial recognition is *AXIS F1025/FA1125* Pinhole, if placed at a lower height and hidden in for instance the control panel. All sensor units are deemed suitable for further testing, in order to find the ideal sensor unit for complete overview of the car.

Table 8.2 Results of Test 1.

Camera	*Lens*	*Possible facial recognition*	*Possible field of view of entire car*
AXIS F4005-E	Standard (in dome housing)	Partly	Yes
AXIS 1035-E	Fisheye	No	Yes
AXIS F1025 ***AXIS FA1125***	Pinhole	Yes	No
AXIS F1015 ***AXIS FA4115***	Varifocal	Partly	Partly
AXIS F1005-E ***AXIS FA1105***	Standard	Partly	Yes

8.3.2 **Test 2 – Ideal use of sensor units**

All sensor units were tested on the predetermined positions shown earlier in Figure 8.1. Based on findings from the first test all sensor units, except the Pinhole, were tested using a corridor format as described above.

The results from the second test proves that sensor units placed on the short side of the elevator gives by far the best field of view. Cameras placed on the same side as the door looking in towards the elevator, position 7 and 8 in Figure 8.1, gave a brighter picture. This is because the doors were kept open during the test which provides a much better light. Elevators are in general sparsely illuminated. Positioning a camera in position 1, 2 or 3 shown in Figure 8.1 gives a poorer quality to the image when doors are open because of the backlight. Position 7 or 8 are also superior to 1, 2 and 3 in the regard of video surveillance permit. The permit does not always cover the space outside the elevator and cameras must not be placed so that they record anything outside the car if the permit does not allow it. Pictures from the second test are shown in Table E.2 in Appendix E.

Since the first test proved that Pinhole was not suitable as an ideal overview camera but far superior when it comes to facial recognition, as it can be placed hidden at a lower height, pictures with the Pinhole lens have been taken from a lower position and in landscape format and are therefore not comparable to other sensor units.

8.4 Conclusion and selection of camera sensor units

After testing the sensor units, it soon became clear that the Pinhole lenses would not be able to provide a satisfying overview picture of the elevator. However, a Pinhole could be a great compliment to another sensor unit to provide facial recognition. A Pinhole sensor unit can easily be placed in the control panel which almost every passenger will face when pushing the button for their desired floor. Both the *AXIS F1025* and the *AXIS FA1125* Pinhole sensor units have suitable accessories for mounting in an elevator. The pinhole will therefore not be taken into consideration when selecting a sensor unit for further development of mechanical interaction in an elevator.

The *AXIS F1035-E* fisheye lens was considered an interesting candidate before going into the testing because of its great field of view. However, the testing revealed that the fisheye lens does not provide a good enough picture since big parts of the picture frame consists of walls. This is, as earlier discussed in Section *3.4 User research*, not ideal for an elevator. In addition to this it is hard to identify persons by using the fisheye lens. The varifocal lens, which gives the opportunity for zooming, is according to Axis normally a popular choice. However, in this case the varifocal lens loses a lot of view of the elevator car because of its limited angle of view, in comparison to the standard lens. An elevator is also a small space where the zoom function would not be very useful. Based on these insights the *AXIS F1015* and *AXIS FA4115* are not relevant for further development.

The *AXIS F1005-E, AXIS FA1105* and *AXIS F4005-E* all have the standard type lens which after testing is considered the most suitable lens for use in an elevator. The *F4005-E* is a dome solution whilst the two other sensor units are individual sensor units with customizable mounting solutions. The dome solution of the *F4005-E* is not adapted to the elevator environment and is therefore not an ideal solution for this project.

In regards of the difference between the F and the FA camera series the FA series is newer, smaller and provides better quality pictures than the F series. The FA series also has a removable network connection cable that makes it more flexible and easier to install in an elevator environment. There is also a risk that the FA series will cannibalize on the older F series and it is therefore not considered sustainable to continue with a solution for the F series sensor unit.

Based on the results from the testing and conclusions drawn, the FA series standard sensor unit *AXIS FA1105* is selected for further development. There are no suitable mounting solutions for this sensor unit as of today. A mounting solution developed to fit the elevator environment is therefore desirable and will expand Axis product portfolio in the modular FA series.

When looking into developing a mounting solution for the *AXIS FA1105,* some initial limitations must be considered. The testing of the unit showed that in order to get the desired field of view of the car, it must be possible to angle the sensor unit. This rules out a hidden solution. Mainly because the camera lens must be in a 90° angle to the protective screen in front of it in order to get a good quality video. If this was not the case, the camera could have been integrated in the ceiling or wall and hidden behind a glass screen. Placing it for instance behind a vertical glass screen, prevents if for being angled. Therefore, when going forward different ways of building a visible housing for the sensor unit is be investigated further.

PART III
Concept development

9 Mission statement

This chapter includes the mission statement, which is a clarification of the task and the input in the concept development phase. The model of the mission statement used comes from Ulrich and Eppinger. The statement includes project constraints, primary and secondary market, business goals and key assumptions.

9.1 Product description

The product that is to be developed is based on the selected modular FA camera series presented in Section *6.2 AXIS FA network camera series* and will be a housing for the *FA1105* sensor unit. The housing will be adapted to fit the elevator environment. The product will be a part of a modular solution where customers can choose products according to their needs.

9.2 Benefit proposition

The product will be beneficial because it will provide additional usability for the FA series adapted for an elevator environment. According to the benchmarking done in the background study there is a need for products adapted for elevators that carry an attractive design as well as ensures the quality surveillance of an Axis video surveillance camera.

Using the FA series Axis will be able to provide a modular solution where cameras, microphones, speakers and screens can be integrated into one system. These are all relevant technologies to integrate in an elevator and will all contribute to a better customer experience in the elevator environment. With the modular system customers will be provided with more flexibility and adaptable solutions to fit their needs. The possibilities of connecting several cameras to the same main unit will give unlimited possibilities for surveillance in elevators that can be adopted to fit all sizes and designs of elevators and meet the customer needs.

9.3 Key business goals

The business goals for the product is to expand Axis portfolio to cover surveillance solutions adopted for elevator environments. The proposed product is a versatile product that can be fit to use in other environments than the elevator as well. This will benefit the sales for the FA series because of the expanded product line and meet market needs.

9.4 Target markets

The target market for the product are mainly office building, banks, hotels and other commercial buildings with high demand for surveillance in combination with service. The product aims to fit both the retrofit and the new installation market of elevators.

9.5 Stakeholders

The stakeholders taken into account in the project are camera installers, elevator companies and technicians, owners of building where surveillance is wanted as well as the people being surveilled in the elevator environment.

9.6 Assumptions and constraints

In order to focus completely on the mechanical interaction of a camera in an elevator, certain assumptions need to be made. The background study reveals the complexity of choosing the right network connection for the elevator. Information on the different solutions are presented in Section *3.3.3.2 Common network connection solutions* but in further development network connection is assumed to be available. Furthermore, the placement of the main unit *AXIS FA54* box is beyond the scope for the thesis. It is therefore assumed that the main unit can be placed securely either on top of the elevator roof or on top of an inner ceiling in the elevator car. It is also assumed that required power for the main unit is available on the elevator roof.

10 Customer needs

In this chapter customer needs are identified based on findings from the user research presented in the background study.

10.1 Background

To design a successful product, it is important to identify customer needs in order to meet the market. In this project, the customers taken into account are both the buyers of the camera solution as well as camera installers and elevator technicians.

10.2 Method

The first part of identifying customer needs is to gather raw data from customers. As described in Chapter *4 Stakeholder study* customer needs were collected through both shorter and longer interviews with elevator technicians and camera installers as well as observations of an installation process. Interviews with Axis personnel with a good overview of the market such as product specialists and sales representatives were also done. The gathered customer statements were organized and interpreted into customer needs. Finally, the identified needs were prioritized.

10.3 Identified customer needs

The result from the identification of customer needs are presented in Table 10.1. All identified needs are based on customer statements that are interpreted into a specific need. Some customer statements cover the same need.

The identified customer needs can be divided into three subcategories; Field of View, Design and Installation. The field of view are needs regarding what the camera sees in the elevator which also relates to what purpose the pictures from the surveillance camera serves. Design covers aspects related directly to the mechanical design of the product. Installation are needs related to the installation process. These needs are directly correlated to design and are therefore important factors to take into consideration. The installation process is also very important in means of total costs and is a high priority focus for all Axis products.

Table 10.1 Customer statements and interpreted needs.

Customer statement	***Interpreted need***
Field of view	
The video should be able to identify criminals to help with police investigation	Field of view allows for facial recognition
We want to use videos to establish sequence of events in the elevator	Field of view covers the entire elevator car
It would be nice to see if there actually is an emergency when the emergency button is pressed	Field of view covers the entire elevator car
If the doors are not closing properly, we want to see why and if there is need for us to come fix it or not	Field of view covers the elevator doors
The camera should only cover the elevator space. Too much view outside of the elevator will be problematic due to permission restrictions for surveillance cameras in Sweden	Field of view only covers the elevator car
Too wide field of view that covers a lot of the walls, like a fish eye, is not ideal because it would be problematic if the walls were made of glass and it does not provide a good view of people's faces.	Field of view allows for facial recognition Field of view only covers the elevator car
Design	
A hidden camera is a good idea since it is harder to vandalize.	The design withstand vandalism
We want a visible camera so that people know they are being watched	The design is visible
We want cameras so that people can feel safe	The design is visible The design communicates safety
60% of the cameras in elevators in the subway system in Stockholm are vandalized	The design withstand vandalism
We don’t want our customers to feel as they are being watched	The design is discrete The design communicates safety
Elevators often have a corner strip due to large tolerances and different elevator design	The design is independent of different types of corners in the elevator car
Today it is common to have false ceilings that doesn’t align with the wall	The design is independent of different types of corners in the elevator car

Installation

Repairs and installations can only be done during the night when there are no users of the elevator	The installation process is cost efficient and simple The installation process requires minimal downtime
We need to coordinate the installation of a camera with the elevator technician in order to limit the downtime of the elevator	The installation process requires no interference with elevator technicians The installation process requires minimal downtime
The installation must be cheap, we pay for the camera and don't want additional costs	The installation process is cost efficient and simple
When a camera is vandalized or needs to be replaced we want the change to be quick and cheap	The design is modular The design allows for certain parts to be replaced separately The installation process is cost efficient and simple
The ideal installation would require no involvement of an elevator technician	The installation process requires no interference with elevator technicians

10.4 Prioritized customer needs

The interpreted customer needs were prioritized and relative importance was set for each need. The primary needs are presented as the bolded needs in Table 10.2. These needs were selected as most important based on a general understanding and interpretations from interviews and observations. The secondary needs were graded according to their importance, also based on the general interpretations from the interviews and observations. Three stars indicates a critical important need, as the rated number of stars decrease so does the importance of the need. The exclamation mark (!) indicates a latent need.

Table 10.2 Prioritized customer needs.

No.	*Need*	*Importance*
	Field of view	
	Field of view covers the entire elevator car	
1	Field of view allows for facial recognition[a]	***
2	Field of view covers the elevator doors	**
3	Field of view only covers the elevator car	
	Design	
	The design fits the interior design of the elevator	
4	The design is customizable	*
5	The design is independent of different types of corners in the elevator car	***
	The design withstand vandalism	
6	The design is visible	***
7	The design communicates safety	**!
8	The design is discrete	**
	Installation	
	The installation process is cost efficient and simple	
9	The design is modular	**!
10	The design allows for certain parts to be replaced separately	***
	The installation process requires minimal downtime	
11	The installation process requires no interference with elevator technicians	*

a) As stated before in Part II, Analysis and selection of camera technology, the best way to achieve facial recognition is by the use of a Pinhole lens. This need will therefore not be considered when establishing specifications.

10.5 Reflections on establishing customer needs

After many interviews, observations and discussions with customers as well as Axis employees in close contact with the market the team saw that many of the customer needs were similar to each other. The three identified areas Field of view, Design and Installations together covers the entire elevator environment as well as the different stakeholders in a camera installation in an elevator. The identified customer needs are useful for the following concept generation and selection in order to design a product that will meet the market and customer needs.

11 Establish specifications

In this chapter, initial specifications for the product is presented.

11.1 Background

Before entering the concept generation phase, product specifications are established. The product specifications are a concretization of the customer needs that ease the development and evaluation of the design and functions of the product-to-be. Specifications can be measurable units, binary or subjective.

11.2 Method

The specifications are based on the customer needs, Axis standards and classifications for components in elevator environments. Each specification is linked to at least one customer need, shown in the second column of Table 11.2 below. Furthermore, the specifications are ranked by level of importance, explanations of the levels are shown in Table 11.1 below. The marginal and ideal values are defined based on similar projects at Axis as well as through benchmarking of related products.

As the background study revealed little indications for specifications in elevator environment, and the common response was that there are no general specifications that has to be met in an elevator environment, the team chose to decide what was suitable in close conversation with Axis to meet their standard specifications for camera solutions. Some specifications were hard to measure and therefore set as subjective as the team wanted to include them.

Table 11.1 The interpretation of levels of importance.

Level	*Meaning*
1	Not desirable
2	Insignificant
3	Desirable
4	Significant
5	Essential

11.3 Product Specifications

Table 11.2 The product specifications.

No.	*Need No.*	*Specification*	*Importance*	*Unit*	*Marginal value*	*Ideal value*
1	*1, 4, 13*	Compatible with FA1105 sensor unit	5	binary	Yes	Yes
2	*1, 3, 4, 7, 9, 10*	Possible to mount on ceiling	5	binary	Yes	Yes
3	*1, 3, 4, 7, 9, 10*	Possible to mount on wall	5	binary	No	Yes
4	*1, 3, 4, 7, 9, 15*	Possible to mount on various materials	5	binary	Yes	Yes
5	*1, 3, 4, 7, 9, 15*	Possible to mount on variable thickness of wall/ceiling	5	binary	Yes	Yes
6	*8, 12, 13, 14, 15*	Easy to replace parts if vandalized	4	subj[a]	-	-
7	*12*	Intuitive design	4	subj	-	-
8	*5, 6, 11*	Design to fit most elevator interiors	5	subj	-	-
9	*5, 6, 11, 13, 14*	Adjustable design finish options	4	binary	Yes	Yes
10	*1, 3, 4*	Field of view of elevator car	5	%	<80	100
11	*1, 3, 4, 15*	Adjustable view	5	Axis rotation	x, z	x, y, z
12	*8*	Impact resistance	4	IK[b]	08	10
13	*8*	Resistance from dust and splash of water	4	IP[b]	-	54[c]
14	*12, 15, 16*	Installation possible from within the elevator car	3	binary	No	Yes
15	*12, 15*	Tools required for installation	3	nb	1	0

a) It is to early to quantify this specification in terms of time or other unit.
b) Explanation of the IP and IK Units can be found in Appendix F.
c) Normally there are no requirements for IP.

11.4 Reflections on establishment of specifications

As there was no specific specification for the elevator environment the team had to decide what specifications could be useful for the concept. Many of the specifications are binary or subjective making the specifications not as specific as they usually are for products like a camera housing. Although the concept development is at an early stage where a vague description of specification could be an advantage in order to not limit the concept generation too much.

At this stage in the product development process it was very hard to decide specific values for many the specifications and therefor values such as the IP value has very large margins.

12 Concept generation

In this chapter concept ideas are generated based on the previously identified customer needs.

12.1 Background

In the previous chapters, customer needs and specifications are established. In the concept generation phase solutions for these previously identified needs are generated. The purpose of this phase is to generate as many ideas as possible through methods like problem decomposition, brainstorming and concept combination.

12.2 Method

The concept development phase was divided into four steps. The first step was clarifying the problem to get an understanding of customer needs and identify whether the concept should be divided into sub problems or not. The second and third step was search externally and internally, see Section *2.3.2.5 Generate product concepts*. The external research was done through the previously presented benchmarking, see Section *3.3.3 Benchmark of video camera solutions for elevators* and Appendix B. The internal search was the main focus of the concept generation, where both individual and group exercises were performed. Methods used were brainstorming and related stimuli. After the concept ideas were established the team selected the best ones and then combined the ideas.

12.3 Problem decomposition

The customer needs established in Chapter 10 indicates that field of view, design and installation are three main concerns for customers. When dividing the concept into sub problems the team discovered that it was preferable to explore the functionalities for adjustable field of view before design and installation would be taken into consideration. The functionalities *inside* the design, needs to be established before exploring design options and the concept has to be specified before installation possibilities can be developed.

In order to get the optimal field of view during installation, adjustable to fit all different shapes and sizes of elevators the sensor units' position needs to be adjustable. The team therefore chose to initially divide the solutions into two separate sub concepts with focus on solutions for adjustable field of view.

The first sub concept explored the possibilities of rotation with a single sensor unit whereas the second sub concept explored possibilities of combining two or more sensor units into one camera housing.

12.4 Idea generation

12.4.1 **Sub concept 1: Rotation of single sensor unit**

Ideas for the rotation of a single sensor unit was explored both internally and externally.

12.4.1.1 Internal exploration

Axis offer single sensor unit solutions for similar product such as the *AXIS F4005* and *AXIS FA4115*. An overview of these solutions can be seen in Table 12.1. However, none of these solutions are compatible with the chosen *FA1105* sensor unit. The *FA4115* is a solution using the varifocal sensor unit from the FA series. This solution is not vandal proof at all and will not work in an elevator environment. Additionally, the Analysis and selection of camera technology concludes that the Varifocal lens is not well fit for an elevator environment. The *F4005* dome solution has better vandal proofing but the installation requires making a rather big hole of Ø7-9 cm in the roof. Additionally, the non removable network connection cable in the F series is a great disadvantage in elevators as previously described in Part II.

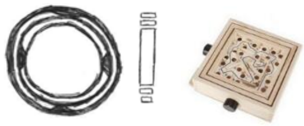
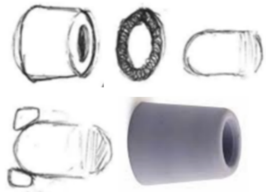
Table 12.1 Existing solutions with similar sensor units.

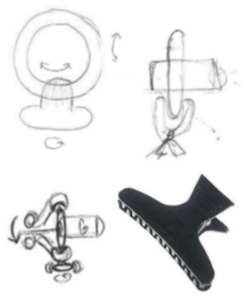
No.	*Picture*	*Description*
1		F4005, Dome F series. A F sensor unit inside a sphere.
2		FA 4115, Dome FA-series. A FA sensor unit build on a sphere

12.4.1.2 External exploration

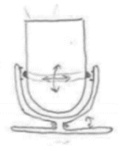
After external exploration, internal idea generation was performed through brainstorming where the primarily focus was to explore solutions for possible rotation mechanisms. The result of the idea generation can be seen in Table 12.2.

Table 12.2 Results after brainstorming rotation mechanism for single sensor units.

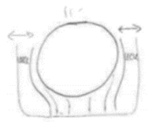
No.	*Sketch*	*Description*
1		**Balance maze** The function is based on a balance maze board, where the different layers of rings rotate around different fixed axes. The sensor unit is placed in the middle of the innermost ring. Washers are placed between the rings to create enough friction for the rings to stay in place once the sensor unit is correctly adjusted.
2		**Magnet ball** Sensor unit wrapped in a sphere with high friction silicone like material. Back plate with circular recess wrapped in same material. The sphere is fastened to the recess through magnetism. The magnetism allows the sphere to be adjusted in any angle.
3		**Door stop** The idea is to add a hemisphere to the bottom of the sensor unit and put it inside a hole, in a part that looks like a door stop. The friction between the hemisphere and the door stop will prevent the sensor unit from moving after it has been adjusted correctly.

4 

Rotating rings
Different rings allow for rotation around fixed axes. The sensor unit is placed in the middle of one of the rings. A lock mechanism similar to the one in a hair clip could be used to fasten the rings.

5 

Cup holder
Sensor unit with small arms added, is placed in a cup holder with a circular cut. The arms fit into the cut and create perfect friction so that the sensor unit both stops but also allows rotation and tilt of the sensor unit. The cup can rotate around its own axis if needed.

6 

Grabbing spring
Sensor unit placed inside a sphere. The sphere is placed in a bed of interlocking arms. The arms hold the sphere still by the tension of springs. The flexible arms allow for rotation of sphere.

7 

Tense spring
The sensor unit is connected to a spring, by pulling it the sensor unit can be adjusted in all angles. When letting go the spring will see too that the sensor unit stays in place.

8 

Spiral track
The sensor unit is placed in the track and can be moved in a spiral movement. The end and beginning of the track stops the sensor unit from being moved any further. The walls of the track are at different heights, this would make the sensor unit tilt in different directions when dragged along the track. Where the sensor unit would be placed along the track is dependent on the desired angle.

9 

Wrap sphere
The first sketch shows a sensor unit placed inside a sphere, which is placed in a silicone material. The material allows for adjustment of the sensor unit and would keep it in place once adjusted correctly.

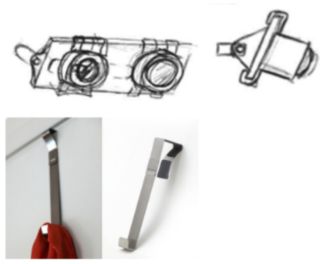
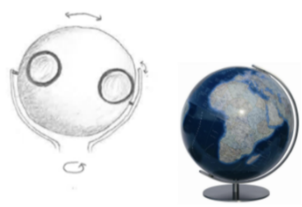
The second sketch shows the sensor unit placed on a sphere, the sphere is then covered with a silicone material. The material will keep the unit in place once it is adjusted correctly.

10		**Motorcycle helmet** A moving ¼ sphere is placed outside a sphere connected by two point that allows the ¼ sphere to rotate freely around the inner sphere like a visor on a motorcycle helmet. The sensor unit is connected to the outer sphere. The outer sphere has a horizontal cut allowing for adjustment of the sensor unit.

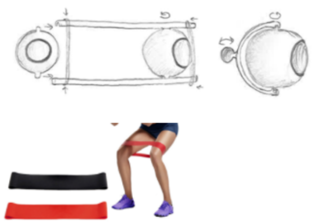
12.4.2 **Sub concept 2: Combination of two sensor units**

Solutions for the second sub concept was explored internally through brainstorming. Solutions for both combining two or more sensor units as well as how to rotate the sensor units were explored. Results from the brainstorming can be seen in Table 12.3.

Table 12.3 Results after brainstorming solutions for combining sensor units.

No.	*Sketch*	*Description*
1		**Hook** The two sensor units are hooked onto a board which can tilt the sensors. The board is placed inside a housing. This allows the sensor units to slide across the board and be fastened at a desired distance from each other.
2		**Click trails** The sensor units are fastened to a clip which can be clicked onto trails and slide across them. The trails are placed inside a housing.
3		**Globe** Two sensor units are placed inside a sphere. The sphere has one pin on each side. The sphere is placed in a cup holder with grooves for the pins, that are optimized to keep the sphere in place but also allows rotation.

4



Sphere trails

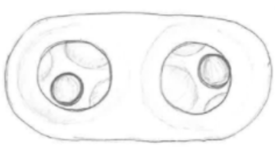
A sensor unit wrapped in a sphere with pins on the top and bottom. The spheres are placed in a trail and adjusted to a wanted distance and angle. One rubber band placed on each side can create pressure to keep the spheres in place. The container can be tilted up and down.

5

Goggles

Two sensor units placed on a track cut out of a holder of flexible material. The track allows for adjustment of sensor units. The holders flexible material allows for adjustment of view.

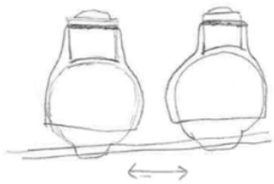
6



Rolling eyeballs

A double dome design where several of the rotation functions can be incorporated. Either with magnet balls or friction based mechanisms. The sensor units are placed inside the balls. The balls are placed in a holder that allows rotation but also keeps the sensor units in desired place.

7



Pole

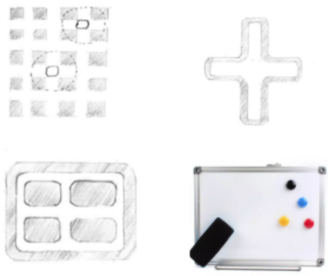
Any type of sphere solution could be fastened to a pole and slide across it in order to adjust the distance between the sensors. The pole is placed inside a housing.

8

Silicone wrap

Sensor units placed in spheres and a holder are all wrapped in silicone elastic material. The material holds the sensor units in place but the elasticity allows for adjusting the sensor units.

9



Magnetism boards
Different patterns of magnetism board can be placed inside the housing. A magnet is placed on the back of the sensor units. This would make it easy to fasten the sensor unit to the board and move them around. There are tracks in the boards which allows for the connection of a cable.

12.5 Combination of concept ideas

12.5.1 **Evaluation of initial ideas**

To be able to handle the amount of concept ideas, the initial ideas were evaluated and decisions were made in order to select which ideas should be combined and developed further. The team evaluated the ideas based on their knowledge and also seeked help from experienced Axis employees to validate the functionalities of the ideas. See Table 12.4 and

Table 12.5 for the result of the evaluation.

Table 12.4 Results of evaluation of sub concept 1: Rotation of single sensor unit.

No.	*Name*	*Continue?*
1.1	Balance maze	No
1.2	Magnet ball	Yes
1.3	Door stop	Yes
1.4	Rotating rings	No
1.5	Cup holder	No
1.6	Grabbing spring	Yes
1.7	Tense spring	No
1.8	Spiral track	No
1.9	Wrap sphere	Yes

1.10	Motorcycle helmet	Yes

Table 12.5 Results of the evaluation of sub concept 2: Combination of sensor units.

No.	***Name***	***Continue?***
2.1	Hook	Yes
2.2	Click trails	Yes
2.3	Globe	No
2.4	Sphere trails	Yes
2.5	Goggles	Yes
2.6	Rolling eyeballs	Yes
2.7	Pole	No
2.8	Silicone wrap	No
2.9	Magnetism boards	No

12.5.2 **Combination tree**

Possible combinations of the selected ideas were explored in order to generate new concept ideas. Combinations that were explored can be seen in Table 12.6.

Table 12.6 Combination tree of sub concept 1 and 2.

Sub concept 1	***Sub concept 2***	***Combinations***
1.2 Magnet ball	**2.1** Hook	**1.2 + 2.6**
1.3 Door stop	**2.2** Clock trails	**1.2 + 1.3**
1.6 Grabbing spring	**2.4** Sphere trails	**1.2 + 1.3 + 2.6**
1.9 Wrap sphere	**2.5** Goggles	**1.2 + 2.1**
1.10 Motorcycle helmet	**2.6** Rolling eyes	**1.2 + 2.4 + 2.5**
		1.9 + 2.1
		1.10 + 2.5
		1.10 + 2.2
		1.10 + 2.3

After taking a closer look at the combinations in Table 12.6 the team discovered four different main solutions forming the base for all possible concepts. The four solutions are all solutions that gives adjustable sensor units in terms of free rotation both for single sensor unit concepts and concepts combining more than one sensor unit. A description of the four main solutions can be found in Table 12.7. An overview of the solutions and related concepts can be seen in Figure 12.1.

Table 12.7 Name and corresponding description to the four main solutions.

Name	***Description of function***
MC, Motorcycle	Sensor unit(s) placed in a track in a visor that can be adjusted up and down like a visor on a motorcycle helmet.
Ball	The sensor unit is placed inside a ball. The balls material or other functions are added to allow for rotation.
Rails	The sensor units are placed inside a holder that can be connected to a rail. Both the holder and the rail allows for adjustments of the view.
Door Stop	The sensor unit is placed inside a silicone holder. The holder is placed inside a suitable hole, also covered in silicone that allows rotation and keeps the sensor unit in the desired place

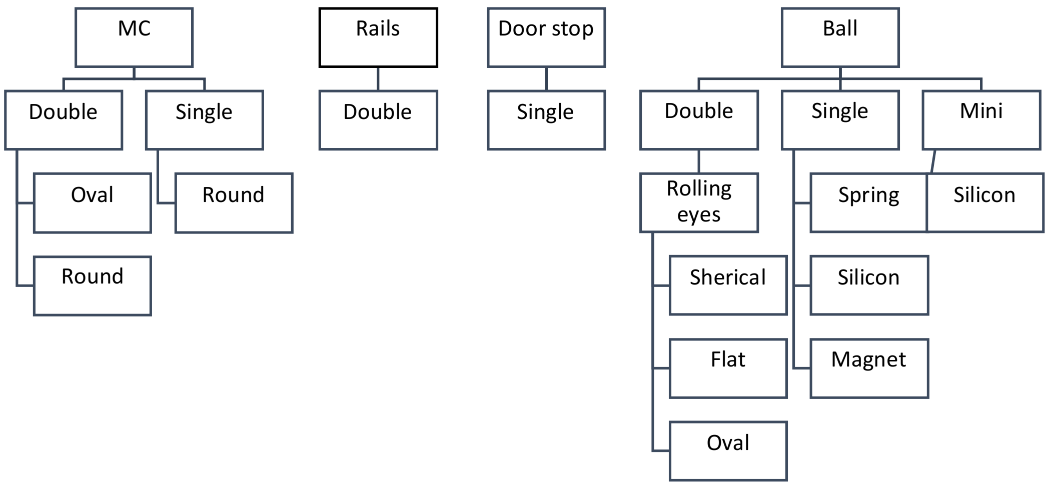
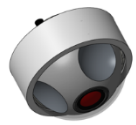


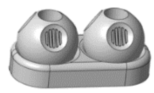
Figure 12.1 Overview of the combinations within each of the four main solutions.

12.6 Concepts

After combining the concept ideas, six ideas for a single sensor unit and six ideas for combining sensor units were developed and improved. CAD models and descriptions of the 12 concepts are presented in Table 12.8.

Table 12.8 Description and picture of developed concepts.

Concept	***Description***	***Picture***
	Single	
A	**MC single** The sensor unit is fastened to a track in a visor. The visor can move up and down to adjust view. The sensor units position can be adjusted by moving it from side to side in the track to desired angle.	
B	**Ball silicone** The sensor unit is placed inside a plastic ball. The ball is surrounded by a circle in silicone. The silicone will allow the ball to be rotated to desired angle. The friction will hold the ball in place after adjustment.	
C	**Ball magnet** The sensor unit is placed inside a metal ball. The ball is surrounded by a circle with magnets. The magnets will allow the ball to be rotated to desired angle. The force from the magnets will hold the ball in place after adjustment.	
D	**Ball spring** The sensor unit is placed inside a plastic ball. The ball is surrounded by a circular spring. The spring will allow the ball to be rotated to desired angle. The spring force will hold the ball in place after adjustment.	
E	**Ball Mini** The sensor unit is placed in a very small silicone ball that has the same diameter as the sensor unit is long (30 mm). The ball is surrounded by a plastic circle. The friction between the silicone and the plastic will allow for rotation of the sensor unit as well as keep it in place at the desired angle.	
F	**Door stop** The back half of the sensor unit is placed in a silicone holder that has a half sphere shaped end. The half sphere is placed in a deep hole in the back part of the housing also covered in silicone. The silicone together with the parts shape will create friction to allow	

	rotation and also hold the sensor unit in placed at the desired angle. Magnets could be added for better support	
	Double	
G	**MC double oval** The sensor units are fastened to a track in a visor. The visor can move up and down to adjust view. The sensor units positions can be adjusted by moving them from side to side in the track to desired angle.	
H	**MC double round** Same function as in concept G, only a round shape instead of oval.	
I	**Rail double** The sensor units are placed inside a holder that allows the sensor units to be rotated. The holders with the sensor units are slid onto a half moon shaped track that allows for adjustments of the sensor units placement.	
J	**Rolling eyes spherical** Sensor units are placed inside a ball. The balls are placed in holes in a spherical holder that allows for full rotation of the sensor units	
K	**Rolling eyes flat** Sensor units are placed inside a ball. The balls are placed in holes in a flat holder that allows for full rotation of the sensor units	
L	**Rolling eyes oval** Sensor units are placed inside a ball. The balls are placed in holes in an oval holder that allows for full rotation of the sensor units	

12.7 Reflections on the concept generation process

In order to meet the customer needs for field of view, a flexible rotation mechanism would be crucial to provide an adjustable solution. This resulted in a variety of ideas for both single and combined sensor units. When exploring ideas for different rotation mechanisms the team found it very useful to use related stimuli to get a visualization of the concept, explain the ideas and validate their functions.

The team had set aside well enough time to generate concept ideas and combining them which lead to many solutions and a qualitative idea generation. After several iterations of combining ideas the team ended up with six concepts for single sensor unit and six concepts for combining sensor units. Modelling the concepts in CAD helped the team get a better feeling of their functionalities, design and dimensions.

13 Concept selection for testing

This chapter presents a systematic selection of the concepts that will proceed to the testing phase of the project.

13.1 Background

Twelve different concepts were presented in Table 12.8 in the previous chapter. Before going into the testing phase several concepts need to be eliminated in order to be able to perform a qualitative testing.

13.2 Method

The concepts were analyzed and evaluated, first using a concept screening matrix and then a concept scoring matrix. The concepts were evaluated based on the selection criteria shown in Table 13.1. These criteria have been decided by the team based on findings from the background study, customer needs as well as goal for the thesis project.

The purpose of the concept screening matrix is to eliminate most of the concepts by comparing them to a predetermined reference concept. All concepts are evaluated and given a "+" if it is considered better than the reference concept, "0" if it is considered equal and "-" if it is inferior. The concepts with the highest score proceed to further development. These are either improved or combined before a more qualitative concept scoring matrix is used to evaluate the concepts once again.

The concept scoring matrix is similar to the concept screening matrix but as stated, more qualitative because each of the selection criteria are given a weight factor, in line with their importance. Each concept is given a score from one to five. The concept scoring matrix also uses a predetermined reference concept that the other concepts are compared to when setting the score.

Table 13.1 Selection criteria and corresponding description.

Selection criteria	*Description*
Reliable rotation mechanism?	Does the concepts rotation mechanism seem reliable? Do we know that it will work?
Possible field of view	Can the sensor unit be adjusted in both x, y and z directions from one maximum angle to the other?
Suitable size	Does the concept have a small and discrete design that takes advantage of the small size of the sensor unit?
Aesthetic impression	How is the impression of the design? Is it satisfying for the beholder or not?
Intuitive design	Is the design intuitive, so that the user (being the installer) will understand how the mechanisms work?
Complexity of assembly	How complex will the assembly be? Are there many different parts that has to be assembled?
Innovation height	How innovative is the concept compared to what Axis products as well as competitors products looks like today?

13.3 Concept screening matrix

Two concept screening matrixes were established. One for concepts solving rotation of single sensor unit and one for the concepts combining several sensor units. Reference concepts was decided by the team based on which concept they considered as the average. The points for each of the concepts were summarized and compared before the team made a final evaluation as to whether to continue with the concept or not. The matrixes and their results are presented in Table 13.2 and Table 13.3.

To help with the selection process the team made some shape and size prototypes in Styrofoam. This gave a good indication of potential size for the concept, the prototypes are shown in Figure 13.1. In addition to the prototypes in the picture a Styrofoam prototype with a diameter of 55 mm was used.

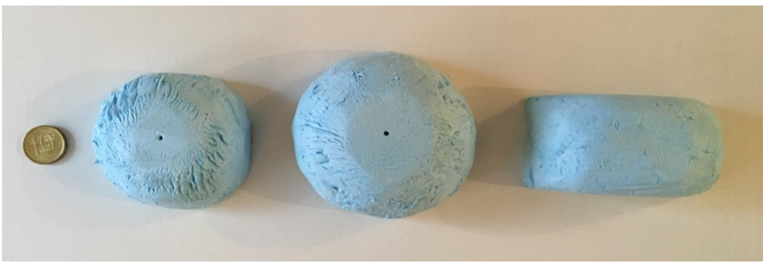


Figure 13.1 Prototypes in Styrofoam. From right to left: Ø70 mm, Ø90 mm, 90 x 45.

Table 13.2 Concept-screening matrix for concepts with rotation of single sensor unit.

	Concepts with rotation of single sensor unit					
Selection criteria	***A*** ***MC single***	***B*** ***Ball silicone***	***C*** ***Ball magnet***	***D*** ***Ball spring***	***E*** ***Door stop (Reference)***	***F*** ***Mini silicone***
Reliable rotation mechanism?	+	+	+	+	**0**	+
Possible field of view	-	+	+	+	**0**	+
Suitable size	-	0	0	0	**0**	+
Aesthetic impression	-	+	+	+	**0**	+
Intuitive design	-	+	+	+	**0**	0
Complexity of assembly	-	-	0	-	**0**	-
Innovation height	0	0	0	-	**0**	0
Result	**-3**	**+3**	**+4**	**+2**	**0**	**+3**
Continue?	***No***	***Combine***	***Combine***	***Combine***	***No***	***Yes/ Combine***

Table 13.3 Concept-screening matrix of concepts with rotation of two sensor units.

	Concepts with rotation of two sensor units					
Selection criteria	***G*** ***MC oval***	***H*** ***MC round***	***I*** ***Rail (Reference)***	***J*** ***Rolling eyes spherical***	***K*** ***Rolling eyes flat***	***L*** ***Rolling eyes oval***
Reliable rotation mechanism?	0	0	**0**	-	-	-
Possible field of view	0	+	**0**	0	0	+
Suitable size	0	-	**0**	-	0	+
Aesthetic impression	+	-	**0**	-	-	-
Intuitive design	+	+	**0**	+	+	+
Complexity of assembly	+	+	**0**	+	+	+
Innovation height	-	-	**0**	0	0	0

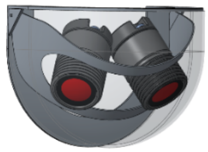
Result	**+2**	**0**	**0**	**-1**	**0**	**0**
Continue?	***Yes***	***No***	***No***	***No***	***No***	***No***

13.4 Combination and improvement of selected concepts

The selected concepts were combined and improved, resulting in the five concepts presented in Table 13.4 below. The concept name indicates what previously presented concept, see Table 12.8, were combined. For instance, BF indicates that the concept is a combination of the previous concept B and F. Also a new concept emerged from the development process inspired by previous solutions. This concept is named “New”.

Table 13.4 Description of the improved concepts with pictures of the models.

Concept	*Description*	*Picture*
BF1	**Mini silicone (Ø45 mm)** The sensor unit is placed inside a small silicone ball. The ball is placed in a circular plastic holder. Friction allows for rotation of the sensor unit as well as holding the sensor unit in the desired place. The network connection cable is secured through a stopper which top is pushed inside the silicone ball.	
BF2	**Medium silicone (Ø60 mm)** The sensor unit is placed inside a silicone ball that covers both the sensor units as well as the end part of the network connection cable. Friction allows for rotation of the sensor unit as well as holding the sensor unit in the desired place.	
CF	**Mini magnet (Ø45 mm)** The sensor unit is placed inside a metal ball. The metal ball is placed in a circular holder with integrated magnets. The magnets are strong enough to hold the metal ball in its desired place but also allows for adjustment of the sensor unit to the desired angle.	
New	**Stainless steel ball (Ø55 mm)** The sensor unit is placed inside a globe made out of two equal hemispheres in stainless steel. A convex glass is placed in front of the sensor unit. The two hemispheres are assembled and placed in a round holder. The holder is split vertically into two semicircles. The semicircles have small dots on the inside to create friction. The semicircles are mounted around the globe and the force is adjusted so that the	

	globe is locked in the desired position. The small dots inside the semicircles provides extra friction and prevents unwanted movements.	
G	**MC double oval corner** The sensor units are fastened to a track in a visor. The visor can move up and down to adjust view. The oval ¼ globe shape of the dome allows for full adjustment of the view. The sensor units' positions can be adjusted by moving them from side to side in the track to desired angle.	

13.5 Concept-scoring matrix

To make the final selection of concepts for testing the five concepts were evaluated using a concept scoring matrix. This time the one remaining solution of combining sensor units, concept G, was evaluated together with the rest of the concepts in order to compare and evaluate all concepts based on the same terms. The New concept was chosen as the reference. All selection criteria were given a weight factor based on findings in the background study, the team's own opinions and consultation with Axis. The points were summarized giving each concept a comparable score. After evaluating the results, the team chose top three concepts to continue on to the testing phase, see Table 13.5 for results.

Table 13.5 Concept-scoring matrix of the five improved concepts.

		Concepts									
		BF1 Mini silicone		***BF2 Medium silicone***		***CF Mini magnet***		***New Stainless Steel ball (Reference)***		***G MC Double oval corner***	
Selection criteria	***Weight factor***	***P***	***WP***	***P***	***WP***	***P***	***WP***	***P***	***WP***	***P***	***WP***
Reliable rotation mechanism?	10%	3	0.30	3	0.30	3	0.30	4	0.40	4	0.40
Possible field of view	10%	3	0.30	4	0.40	3	0.30	3	0.30	5	0.50
Suitable size	20%	4	0.80	2	0.40	4	0.80	4	0.80	1	0.20
Aesthetic impression	20%	4	0.80	4	0.80	4	0.80	3	0.60	1	0.20
Intuitive design	10%	4	0.40	4	0.40	4	0.40	4	0.40	3	0.30

Complexity of assembly	15%	4	0.60	4	0.60	3	0.45	3	0.45	1	0.15
Innovation height	15%	3	0.45	3	0.45	3	0.45	4	0.60	5	0.75
Result			**3.65**		**3.35**		**3.50**		**3.55**		**2.50**
Continue?			***Yes***		***No***		***Yes***		***Yes***		***No***

13.6 Reflections on the concept selection process

After two iterations of evaluation and selections of concepts the team chose to continue with three concepts for further testing. After the concept generation, the team had an even number of concepts for both single sensor unit housing as well as combined sensor unit housings. The team also reflected a lot on the user case for a combined sensor unit concept and came to the conclusion that this might not be beneficial when seeing how small a single sensor unit concept could become. Such small single sensor unit housings would be easy to combine, as desired in larger and more complex elevator environments. Thus, giving the same potential user case as the combined sensor unit concepts. In other words, it would be better to use two single sensor units than to use a combined one.

The three selected concepts for testing are all interesting concepts for Axis product portfolio. Even though the design looks similar to existing camera solutions, these concepts differentiate themselves in term of their small size as well as their functionalities that have not yet been used in Axis products.

14 Concept testing

In this chapter testing of the chosen concepts is presented and improved concepts are developed based on results from the testing.

14.1 Background

In order to validate the concept and achieve a proof of concept the functions need to be tested. This is done by building prototypes that simulate important functionalities for the concepts. Concept BF1, CF and the New concept was selected for testing. The concepts will from now on be called by their names Mini silicone (BF1), Mini magnet (CF) and Stainless Steel ball (New) to facilitate the reading.

14.2 Method

The three chosen concepts were tested using physical and digital 3D models to communicate the concepts and their functions. The evaluation of the concepts was based on how well their functions work, the size, how the assembly works and finally how well the installation would work. The team tested the 3D models functions and consulted with Axis employees to validate proof of concept. The results were the interpreted and improvements were done to the designs.

In order to create physical 3D models with the desired functionalities the team had to get creative and find alternative solutions for certain parts and materials that was not fit for 3D printing. How the prototypes were created is described in detail in the following chapters.

14.2.1 **Mini silicone**

The crucial function to this concept is the friction between the silicone ball and the plastic ring that both allows rotation for the ball but also enough friction for the ball to stay in its place. To recreate the friction and the feeling of a silicone ball a bouncing ball and a 3D print of the ring was used, see Figure 14.1. The diameter of the bouncing ball was a few mm smaller than the desired size of 45 mm and therefore the ring was adjusted to fit the bouncing ball. Because of the minimal difference in size the prototype gave a good indication of the actual size of the concept.

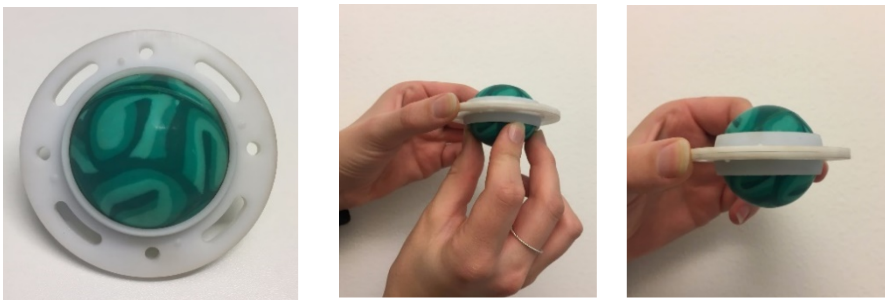


Figure 14.1 Prototype of the Mini Silicon concept using a bouncing ball and 3D printed parts.

14.2.2 **Mini magnet**

This concept is based on magnetic force between a metal ball and magnets placed inside the ring that surrounds the ball. To create this function, magnets and a metal ball was used, see Figure 14.2. Before 3D printing the ring, it was adjusted to fit the magnets and the metal ball that was used. The sizes of the magnets and the metal ball varies a few mm from the desired sizes for the design but gave a good indication of the actual size. The desired size for the metal ball is a diameter of 40 mm while the metal ball used in the testing measures 30 mm.

Figure 14.2 Prototype of the Mini Magnet concept using a metal ball, magnets and 3D printed parts.

14.2.3 **Stainless Steel ball**

The crucial function for the Stainless Steel Ball concept is the grip mechanism of the ring around the ball. This function was tested through 3D printing of the ball and the ring, see Figure 14.3. The prototype was tested in the desired size using a diameter of 55 mm for the ball.

Figure 14.3 Prototype of the Stainless Steel Ball using 3D printed

14.3 Results from testing

The results from the testing is presented in Table 14.1. The results were based on the four main evaluation factors for the prototypes; function, size, assembly and installation.

Table 14.1 Results from the testing of the prototypes.

Concept	*Function*	*Size*	*Assembly*	*Installation*	*Other comments*
Mini silicone	Good	Hard to get a good grip because of small size and smooth surface	Simple and easy assembly and the ball stays in place	Easy to install because of the horizontal split of the grip ring	Silicone outgas has to be taken into account. Cheap materials and easy to produce
Mini magnet	Good The number of magnets needs to be reduced to 3-4	Too small to get a good grip. The smooth surface makes it hard to grip as well	Needs to add a way of stopping the metal ball from moving vertically. How the magnets will be fastened in the grip ring has to be decided.	A heavy metal ball will make it harder to install in ceilings.	Magnets and a metal ball is relatively exp ensive
Stainless Steel ball	Good	Good	The fastening of the grip ring needs to be developed further.	The amount of steel makes it quite heavy which will make it harder to install in ceilings. It is hard to adjust the grip mechanism after installation	Metal is expensive. An alternative in plastic might be beneficial.

14.4 Concepts after testing

The results from the testing was reviewed and improvements were done accordingly on the concepts. A new concept emerged from the Stainless Steel Ball called the Plastic Ball. The four concepts are presented briefly in the following paragraphs together with a detailed view of the concept components and function.

14.4.1 **Mini silicone**

The sensor unit is placed inside a Ø45 mm silicone ball, see Figure 14.4 and Figure 14.5. The silicone ball has recess holes for easier and more intuitive adjustment of the ball. The ball is placed in a circular plastic holder. The plastic holder is split horizontally in two parts, a front and a back part. Friction between the rings and the silicone ball allows for rotation of the sensor unit as well as holding the sensor unit in the desired place. The back part of the ring is mounted to the ceiling or wall. A hole the size of the silicone balls diameter is made in the wall or the ceiling hiding the back of the camera and cables like a recess mount. The silicone ball is covered by a cover ring and a glass dome that is fastened to the rings. The network connection cable is secured through a stopper which is pushed inside the silicone ball preventing the cable from being pulled out easily.

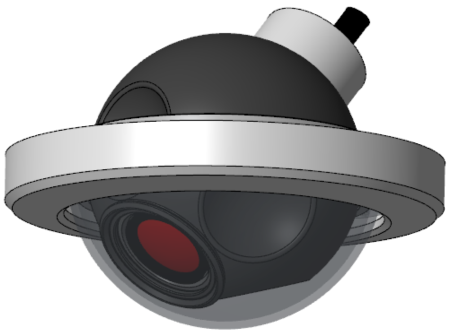


Figure 14.4 CAD model of the assembled Mini Silicone concept.

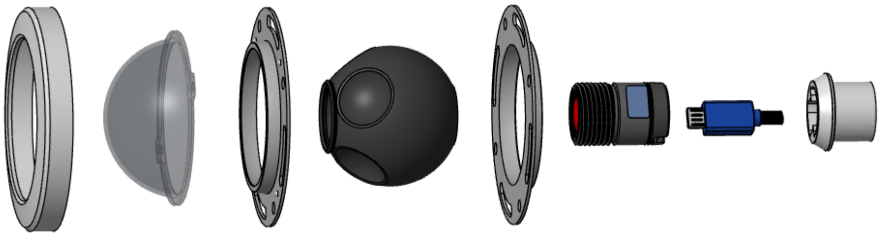


Figure 14.5 CAD model of the exploded view of the Mini Silicone concept.

14.4.2 **Mini Magnet**

The sensor unit is placed inside a Ø40 mm metal ball, see Figure 14.6 and Figure 14.7. The metal ball is placed in a circular plastic holder. The holder is split vertically in two semi circled parts. The magnets are placed inside these semi circled parts. The parts are assembled together around the metal ball. The magnets are strong enough to hold the metal ball in its desired place but also allows for adjustment of the sensor unit to the desired angle. The holder is mounted to the ceiling or wall. A hole the size of the metal balls diameter is made in the wall or the ceiling hiding the back of the camera and cables like a recess mount. The metal ball is covered by a cover ring and a glass dome that is fastened to the ring.

Figure 14.6 CAD model of the assembled Mini Magnet concept.

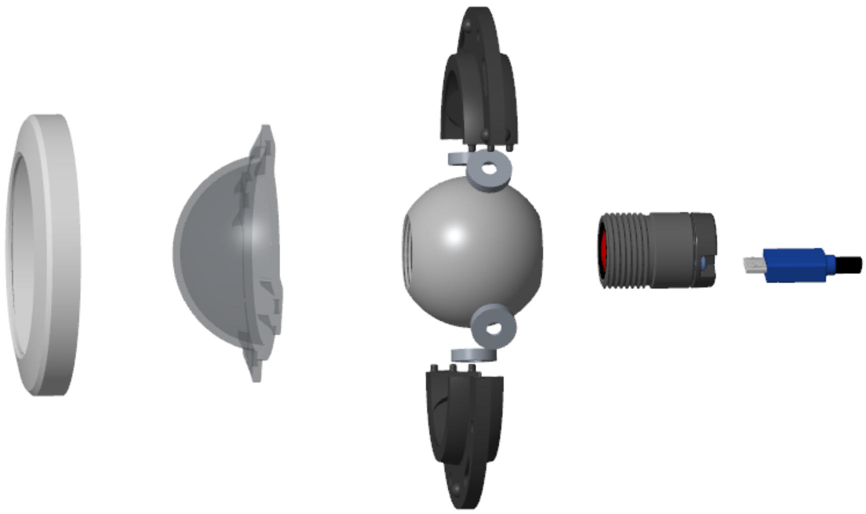


Figure 14.7 CAD model of the exploded view of the Mini Magnet concept.

14.4.3 **Stainless Steel Ball**

The sensor unit is placed inside a Ø55 mm globe made out of two equal hemispheres in stainless steel, see Figure 14.8 and Figure 14.9. A convex glass is placed in front of the sensor unit. The two hemispheres are assembled and placed in a round holder. The holder is split vertically into two semicircles. The semicircles have small dots on the inside to create friction against the stainless steel ball. The semicircles are mounted around the stainless steel ball and the force is adjusted so that the ball is locked in the desired position. The small dots inside the semicircles provides extra friction and prevents movements. The semicircles are mounted to the ceiling or wall. A hole the size of the stainless steel balls diameter is made in the wall or the ceiling hiding the back of the camera and cables like a recess mount. The network cable is secured by a holder surrounding the cable and preventing it from being pulled out.

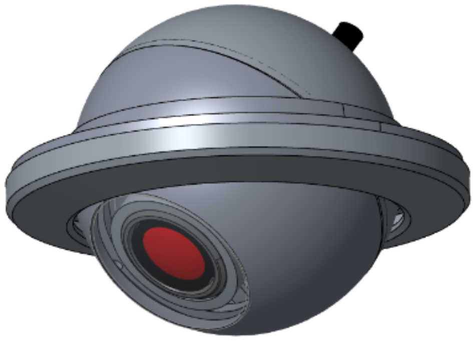


Figure 14.8 CAD model of the assembled Stainless Steel Ball concept.

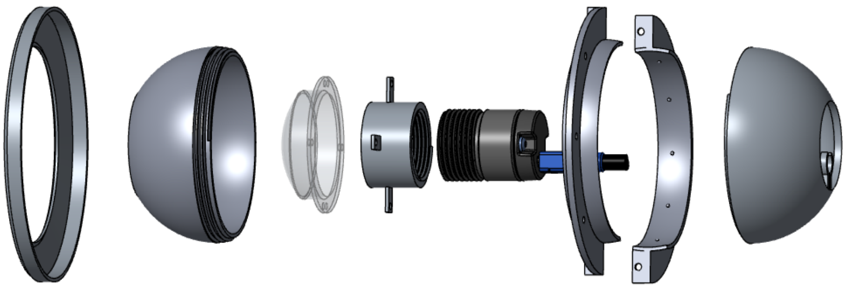


Figure 14.9 CAD model of the exploded view of the Stainless Steel Ball concept.

14.4.4 **Plastic Ball**

The concept carries the same basic functions as the previously described Stainless Steel Ball but all components are made out of plastic material instead of metal. The plastic balls diameter is the same as for the Stainless Steel Ball, Ø55 mm. See Figure 14.10 and Figure 14.11. Certain construction features are adapted for plastic material.

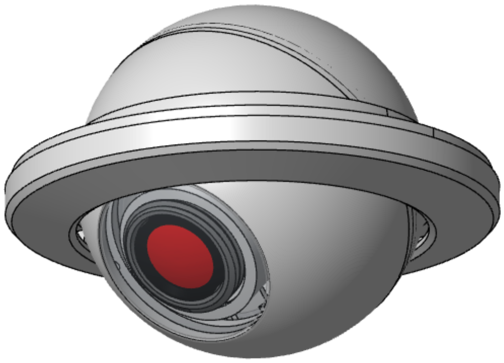


Figure 14.10 CAD model of the assembled Plastic Ball concept

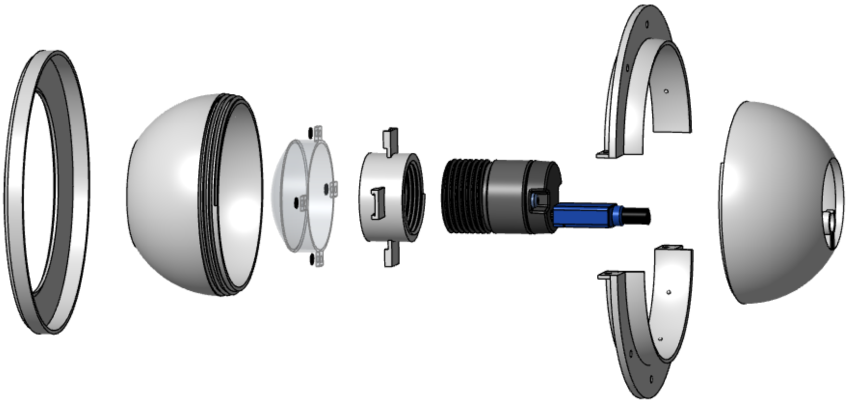


Figure 14.11 CAD model of the exploded view of the Plastic Ball concept.

14.5 Reflections on concept testing

The testing and building prototypes was an insightful experience for the team. The Mini Magnet as well as the Mini Silicone concept both have functions that required the team to get creative in order to build a prototype. Seeing and feeling the prototypes and test their functionalities gave valuable experiences and insights on how the designs should be improved. The testing of the Stainless Steel Ball even resulted in an alternative concept the Plastic Ball.

15 Final concept selection

This chapter presents the selection process of the final concept.

15.1 Background

Four concepts were tested and improved and the results from the testing gives a good indication of proof of concept for all four. In order to proceed with the product development project one concept has to be selected as the final concept. In this chapter the four concepts are evaluated and one concept is selected for further development.

15.2 Method

As all four concepts have proved to work and they are all unique in their own way the team decided that the best way of selecting one of the concept was through consulting key personnel for the project at Axis to figure out which concept had the best future prospects. The selection was done through discussions with the product manager for the Axis FA series as well as mechanical engineers from the EVP department at Axis. The function of the concept, estimated potential price, innovation height and how the concept would fit with future projects at Axis was discussed.

15.3 Results of final concept selection

To summarize the results a concept screening matrix was used. The Plastic Ball was set as a reference and points were given based on discussions with Axis expertise. The results are presented in Table 15.1.

Table 15.1 Concept screening matrix for final concept selection.

	Mini silicone	*Mini magnet*	*Stainless Steel ball*	*Plastic ball (Reference)*
Price	0	-	-	**0**
Innovation height	+	+	0	**0**
Axis further projects	+	+	0	**0**
Function	+	0	0	**0**
Result	**+3**	**+1**	**-1**	**0**
Continue?	***Yes***	***No***	***No***	***No***

15.4 Reflections on final concept selection

The result shows that the Mini Silicone concept was a clear winner. The team agrees with these results. The functionalities of the Mini Silicone are tested and the concept is by all means not in need for any bigger development in order to provide a well working prototype. It has a strong innovation height as the way of using silicone material has not yet been studied any further at Axis. The product will most certainly be a lot cheaper to produce than the other concepts using metal and magnets as the materials are cheap and the number of parts is low. It will also be easy to install as well as replace vandalized parts. Additionally, this concept has the best prerequisites to fit into Axis future product portfolio for the FA series.

16 Detailed development of final concept

In this chapter, the detailed development of the final concept is presented

16.1 Background

The final concept is selected but several functionalities of the concept are not decided or should be developed and tested further in order to present a fully functional final concept.

16.2 Method

The detailed development was done by first dividing the final concept into sub problems. Ideas for solutions were then generated for the sub problems which solutions had not yet been explored. The solutions were discussed with Axis and tested using 3D print in order to validate the solutions. Axis has a range of products that already solves similar functionalities. To limit the development time, the team took a lot of inspirations from these solutions to secure the functionalities without the need for too much testing.

The sub problems discovered for the concept are presented in Table 16.1. Figure 16.1 shows a numbered model of all components. Table 16.2 shows the naming of each of the components.

Table 16.1 Sub problems of the concept.

	Sub problem	*Solved?*
A	Fastening of sensor unit in the silicone ball	Yes
B	Fastening of network cable	Yes
C	Fixation of silicone ball	Partly
D	Mounting of bracket to ceiling/wall	No
E	Mounting of brackets together	No
F	Fixation of dome glass	No
G	Fixation of cover ring	No

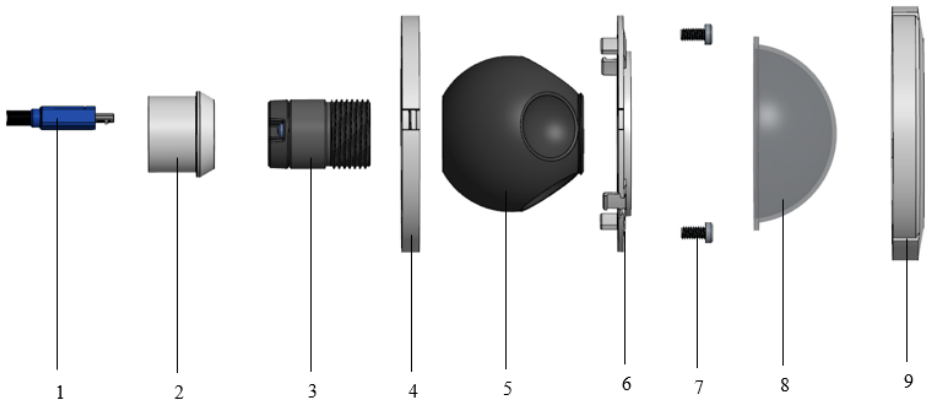


Figure 16.1 Illustration of the parts that make up the final concept.

Table 16.2 Names and corresponding numbers of parts.

No.	*Name*
1	USB network connection cable
2	Stopper
3	*AXIS FA1105* sensor unit
4	Bottom bracket
5	Silicone ball
6	Top bracket
7	Screws from mounting
8	Dome glass hemisphere
9	Cover ring

16.3 Result

The solutions explored for the sub problems are presented in Table 16.3.

Table 16.3 Sub problems and corresponding solutions.

	Sub problem	*Solution*
C	Fixation of silicone ball	**Only friction:** The friction between the ball and the bracket is sufficient to hold the ball in place. **Friction and locking:** The fixation of the ball in the brackets has two stages; one where it can be adjusted to desired field of view and one where it is locked in place. In the adjustment stage the brackets are interlocked but with a gap between making the diameter where the silicone ball is fastened wider allowing adjustment. The locking of the ball occurs only when the brackets are pushed together and fastened completely. The locking can be done by using: **Screws:** The top bracket is screwed onto the bottom bracket. **Snap fit:** The top bracket is locked to the bottom bracket using snap fits
D	Mounting of bracket to ceiling/wall	**Screws:** The bracket is mounted to the wall or ceiling using screws. **Using the top of the roof/outside of the wall:** A clamp mechanism is used to mount the bracket using pressure from the top of the roof or outside the wall through the hole.
E	Mounting of brackets together	**Snap fit:** Snap fit that interlocks the brackets.
F	Fixation of dome glass	**Screws to top bracket:** The dome glass is mounted to the top bracket using screws. **Snap fits to cover ring:** The dome glass is fastened to the cover ring using snap fits. **Snap fits to bracket:** The dome glass is fastened to the top bracket using snap fits. **Pressure to cover ring:** The dome glass is fastened to the cover ring only using pressure between the dome diameter and the cover ring inner diameter.
G	Fixation of cover ring	**Snap fit around the dome glass fastening:** If the dome glass is fastened with screws or nap fits to the top bracket the cover ring can be fastened with snap fits onto the dome glass. **Snap fits to top bracket:** The cover ring is fastened to the top bracket using snap fits. **Snap fits to bottom bracket:** The cover ring is fastened to the bottom bracket using snap fits.

After testing the solutions using 3D print and consultation with the EVP department at Axis one solution was selected for each sub problem. The selected solutions for the sub problems are shown in Table 16.4. The detailed description of the design will be given in Chapter 17. During the testing it was discovered that some of the sub problems could benefit from being combined into one sub problem. The solution for sub problem G was therefore combined into solving even sub problem C, E and F.

Table 16.4 Sub problem and selected solutions.

	Sub problem	***Solution***
C	Fixation/Locking of silicone ball in bracket	Friction and locking
D	Mounting of bracket to ceiling/wall	Screws
E	Mounting of brackets together	Snap fit
F	Fixation of dome glass	Pressure to cover ring
G	Fixation of cover ring	Snap fit to bottom bracket

16.4 Reflection on the detailed development of the final concept

Due to limited time the team chose to take some inspiration from solutions already proven to work in other Axis products. This was a good way of validating the solutions and get the geometries right without too much testing. This saved the team a lot of time.

The team discovered that the combination of the different functionalities using the cover ring to lock the entire installation was very time efficient with less risk of doing a wrongful installation.

When limiting the use of tools and screws by implementing alternative solutions like snap fits, the installation is simplified a lot. The snap fits will also contribute to an easy demount of the construction.

17 Presentation of final concept

In this chapter, a detailed design analysis of the final concept is presented through descriptions and CAD models. The functions of the final concept were tested using a 3D printed model.

17.1 Background

The chosen final concept; Mini silicone has been tested and functionalities has been developed further. To understand the functionalities a detailed description of the design is needed.

17.2 Method

Final adjustments of the design were done after the detailed development of the final concept. The final designs were modeled and assembled in CAD as well as 3D printed. In order to get a fully working prototype some adjustments were made due to use of alternative parts.

17.3 Detailed design of final concept

The final design consists of six components in addition to the sensor unit and USB network cable as well as screws for mounting to the ceiling or wall. An illustration of the final concept can be seen in Figure 17.1.

Figure 17.1 Illustration of the final concept.

Figure 17.2 shows an exploded view of the final concept. All parts are labeled 1-10, names of each component is shown in Table 17.1. The product will be delivered to the consumer in three pre assembled parts as shown in Figure 17.3. Part one consists of the glass dome hemisphere and cover ring. Part two of the top bracket, bottom bracket, silicone ball and sensor unit. Part three is the stopper and USB network cable. The silicone ball has a diameter of 45 mm, the dome hemisphere 52.5 mm and the dome cover ring 73 mm. The silicone ball can be rotated 50 degrees in all directions. The camera protrudes less than 30 mm from the wall or ceiling inside the elevator car and no more than 30 mm above the ceiling or outside of wall depending on the wall or ceiling thickness. Drawings of all components can be found in Appendix H.

Table 17.1 Names and numbers corresponding to those in Figure 17.2.

No.	***Name***
1	Stopper
2	USB connection cable
3	Ceiling or wall
4	Silicone ball
5	Bottom bracket
6	Top bracket
7	M3 screws
8	*AXIS FA1105* sensor unit
9	Dome glass hemisphere
10	Cover ring

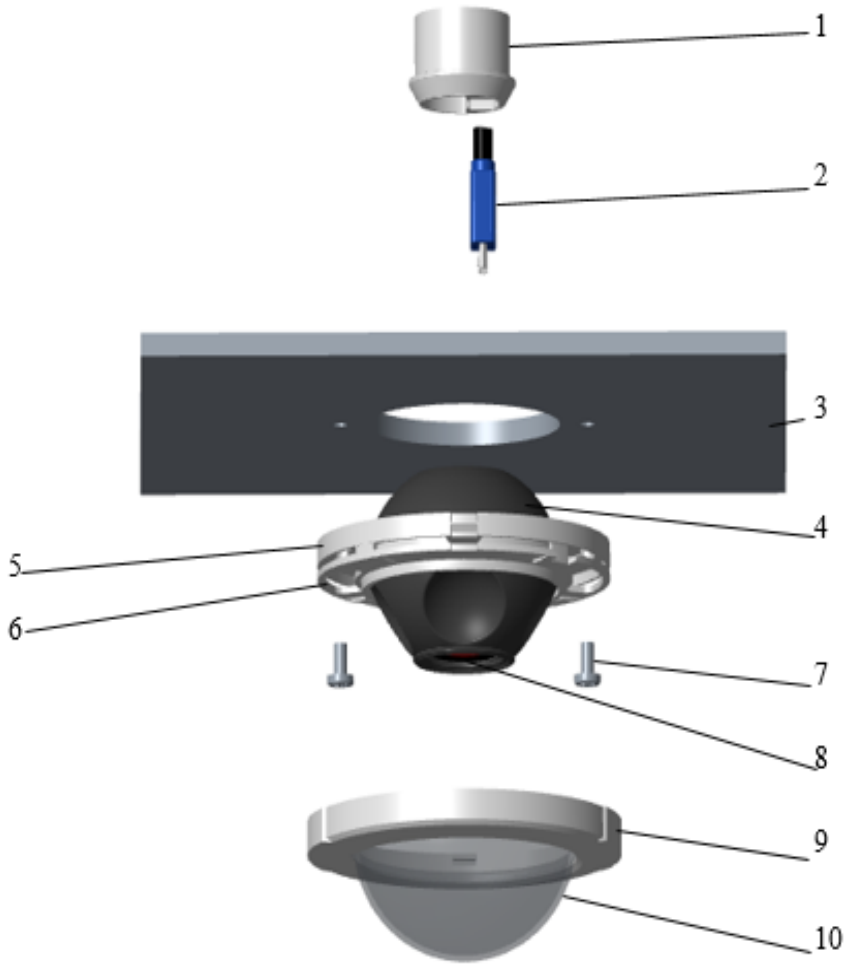


Figure 17.2 Exploded view of the final concept with numbered parts.

Figure 17.3 Illustration of the three pre assembled parts that will be delivered to the customer.

17.3.1 **Installation**

The installation process can be divided into two sequences: preparation and mounting. The installation is prepared by drilling a hole of about 45 mm in diameter in the ceiling or wall as well as installing the main unit, preferably on the roof of the elevator car or inner ceiling. The USB network cable connecting the sensor unit to the main unit is pulled from the main unit and into the elevator car through the drilled hole. After the preparation, the USB network cable is connected to the sensor unit using the stopper, part two and three of the construction is mounted to the wall or ceiling and the sensor unit adjusted to desired field of view. Finally, the cover ring and dome is assembled to complete the installation. A cross section of the complete installation is shown in Figure 17.4. The *AXIS FA1105* sensor unit and USB network cable which the camera housing is built around are shown in Figure 17.5. A more detailed description of the parts and the assembly functions are presented in the following sections.

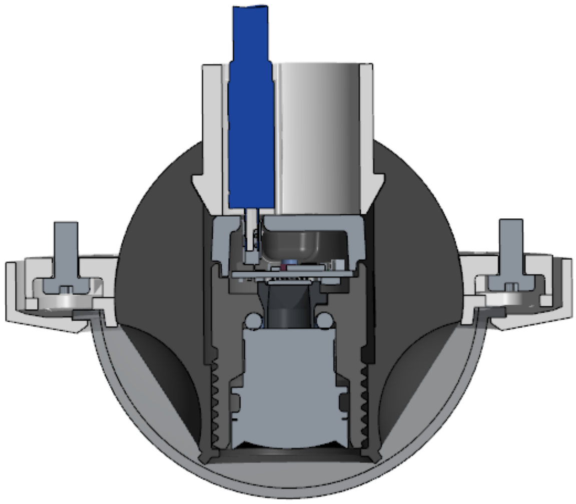


Figure 17.4 Cross section illustration of complete assembly

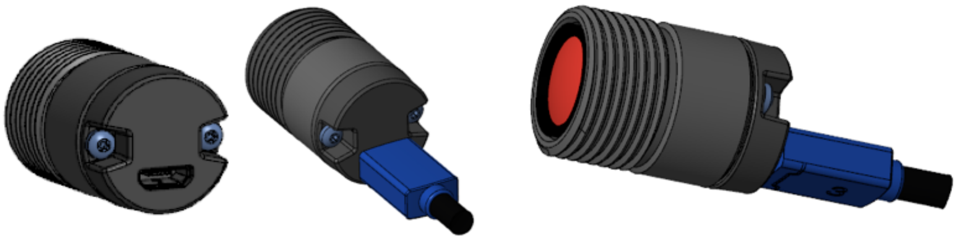


Figure 17.5 Illustrated the *AXIS FA1105* sensor unit and USB network cable provided by Axis.

17.3.2 **Part one**

The dome and cover ring consists of two parts: a see-through dome glass hemisphere and a plastic cover ring. The hemisphere is simply pushed into the cover ring and locks into a cut out on the inside of the cover ring, this is done prior to delivery. This construction allows for easy disassembly of the two parts. The two snap fits on the bottom of the cover ring are used to lock the whole construction, this will be explained in further detail later in *Section 16.3.2.3 Fastening mechanism*. Figure 17.6 illustrates the functions of part one.

Figure 17.6 Detailed view of functions for part one.

17.3.3 **Part two**

Part two is assembled prior to delivery as shown in Figure 17.7 below. The different functions of part two are explained in the following sections.

Figure 17.7 Illustration of part two of the assembly

17.3.3.1 Silicone ball and sensor unit

The sensor unit is simply pushed into the silicone ball and kept in place by the friction between the two parts. The sensor unit can therefore easily be taken out and replaced if vandalized. Figure 17.8 shows a cross section cut of the silicone ball with the sensor unit. The figure also shows an enlarged image of an edge used to stop the sensor unit from being pushed too far into the ball and an edge which is used to stop the ball from rotating too far. When the ball is rotated 50 degrees the edge aligns with the top bracket, the ball can therefore not rotate further. In order to get a good grip of the silicone ball so that the angle of the camera can be adjusted there are four spherical cut out on the ball.

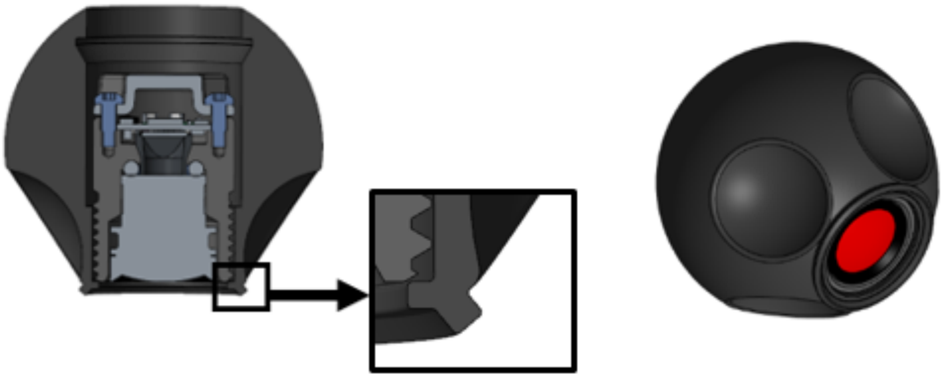


Figure 17.8 Detailed view of the silicone ball.

17.3.3.2 Brackets

The brackets have many functions, the primary being to keep the ball in place. The bottom bracket, shown in Figure 17.9, has two long holes (1) which are used to fasten the construction to the ceiling or wall. It also has two holes for guiding pegs (2) and two for snap fits (3) used to assemble the bottom bracket to the top bracket. Two more snap fits are added to the outside of the bracket (4), these are used together with the dome to lock the whole construction. This is explained further in Section *17.3.3.3 Fastening mechanism*.

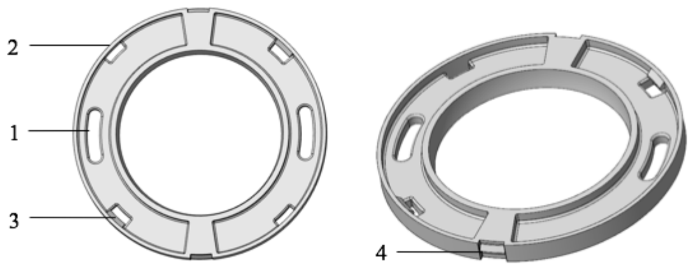


Figure 17.9 Detailed view of the bottom bracket that is mounted to the ceiling or wall.

The top bracket, shown in Figure 17.10, is constructed with large cut outs (1) so that the construction can be mounted to the ceiling or wall, using the long holes on the bottom bracket, when the two brackets are assembled. Furthermore, there are two guiding pegs (2) which stops the brackets from rotating relative to each other, two snap fits (3) which locks the top bracket to the bottom bracket and to cut outs (4) on the outside of the bracket allowing the snap fit from the dome to connect to the bottom bracket.

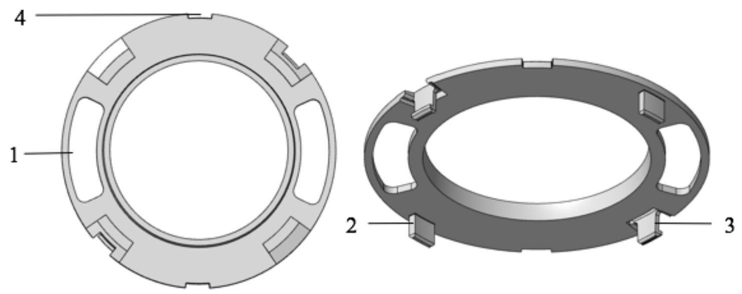


Figure 17.10 Detailed view of the top bracket.

17.3.3.3 Fastening mechanism

The principle of how the brackets are used to lock the silicone ball in a chosen position is explained by the cross-sectional pictures of the parts in Figure 17.11 and Figure 17.13 below. There are two stages of the fastening mechanism, the first stage is when the construction is fastened to the ceiling or wall using screws and the second when the snap fits of the cover ring is fastened to the bottom bracket. In the first stage, the snap fit locks the top and bottom brackets together, see Figure 17.11 and Figure 17.12. The gap between the brackets allows for movements of the silicone ball. It is small enough for the ball to stay in place but large enough so that it can be adjusted, see Figure 17.12. In the second stage, part one, the cover ring and the dome, is assembled onto the bottom bracket by snap fits, see Figure 17.13 and Figure 17.14. This eliminates the gap between the bottom and top bracket and creates less space for the silicone ball. This movement locks in the silicone ball at the set position, see Figure 17.14.

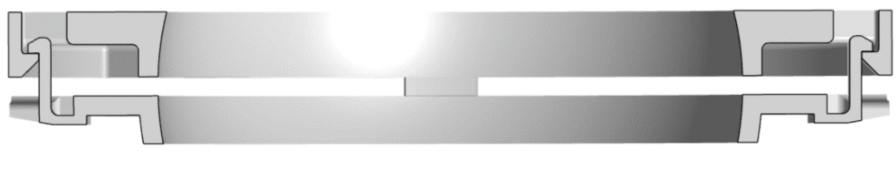


Figure 17.11 Detailed view of the first stage, the assembled brackets before locked by the dome part.

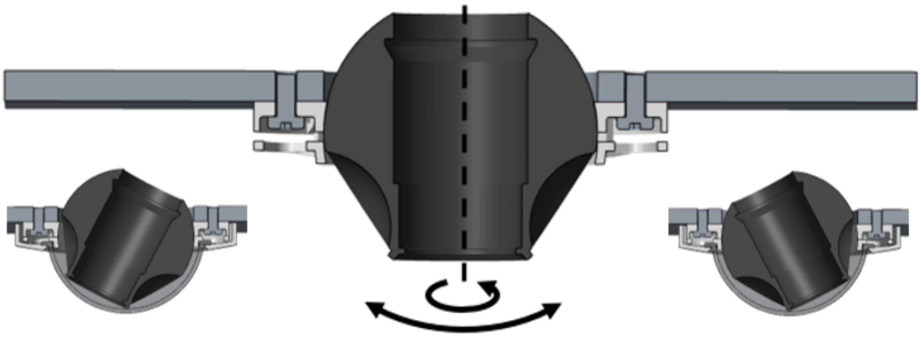


Figure 17.12 The first stage. Before brackets are locked together by the dome, the silicone ball can rotate freely to adjust to the perfect view for the camera.

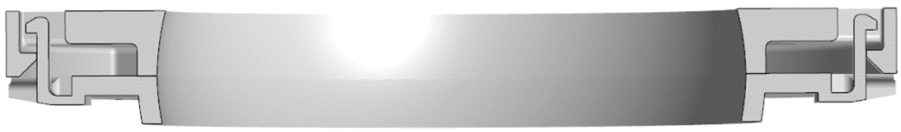


Figure 17.13 Detailed view of the second stage, the assembled brackets after they are locked by the dome part.

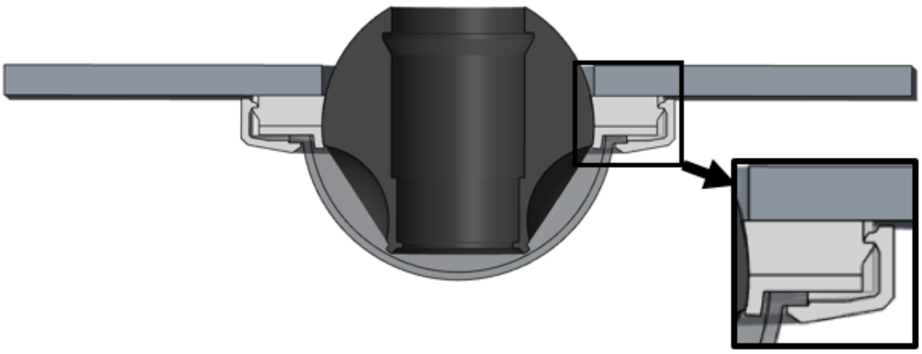


Figure 17.14 The second stage. Detailed cross section view of the brackets in the locked position, after the dome is installed.

The enlarged picture in Figure 17.14 illustrated how the dome pushes the brackets together and locks the construction using the two snap fits.

17.3.4 **Part three**

Part three consists of the USB network cable and the stopper, see Figure 17.15. The USB network cable is placed inside the stopper which in turn is pressed into place in the silicone ball, connecting the cable to the sensor unit. The function of the stopper is to keep the cable from being disconnected. The cable is connected to the main unit which will probably be placed on the roof of the elevator car. If someone accidentally tugs the cable on the roof, the stopper will prevent the USB connection cable from being disconnected from the sensor unit.

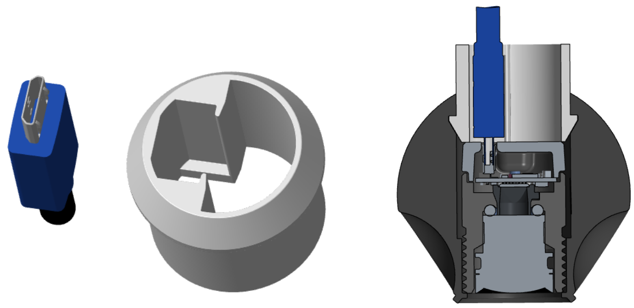


Figure 17.15 Detailed view of the stopper and part three.

17.3.5 **Demounting**

The camera can easily be demounted. By squeezing the Axis ”wings” on the cover ring that locks the installation, the snap fits holding the parts together will unlock. The dome and the cover ring can then be removed and the screws mounting the camera to the ceiling or wall can be loosened and the camera demounted.

17.4 Final prototype

A 3D printed version of the CAD assembly was created to serve as a proof of concept. Three iterations of 3D printing were done before the fastening mechanisms and adjustment of the ball worked smoothly. In the final prototype, the silicone ball was made in 3D printed plastic since making it in silicone at this early stage would be difficult, time consuming and costly. The glass dome used in the prototype is borrowed from another Axis camera. The size of this is therefore not optimized for the construction. However, it gives an indication as to how the final product would look. Figure 17.16, Figure 17.17 and Figure 17.18 shows the final prototype, except for the USB network cable and the stopper.

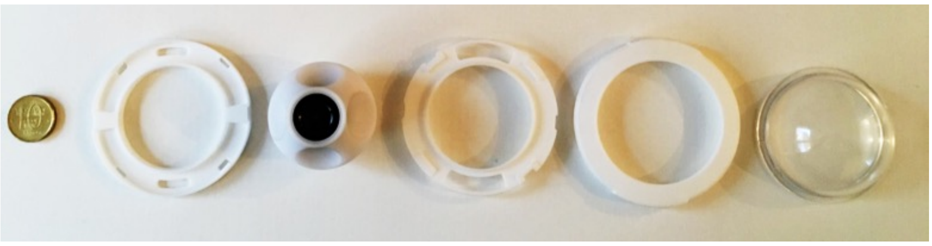


Figure 17.16 The parts of the final prototype.

Figure 17.17 Illustration of the pre assembled part one and part two.

Figure 17.18 The assembled final prototype.

17.5 Accomplishment of customer needs

Table 17.2 below shows weather or not the final concept fulfills the customer needs. Needs that have not been tested or are subjective have been marked with "-". All needs but one, number 17, are according to the team fulfilled in some manner. Number 17 can not be achieved since both power and network connection has to be collected on the elevator roof, which requires the involvement of an elevator technician.

Table 17.2 Results of fulfilled customer needs for the final concept.

No.	***Need***	***Importance***	***Fulfilled?***
	Field of view		
	Field of view covers the entire elevator car		Yes
1	Field of view allows for facial recognition*	***	Pinhole[a]
2	Field of view covers the elevator doors	**	Yes
3	Field of view only covers the elevator car		Yes
	Design		
	The design fits the interior design of the elevator		Yes
4	The design is customizable	*	Yes
5	The design is independent of different types of corners in the elevator car	***	Yes
	The design withstand vandalism		Yes[b]
6	The design is visible	***	Yes
7	The design communicates safety	**!	-
8	The design is discrete	**	Yes
	Installation		
	The installation process is cost efficient and simple		-
9	The design is modular	**!	Yes
10	The design allows for certain parts to be replaced separately	***	Yes
	The installation process requires minimal downtime		-
11	The installation process requires no interference with elevator technicians	*	No

a) As previously stated, to achieve good facial recognition Pinhole should be used in addition to the main camera.
b) The product must go through further testing to ensure that this need is fulfilled. However, according to employees at Axis the design should be able to withstand vandalism.

17.6 Cost analysis of final concept

A crucial part of product design is designing for cost. In order to be competitive, cost is an important factor when deciding whether a project is reasonable or not. Throughout the process the team has been in close dialog with Axis experts in order to get an understanding for the cost difference for different concepts. To get a more detailed cost analysis of the final product concept and its parts, costs were estimated based on the costs for similar parts from existing Axis products, as well as through consultation with a company frequently used by Axis to get consultancy regarding plastic parts for production. The estimated price results; including manufacturing, assembly and transportation to Sweden are presented in Table 17.3. The total estimated price for the concept, when making 1,000 products, is 3.1 USD.

Table 17.3 Estimated cost analysis for manufacturing, assembly and transpiration to Sweden for the final concept.

Part	*Estimated price*
Stopper	0.2
Silicone ball	0.9
Bottom bracket	0.4
Top bracket	0.4
Dome cover ring	0.6
Dome hemisphere	0.6
Total cost	***3.1***

17.7 Reflections on the final concept

The final concept accomplished most of the previously discovered customer needs, as presented in Table 17.2, which gives a good indication that this is a concept that potentially could meet a market need. The design is very small and discrete which give several advantages for use in the elevator environment. As the elevator environment is a confined space, a small and discrete design would be beneficial both in terms of installation possibilities as well as design aspects of the elevator. A smaller design is easier to implement in the elevator when the aesthetics of the elevator design is an important factor as it often is. Additionally, the estimated price for the camera housing is very low which is a huge competitive advantage.

The installation process of the camera housing will be fast, easy and only require tools for drilling the hole for the camera as well as two screws that mounts the housing to the ceiling or wall which is very beneficial and cost effective for the installer. The design allows for both installations in ceiling and walls which makes the design very flexible. The installation will require drilling a hole the size of the silicone balls diameter. This could be problematic if the ceiling or wall is made from thick and hard materials, but in a normal steel plate of about 2 mm thick this is not a hard procedure. If drilling of a hole in the ceiling or wall proves to be too difficult a back part can be developed for the housing that allows for mounting completely on the outside of the ceiling or wall, without the need of a bigger hole. This will however result in a camera that is in total about 30 mm higher and the camera will lose some of its design advantages. The part of the camera that will protrude from the outside of the wall or inner ceiling will only be about 30 mm long which is very beneficial for the installation both in inner ceiling as well as walls. Because the camera can be delivered in only three parts the risk of wrong installations is very low. The design is also very intuitive for the installer with guiding pegs and intuitive cut outs on the silicone ball for easy adjustment of field of view. Disassembling the camera is also facilitated through snap fits that will release when squeezing the classic Axis “wings” on the cover ring.

In the making of the prototype the silicone ball was 3D printed in plastic instead of using silicone. Because of this the team discovered that a hard plastic material could work just as well as the silicone material in terms of rotation and locking mechanisms. However, the soft silicone material has additional characteristics that could serve as an advantage and should therefore be explored further.

The design could possibly reduce vandalism. As discussed in the background study a camera in a confined elevator space can seem intrusive to one's personal space which could lead to vandalism. This feeling would by all means be reduced using a small dome. Because of the small size it would also be way harder for potential vandalisms to grab the camera. The design with the silicone ball will also possibly absorb a lot of potential hits and limit the possibility for breaking both the housing and more importantly the sensor unit. However, the design has an easy demounting mechanism that when placed within reach could be considered not vandal proof despite this function being unknown to the user of the elevator. Several vandal proof Axis cameras has a similar solution but these are not usually placed within reach. Axis will need to decide whether or not this solution will be considered vandal proof.

Despite the small design the camera will still be visible which is very important both in preventing vandalism of the elevator as well as in the aspects of people feeling safe when using the elevator.

Because the camera is a part of the modular FA series the small and discrete dome design would be perfect for combining several cameras in one elevator. This would be a good solution in for instance bigger elevators that need a bigger coverage or elevators that has doors on both sides of the car, in which it would be possible to place cameras above both doors.

Even though the product was initially designed to fit in an elevator environment the final concept might as well be placed in any other environment where a small, discrete and modular system would be beneficial as long as the camera meets the specifications for that specific environment. Examples could be public transport as well as retail.

18 Final specifications

This chapter presents the final product specifications for the chosen product concept.

18.1 Background

In Chapter 11, specifications for the concept were established based on previously discovered customer needs. The specifications were given a marginal and ideal value based on findings in the background study. When the final concept is selected these specifications are modified and a final value is decided based on the results of the concept development process. How well the final concept fulfills the previously established specification values gives a good proof of whether the concept meets initial customer needs or not.

18.2 Method

The final concept was analyzed to establish the values for the final specifications.

18.3 List of final specifications

Results for the final specifications is presented in Table 18.1. The Marginal and Ideal values from the initial specifications presented in Chapter 11 are included for easier analysis of the final values.

Table 18.1 Final product specifications.

No.	*Need No.*	*Specification*	*Importance*	*Unit*	*Marginal value*	*Ideal value*	*Final value*
1	*1, 4, 13*	Compatible with FA1105 sensor unit	5	binary	Yes	Yes	Yes
2	*1, 3, 4, 7, 9, 10*	Possible to mount on ceiling	5	binary	Yes	Yes	Yes
3	*1, 3, 4, 7, 9, 10*	Possible to mount on wall	5	binary	No	Yes	Yes
4	*1, 3, 4, 7, 9, 15*	Possible to mount on various materials	5	binary	Yes	Yes	Yes
5	*1, 3, 4, 7, 9, 15*	Possible to mount on variable thickness of wall/ceiling	5	binary	Yes	Yes	Yes
6	*8, 12, 13, 14, 15*	Easy to replace parts if vandalized	4	subj	-	-	Yes[a]
7	*12*	Intuitive design	4	subj	-	-	Yes[a]
8	*5, 6, 11*	Design to fit most elevator interiors	5	subj	-	-	Yes[a]
9	*5, 6, 11, 13, 14*	Adjustable design finish options	4	binary	Yes	Yes	Yes
10	*1, 3, 4*	Field of view of elevator car	5	%	<80	100	90-100
11	*1, 3, 4, 15*	Adjustable view	5	Axis rotation	x, z	x, y, z	x,y,z
12	*8*	Impact resistance	4	IK	08	10	10[b]
13	*8*	Resistance from dust and splash of water	4	IP	-	54	54[b]
14	*12, 15, 16*	Installation possible from within the elevator car	3	binary	No	Yes	No
15	*12, 15*	Tools required for installation	3	nb	1	0	2

a) The team in discussions with Axis concludes that the subjective specifications are all fulfilled in the final concept.
b) The IK and IP standards are not yet tested.

18.4 Reflections on final specification

Although the concept is still at an early stage where certain specifications are not yet set the final specifications lines up good with the previously established specifications in Chapter 11. In most cases the Ideal value has been met. The specification that only fulfills the marginal value is number 14 regarding possible installation from inside the elevator. This was unfortunately not met as the installation will require pulling network and power cables from the elevator car roof. Solving this issue will require more development and possibly a bigger development of the Axis portfolio than possible in this project. Specification number 15 regarding the number of tools required for installation the final number of tools ended up being even higher than the marginal value. This is a result from the fact that the final concept will require the drilling of a rather big hole in the ceiling or wall which the team did not foresee before going into the concept generation. However, the team is pleased with the final specification of two tools as in total the installation of the final concept is easy and time efficient.

19 Plan for further development

In this chapter, a suggestion for further development of the product concept is presented.

19.1 Background

The aim of this thesis was to provide a background study for how a camera could be implemented in an elevator environment. As for the presented product concept Axis will have to decide if further development of the product concept fits into their future project plan or not.

As described in Section 2.3.2 Figure 2.2, the generic product development process by Ulrich and Eppinger includes six steps; Planning, Concept Development, System-Level Design, Detailed design, Testing and Refinement and Production Ramp-up. This thesis covers the Planning as well as the Concept Development phase. For the product to be ready for production the four remaining steps need to be completed.

19.2 System-level design

The system level design covers the establishment of the product architecture, decomposition of the product into sub systems and preliminary design as well as preliminary plans for production and assembly.

The concepts different sub systems have already been developed, see Chapter 16 *Detailed development of final concept*. However, some functionalities as well as geometries has to be tested and developed further and decisions for assembly has to be made. The placement of the glass in the cover has to be looked harder in order to find a well working solution for assembly. Also, the mounting of both the sensor unit as well as the stopper part in the silicone ball has to be tested with the right materials in order to get proof of concept and develop the design of these parts further.

19.3 Detailed design

In the detailed design, the final specifications for the geometry and tolerances are established. Materials are selected and standard parts that are purchased from suppliers such as screws are identified.

The material selection for the parts has to be done. The material chosen for the cover ring and the back and front ring of the holder has to be selected so that they fulfill set specifications as well as provides well enough flexibility for the snap fit functions. The dome material has to be chosen so that it withstands vandalism and provides the best possible cover as well as vision for the sensor unit lens. The silicone material of the ball is the most uncertain part when it comes to material selection because this is not a material Axis has too much experience with. The silicone has to be a type that has minimal outgassing properties. Outgassing is something that happens to most silicone materials over time, where small particles for the silicon is released and build a layer on the glass dome and cover the view of the camera. This is not tolerable for an Axis camera and alternative silicone materials that does not produce the outgassing has to be chosen. The hardness of the silicone is another important factor that affects the functionality of the product. After consulting with manufactures the recommended hardness of the silicone would most likely be somewhere around shore 70. Also the difference in heat transfer in the different materials such as the silicone and the plastic materials used has to be research in order to get a well working construction.

The final design geometry has to be established and the tolerances for the geometry needs to be set. For instance, the tolerance for the snap fits locking the installation are an important function that has to be quite accurate in order for the concept to work as desired. Also, the diameter of the silicone ball as well as the brackets has to be optimized to provide the ideal friction when open and locked.

To optimize the design of the geometry and minimize the use of material a FEM-analysis should be conducted on all parts. To strengthen certain parts and minimize the use of materials ribs can be added to crucial point in the geometry such as inside the cover ring.

Furthermore, the product concept has to be optimized for manufacturing. The presented design has not been studied in detail from a molding perspective and has to be optimized to fit the molding process. This can be done through a digital analysis of the parts and follow up by implementing suggested design improvements in the design.

Additionally, a potential plan for alternative product options has to be decided. One important identified customer need was that design is important in an elevator environment and as discovered elevator design varies a lot. Therefore, a possibility would be to offer several options for material finish on the cover ring, similar to the *Axis M2014* shown in Figure 19.1. This allows customers to customize the solution to fit their specific elevator designs.

Figure 19.1 Axis cover rings in different material finish for the M2014 net work camera.

The final design also has to be checked so that it is in line with the Axis Design Policy.

19.4 Testing and Refinement

The testing phase involves evaluation of several prototypes both 3D printed as well as prototypes made by the intended production process.

The finished product design should be tested with the correct materials. To validate the specifications such as IK and IP, suitable tests on the product has to be done by test engineers. The design should also be tested in the elevator environment in order to validate the functionalities and gather insights on relevant information for the installation guide. Tests should also be done using the intended production process and tools for the product in order to verify the functionalities of the product and production line.

19.5 Production Ramp-Up

During the production ramp-up the intended production system is tested and the workforce is trained to prepare for production roll out of the product.

To prepare for production it will be important for Axis to have close contact with the production plant and other suppliers. The production workforce has to be trained to this specific production process and get to know the product and it functionalities. How the assembly will be done has to be communicated and instruction for potential manual assembly has to be provided. Also the packaging and transportation of the products needs to be decided.

PART IV
Conclusion and discussion

20 Conclusion and discussion

This chapter presents the conclusion and discussion for the thesis project. The chapter involves recommendations to Axis, discussions on discoveries and learnings from the project as well as a more personal reflection on the process.

Based on findings in the background study as well as results from the concept development phase the team recommends Axis to continue on with the project. The camera housing for the *FA1105* sensor unit will potentially be a good extension of the FA series product family. It will expand the use case for the *FA1105* sensor unit and give Axis a well fit camera solution for both elevator environment as well as other environment where a modular, durable and small dome camera would be beneficial.

The comprehensive background study reveals a complex elevator environment where Axis could benefit from offering custom made solutions as well as providing expertise on options for network connection alternatives; a crucial factor for Axis competitive advantage. One identified aspect that could possibly give a very cost-efficient solution is by eliminating the need for elevator technicians in the installation process. As for now all camera solutions including the presented concept in this thesis would require an elevator technician to stop the elevator to get both network and power from the elevator roof. A solution eliminating this part would possibly have a great competitive advantage.

As for the theoretical methods used in the project the team is pleased with how they provided a good structure throughout the project. The Double Diamond Method, presented in Section 2.3.1, provided a very good overview and visualization of the development process which helped the team visualize the different stages of the process and separate the divergent information exploring phases from the convergent information processing phases throughout the entire project. The Ulrich and Eppinger's product development process model, presented in Section 2.3.2, gave a great base for the concept development part of the project that was easy to follow. The comprehensive study of customer needs, suggested in the Ulrich and Eppinger's method, was very valuable for the project and gave essential information that helped the team understanding what the final concept should fulfill. Also the systematic selection matrixes provided in the method was also very useful for the team and helped a lot with structuring the selections and give a qualitative analysis of every concept in order to select the best possible solution.

The work distribution and initially set project plan worked very well for the team. Some minor differences occurred throughout the project because of the many iterations during the concept development phase, but the team managed to stick to the plan. See appendix A for detailed initial and actual project plan.

During the thesis, both team members have expanded their product development and design skills and also been given great experience of project management. The collaboration between the team members has worked very well and the different knowledge bases from studying Technical Design and Product Development has been a great advantage. The collaboration with employees and supervisors at Axis as well as LTH has worked very well and been very valuable for the project as well as for expanding the team member’s knowledge.

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Appendix A Work distribution and time plan

The appendix includes a presentation on the initial and actual project plan.

The team used a Gantt Chart to present the product plan. Initially the activities were set based on the activities presented in the Ulrich & Eppinger's Product Development Process [2] supplemented with the steps of the Double Diamond [1] method represented by the diamond shaped squares in the Gantt Charts. The timeframe for the activities was initially estimated based on the team's own experience as well as advice from supervisors.

The team managed to stick to the plan for most of the project with only minor differences from the initial and the actual project plan. Some activities were finished earlier, some took a bit more time than estimated. Two more activities were also added to the project plan during the time, Analysis and selection of camera technology and Final Concept Selection due to new insights during the project.

A.1 Initial Project plan

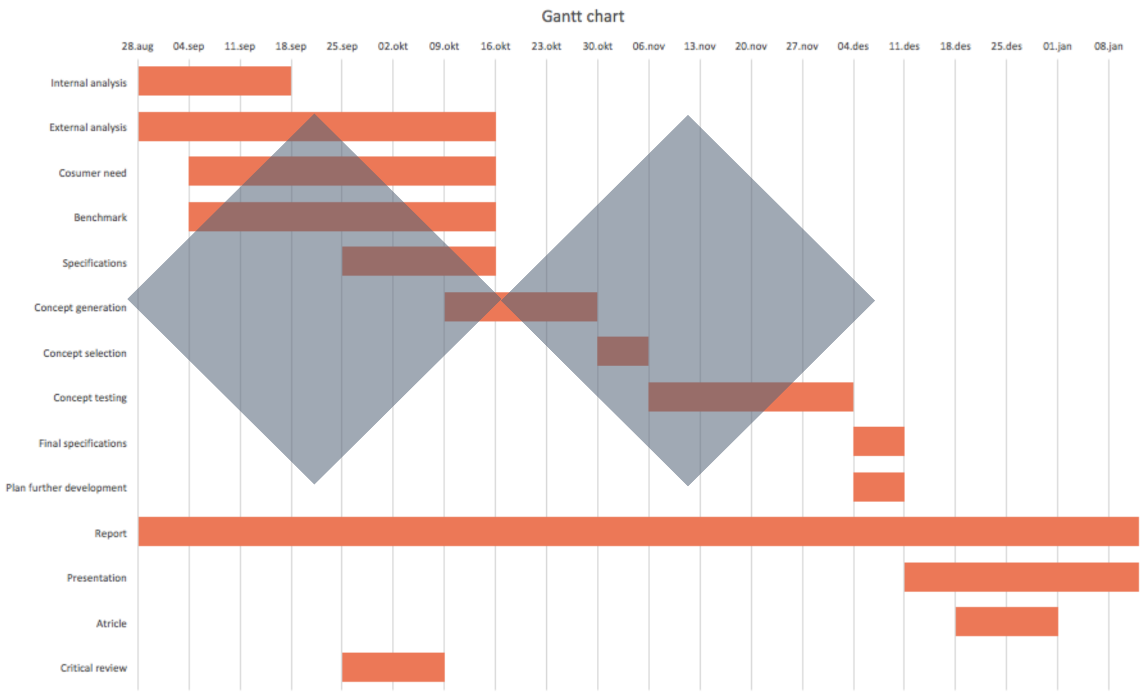


Figure A.1 Initial Gantt chart for the project.

A.2 Actual Project plan

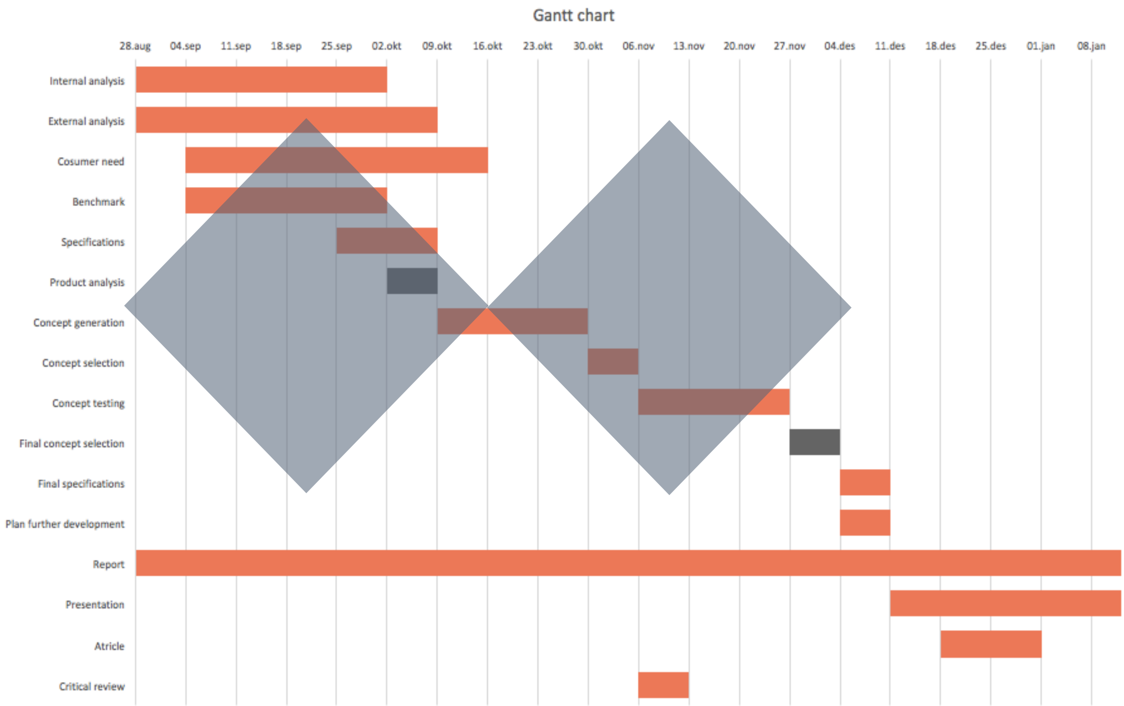


Figure A.2 Actual Gantt chart for the project.

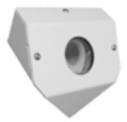
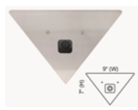
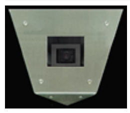
Appendix B Benchmark

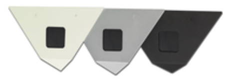
This Appendix includes benchmark of existing elevator camera solutions.

The benchmark is presented in two tables; one for corner mounts solutions and one for other elevator camera solutions.

B.1 Corner mount solutions

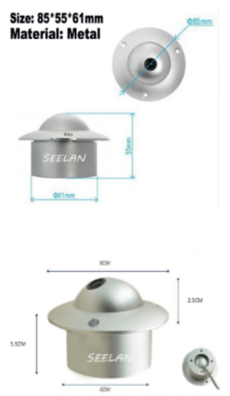
Table B.1 Benchmarking of corner mount cameras for elevators.

No.	***Name***	***Picture***
1	Pelco HS1500 [B.1]	
2	Wren CM1WAXFX8D [B.2]	
3	American Dynamics AD1305 [B.3]	
4	Speco Technologies CVC605CM [B.4] MSRP $220	
5	Alpha communications CHCSS [B.4]	
6	Bosch Flexidome IP 9000 – MSRP $920 [B.6]	

7	Ganz Security CMC-37-4 [B.7]	
8	1.Mobotix MX-V15D 2.Vivotek CD8371 3.Videocomm CCD-S650EV 4.Everfocus EC900IR 5.Speco CVC607CMTP2.5 6. Cantek [B.8]	

B.2 Other elevator cameras on the market

Table B.2 Benchmarking of camera solutions for elevators.

No.	*Name*	*Picture*
1	1080P IP flying saucer elevator monitoring video camera [B.9]	
2	1.0MP 720P Plastic Dome IP Camera for Elevator Using 2.8-12mm Varifocal Lens [B.10]	
3	POE 720P Dome UFO Lift Wide Angle 2.5mm mini IP camera P2P Function Elevator camera Metal Security Camera POE camera [B.11]	

Appendix B References

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Appendix C Elevator design

This appendix presents examples of different elevator car interior designs.

When exploring elevator designs the team discovered a great variety. Some example designs are presented in Figure C.1-5. The designs are both own observations as well as research done through the web for a variety of elevator manufacturers. The difference in materials used as well as corners and mounting of the ceiling was primarily the focus for the research.

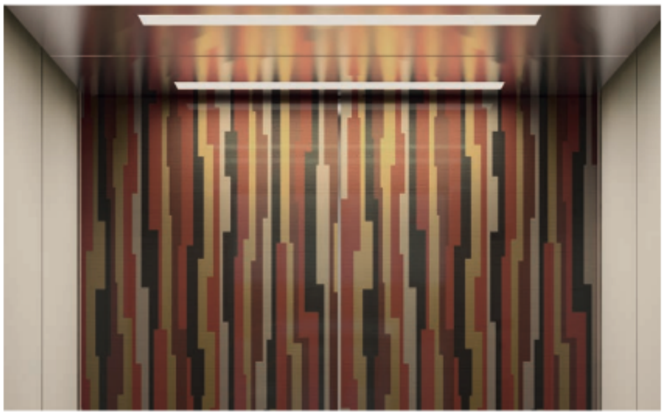


Figure C.1 Examples of elevator design options from Kone. [C.1]

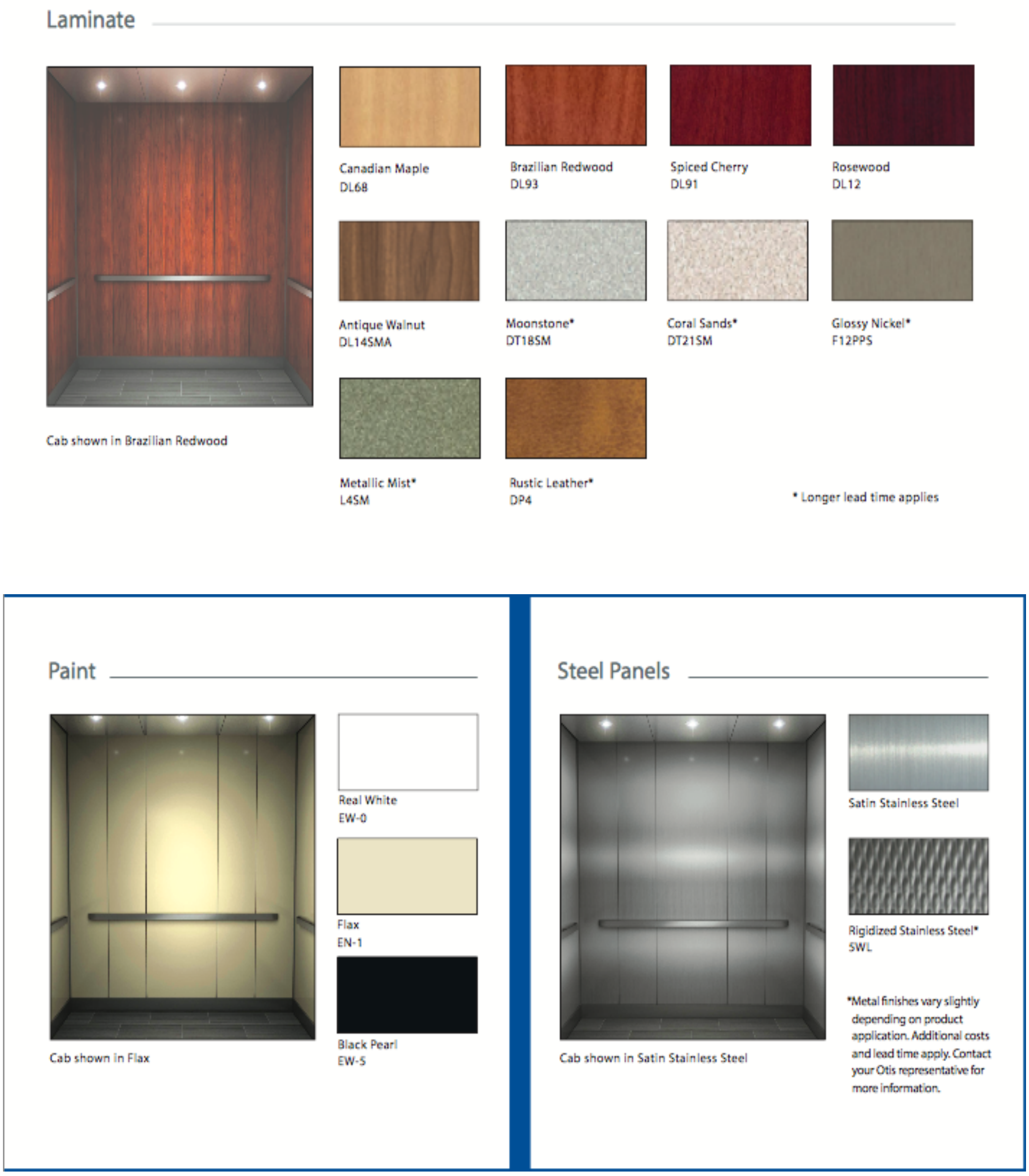
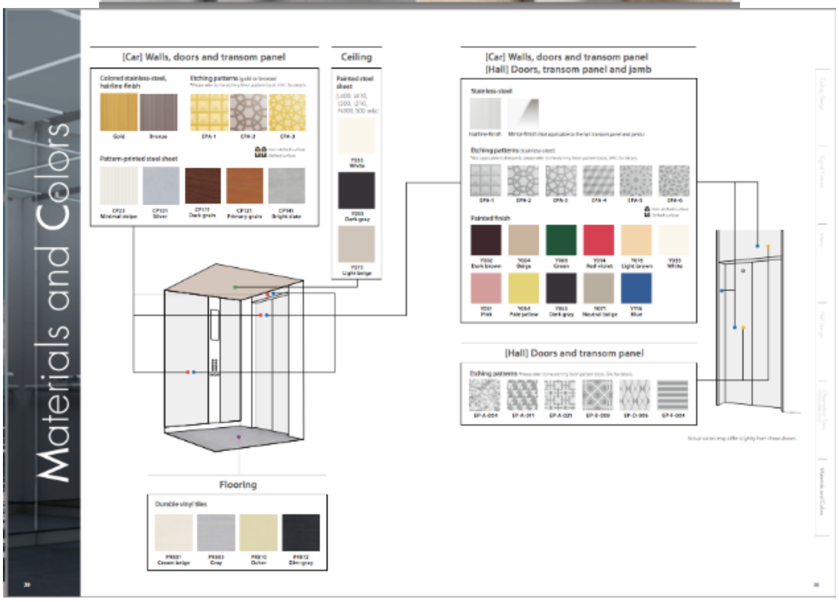


Figure C.2 Examples of elevator design options from Otis. [C.2-3]

Ceiling
Design



Materials and Colors
[Car] Walls, doors and transom panel
Colored stainless-steel, hairline finish
Etching patterns
Gold
Bronze
Pattern-printed steel sheet
Ceiling
Painted steel sheet
Y033 White
Y003 Dark gray
Y273 Light beige
[Car] Walls, doors and transom panel
[Hall] Doors, transom panel and jamb
Stainless-steel
Etching patterns
Painted finish
Dark brown
Beige
Green
Red-violet
Light brown
White
Pink
Pale yellow
Dark gray
Neutral beige
Blue
[Hall] Doors and transom panel
Etching patterns
Flooring
Durable vinyl tiles
Cream beige
Gray
Ocher
Dim gray

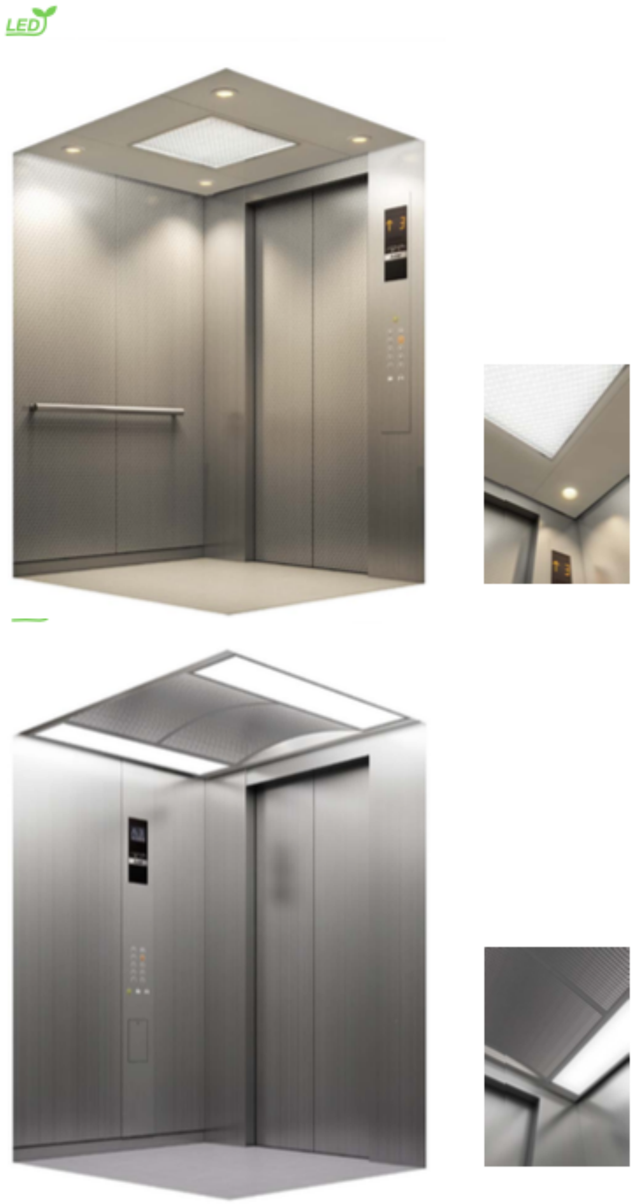


Figure C.3 Examples of elevator design options from Mitsubishi. [C.4]

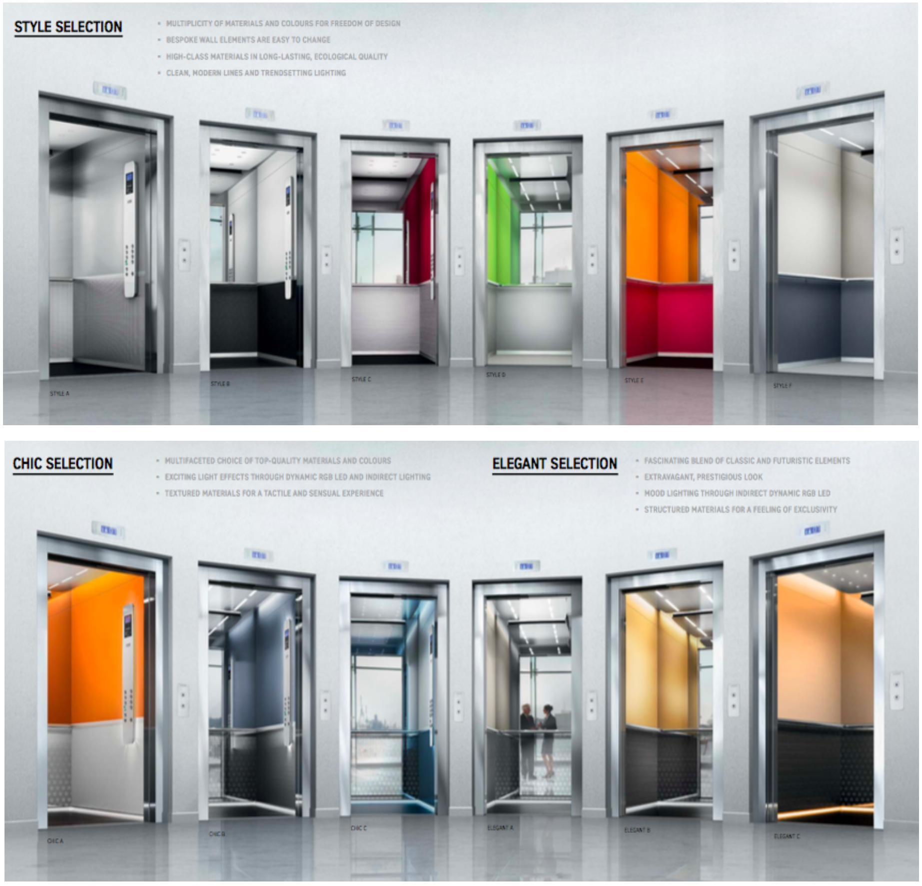


Figure C.4 Examples of elevator design options from ThyssenKrupp. [C.5]


Figure C.5 Example of privately explored elevator designs. [C.6]

Appendix C References

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[C.6] Pictures taken by Anna Papée and Fredrik Axelsson.

Appendix D Interview e-mail

This appendix shows the e-mail interview between the team and elevator manufacturers regarding the elevator environment. As the interviews were done in Swedish the results are presented in Swedish as well.

Table D.1 Results from e-mail interviews with elevator manufacturers.

Fråga	***ThyssenKrupp***	***Otis***	***Schindler***
Väggar			
Vilket material är väggplattorna uppbyggda av, både beklädnaden samt materialet i plattorna?	Trä eller stål och beklädnaden är oftast laminat eller rostfri plåt.	Några "plattor" är det sällan frågan om. Ofta är korgen uppbyggd av vertikala sektioner. Ytterväggarna kan vara av trä eller plåt. Inredningen kan vara allt från bara målad till laminat, trä eller glas.	Vanligtvis en stålplåt med en tjocklek mellan 1…2 mm, beroende på användningsområde. Finns också väggpaneler som består av så kallade Honeycomb-paneler. Beroende på kundönskningar kan man limma eller tejpa fast ytskikt element, t.ex. HDF-plattor i olika färger eller bakmålad glas
Vilken tjockleken varierar väggplattorna mellan?	2mm stål, 1,5mm rostfri plåt eller 25mm trä.	Kan vara allt från några mm till flera cm.	Stålplåt har en tjocklek mellan 1-2 mm.
Om något behöver fästas i väggen, är det då okej att borra i den?	Ja.	Beror på hur korgen är konstruerad, men oftast går det bra.	Brukar inte vara något problem. Det kan dock finnas tjänslig utrustning på baksidan, t.ex. kablage
Vem har rätt att plocka ner plattorna alt. borra i dem? Endast era hissmontörer eller övriga installatörer som t.ex. Elektriker som ska installera en kamera?	Det bör vara en person som har kännedom om hiss eftersom där kan ligga elkablar mm bakom väggarna.	Det är fastighetsägaren som äger hissen alltså är det vederbörande som bestämmer detta.	Så länge vi har Service på hissen är det endast vi som utför sådana arbeten där man förändrar bärande element av hissen. Är hissen inte längre i vår portfölj kan vi inte undvika att obehörig personal manipulerar

			hissen. Det går dock alltid att be om råd, så kan våra tekniker vara behjälpliga (då oftast mot ersättning)
Hur monteras plattorna vanligtvis i hisskorgen? Är det vanligtvis ett mellanrum mellan plattorna och yttre delen av hisskorgen eller är de monterade direkt mot "skalet" av hisskorgen?	Det limmas oftast upp direkt på väggen så inga mellanrum.	Inredningen är ofta limmad mot ytterväggarna.	Det finns olika kombinationer. Är ytskiktelement limmade blir det svårt att bytta ut de vid en skada, men det blir en bra performance gällande ljud och vibrationer, det är en rejäl konstruktion. Tejpade element går lättare att byta ut.
Har era hörn i hissen vanligtvis en 90 graders vinkel, en radie eller en glipa?	90 graders vinkel är absolut det vanligaste men det finns också rundade hörn.	Det vanligaste är 90 graders vinkel.	90 grader är det absolut vanligaste. Det är väldigt svårt att få olika element att matcha med varandra till 100 % pga tillverkningstoleranser na. Därför brukar man använda smyg, hörnprofiler och lister där väggelement möter varandra.
Tak			
Vilket material är takplattorna uppbyggda av, både beklädnaden samt materialet i plattorna?	Trä eller plåt.	Samma sak här, det är inte fråga om några "plattor" utan ett helt tak eller ett tak i sektioner.	Vanligtvis är taket i rostfritt stål, målad eller utformad som bärande struktur i syntetmaterial. Jag har aldrig sett att man har limmat eller tejpad ytskikt under ett innertak. Helt enkelt pga faran att det kan lossna och skada personer.
Vilken tjockleken varierar takplattorna mellan?	Plåt 2-3mm, trä 25mm	Från några mm till några cm.	En bärande konstruktion i rostfri plåt är mellan 1…2 mm tjock med förstärkningsremsar på baksidan.
Om något behöver fästas i taket, är det då okej att borra i det?	Ja	Oftast	Oftast ja, men det bör inte hänga något i det. Men det är t.ex. inget problem att montera en dold högtalare på

			insida. En övervakningskamera skulle nog också gå att fästa.
Vem har rätt att plocka ner plattorna alt. borra i dem? Endast ni som företag eller övriga installatörer som t.ex. elektriker?	Det bör vara en person som har kännedom om hiss eftersom där kan ligga elkablar mm bakom väggarna.	Det är fastighetsägaren som äger hissen alltså är det vederbörande som bestämmer detta.	De som har service på hissen.
Hur monteras plattorna vanligtvis i hisskorgen? Är det vanligtvis ett mellanrum mellan plattorna och yttre delen av hisskorgen eller är de monterade direkt mot "skalet" av hisskorgen?	Taket är oftast 2 träskivor men sen kan där hänga ett innertak med belysning i och där är ca50mm mellanrum.	Antingen är de monterade direkt mot skalet (vanligast), men det är också ganska vanligt med undertak som har ett mellanrum till yttertaket.	Oftast är det en glipa mellan taket och väggarna. Det går inte att få det utan glipa pga toleranserna, samt att man måste kunna plocka ner taket för att kunna byta ut ljusarmaturer.
Krävs det viss klassificering då något ska vara placerat i takplattorna? Vi har sett att många lampor i hissar är IP54 klassade. Är det en standard ni använder er av? Finns det andra standarder som måste uppnås?	Nej det finns klassificering eller IP klass på det som sitter i hisstaket.	Finns ingen direkt "hisstandard" för detta. Det är el-regler som tillämpas för detta.	I en vanlig hisskorg räcker det med IPX2. Högre klassningar är inget krav men kan vara bra ha beroende på hissens användningsområde.
El och kablar			
Om man vill koppla in en kamera, hur får man ström till den? Vilken volt finns det tillgång till?	Det finns stort sätt alltid 230V ovanpå hisskorgen ibland även 24V.	Oftast finns det 230 vac neddraget till korgen till belysning, eluttag på utsidan av korgtaket etc.	230 V kan man plocka ifrån hisstaket. Olika hisstyper kan även ha 24 V.
Finns följande kablar i befintliga hissar för att koppla till nätverk? Coax, 2 wire, nätverkskabel (RJ45)? Eller hur brukar ni lösa det om kunden vill ha tillgång till nätverk inuti hissen?	Det är inte standar med någon nätverkskabel till hisskorgen men det går att eftermontera.	Dessa kablar finns normalt inte. Man får hänga ned en kompletterande kabel från maskinrum till hisskorgen om man behöver dessa kablar.	I en standard hiss finns det inga lediga trådar i hängekabeln. Och vanligtvis vill vi skilja mellan egen utrustning och tredje parts utrustning för att undvika att de olika komponenterna stör varandra. Vanliga RJ45 kablar uppfyller inte krav på hängekabel. Olika typer av korgkablar finns t.ex. här: https://www.hissmekano.se/category/117

Om kunden vill installera en kamera som kräver ström och ska kopplas till nätverk, hur går ni tillväga för att förbereda det för installatören av kameran? Dvs. var hittar installatören de sladdar som behövs för installationen?	Vi installerar kabeln som installatören av kameran vill ha samt förbereder matning till honom och det installeras på hisstaket. Sen vid installeringen av kameran så måste vi vara med vid inkopplingen eftersom kablaget är på hisstaket.	Detta är inte med på någon hiss som standard, men kunden kan naturligtvis köpa till detta. Tillgång till nätverksuttag i exempelvis hissmaskinrum måste fastighetsägaren ombesörja. Vi kan exempelvis avsluta kablaget på plint på utsidan av korgtaket.	Man samordnar installationen på plats. Dvs hisstekniker och elinstallatören jobbar tillsammans. Det är också en säkerhetsfråga då man måste jobba på korgtaket (fallrisk), sätta fast kabeln på schaktväggen osv. Aldrig att elinstallatören får utföra arbetet själv utan uppsikt.

Appendix E Testing of camera system

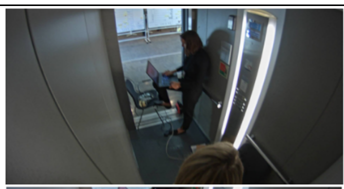
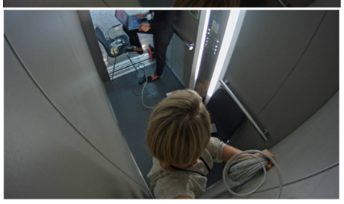
This Appendix presents results from the testing of the F and FA camera system.

The sensor units were tested in an elevator by taking pictures from different angles and placements in the elevator. The test elevator is a Otis Gen2 13 persons or 1000kg. It has a depth of 210 cm, width of 110 cm and height of 220 cm.

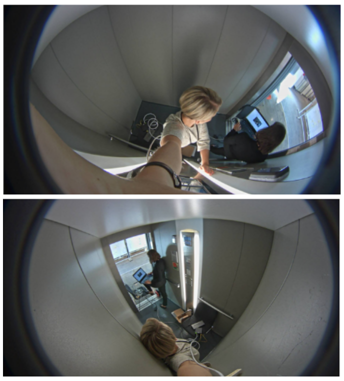
The results from the product testing are divided into Test 1 and Test 2. The first test was a general test to figure out what sensor units could be suitable for an elevator environment. The second test was a more systematic test of the sensor units and their exact placement in the elevator. The results are presented in Table E.1 and 2 and gives results of pictures taken as well as general comments.

E.1 Test 1: Suitable cameras

Table E.1 Results from Analysis and selection of camera technology Test 1.

Camera	*Picture*	*Insights*
F4005-E, Dome 	 	**View of car:** Hard to adjust camera to cover entire car. Results in blind spots either beneath the camera or on the opposite side by the door. The camera is placed in a corner and a fair bit of the video consists of walls. **View of faces:** Hard to capture both faces in the car. Can’t identify people facing the door.

F1035-E, Fisheye



View of car: The camera is placed on top of the control panel in the first picture and in the corner in the second one. The first picture gives a better view of the car. Walls take up most of the pictures and the people in the elevator are not the focus of the picture. There are no blind spots in either of the pictures, they cover the car completely.

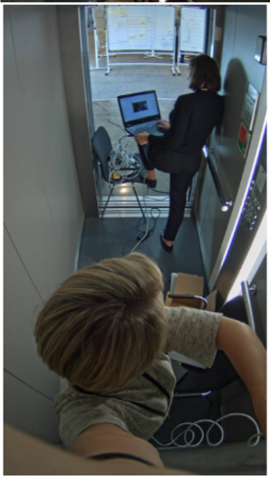
View of faces: The faces are less recognisable with this lens and somewhat distorted.

F1025, Pinhole

View of car: The camera does not give a clear overview of the car.

View of faces: Camera is suitable to place further down so that the image covers the faces of the people in the car. The pinhole lens gives the best view of faces. Camera is placed on the side of the door in the second picture and on the control panel in the third.

F1015, Varifocal



View of car: The first picture gives a poor view of the car. In the second picture the camera is twisted 90 degrees and the picture is later on rotated to an upright position. The same effect can be achieved through set ups in the software. This would be suitable for rectangular elevators. In the same way it would be possible to rotate for instance the dome, which would result in a better picture. The camera is placed in the middle of the back wall.

View of faces: Hard to capture both faces in the car. Can’t identify people facing the door.

F1005-E, Standard

View of car: Placing the standard lens just below the ceiling on the back wall and rotating the image seems to give a clear view of the car, as shown in the first picture.

View of faces: Placing the camera in the corner next to the doors gives a better view of the people in the elevator who are facing the door.

E.2 Test 2: Ideal main camera

The cameras in Test 2 are positioned according to the map in Figure E.1 where the double headed arrow symbolizes the elevator door and the line symbolizes the panel.

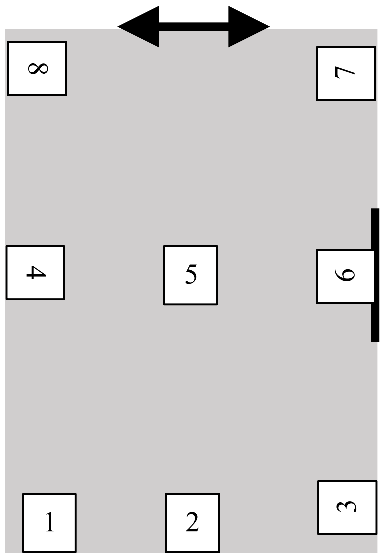


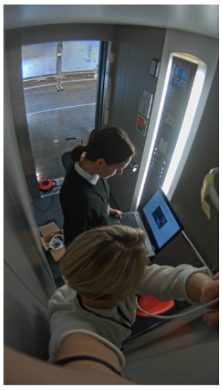
Figure E.1 Positions in elevator for systematic testing of ideal camera. The arrow at the top represent the door and the black line at the right the control panel.

Table E.2 Results from Test 2 of the Analysis and selection of camera technology.

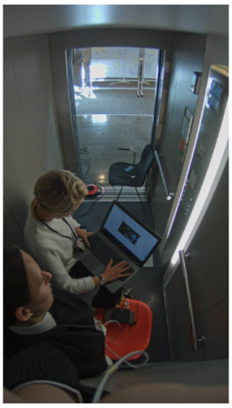
Pictures and corresponding positions

Standard F1005-E

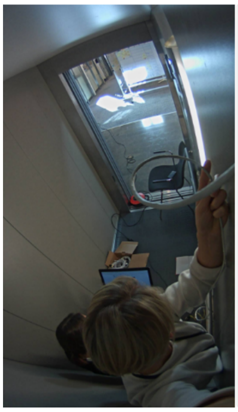
1.



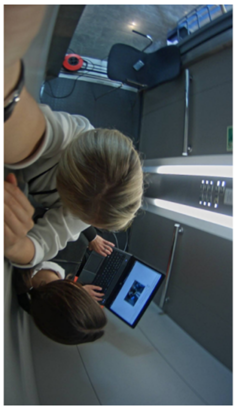
2.



3.



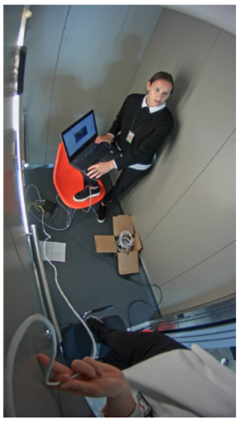
4.



5.

6.

7.

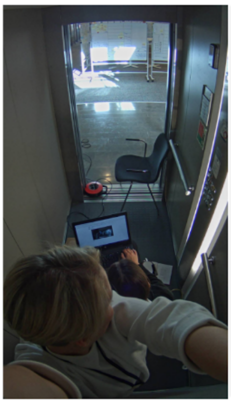


8.

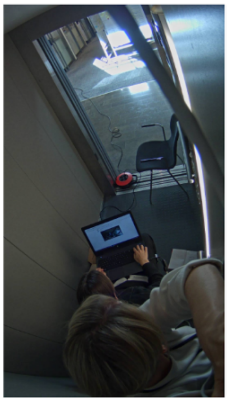
Varifocal F1015

1.

2.



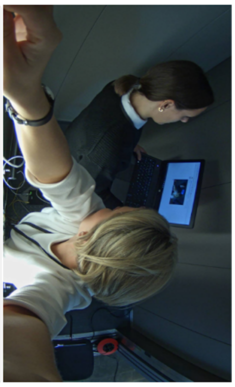
3.



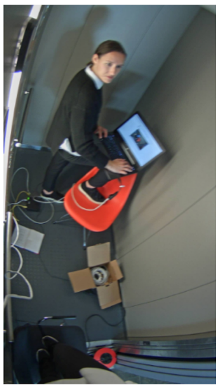
4.

5.

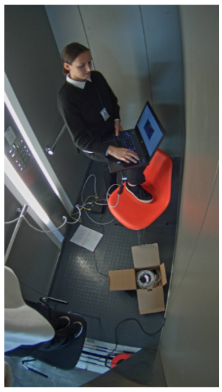
6.



7.



8.



Fisheye F1035-E

1.

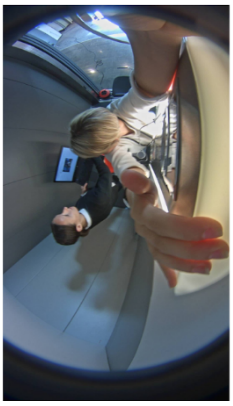
2.

3.

4.

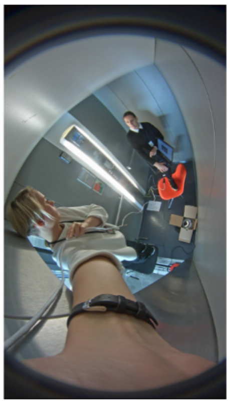
5.

6.



7.

8.



Pinhole F1025 – Pictures are taken from a height of 1.80m

1.

2.

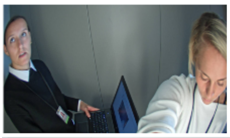
3.

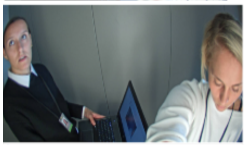
4.

5.

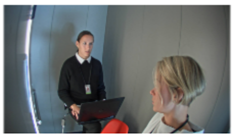
Not relevant

6.

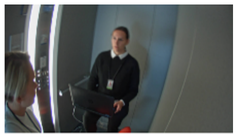




7.



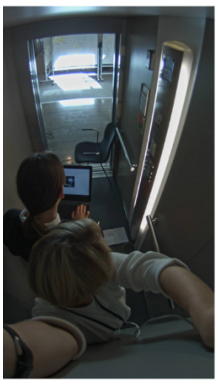
8.



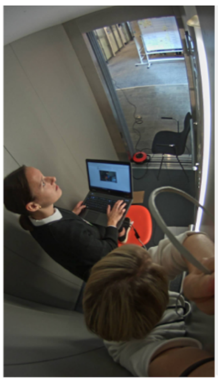
Dome F1005-E

1.

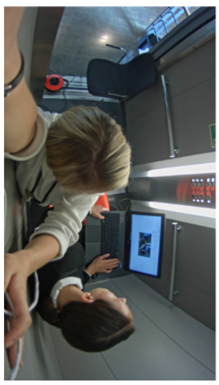
2.



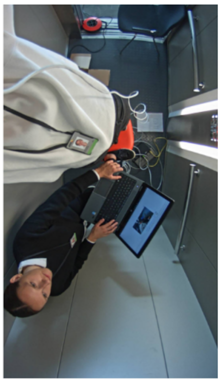
3.



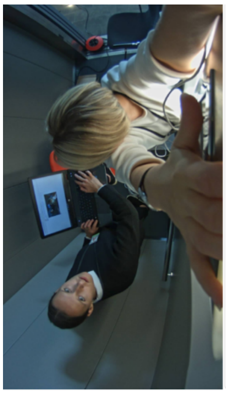
4.



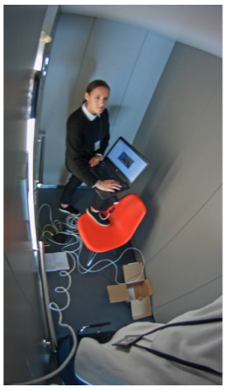
5.



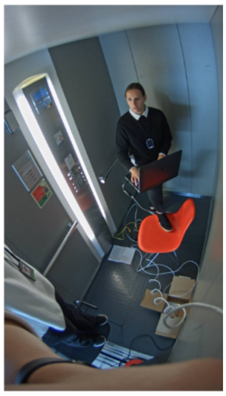
6.



7.



8.



Appendix F IP and IK rating standards

This appendix aims to explain the IP and IK rating standards.

F.1 IP rating

IP stands for Ingress Protection and is a rating system provided by the European Committee for Electrotechnical Standardization. Numbers following the abbreviation describes the level of protection against ingress of solids and water of equipment inside an enclosure. [F.1] A higher number indicates a higher level of protection. The first number regards solids, it can vary from zero to six. Level 5 protects against dust limited ingress. The second number regards water, it can vary from zero to eight. Level 4 protects against water sprayed from all directions. [F.2]

F.2 IK rating

The IK ratings refers to the European standard EN62262 that presents how well an electrical equipment can withstand external mechanical impacts. [F.3] The IK code ranges between IK00 and IK10. [F.4] Normal parameters for the tests are shown in Figure F.1. At Axis these tests are performed by test engineers. The IK rating for Axis products vary according to market segment and what the cameras are intended for. Axis usually have a high IK standard for their products and have a range of products in the IK09 and IK10 range.

IK code and impact energy (values changed in Amd 1:1998)

IK code	IK00	IK01	IK02	IK03	IK04	IK05	IK06	IK07	IK08	IK09	IK10
Impact energy (joule)	*	0.14	0.2	0.35	0.5	0.7	1	2	5	10	20

Impact test characteristics

IK code	IK00	IK01 to IK05	IK06	IK07	IK08	IK09	IK10
Impact energy (joules)	*	<1	1	2	5	10	20
R mm (radius of striking element)	*	10	10	25	25	50	50
Material	*	polyamide[1]	polyamide[1]	steel[2]	steel[2]	steel[2]	steel[2]
Mass kg	*	0.2	0.5	0.5	1.7	5	5
Pendulum hammer	*	Yes	Yes	Yes	Yes	Yes	Yes
Spring hammer	*	Yes	Yes	Yes	No	No	No
Free fall hammer	*	No	No	Yes	Yes	Yes	Yes

Figure F.1 Illustration of the IK rating system.

Appendix F References

[F.1] IEEE GlobalSpec. (2017). Standard: CENELEC - EN 60529. Retrieved December 17, 2017, from http://standards.globalspec.com/std/1638833/cenelec-en-60529

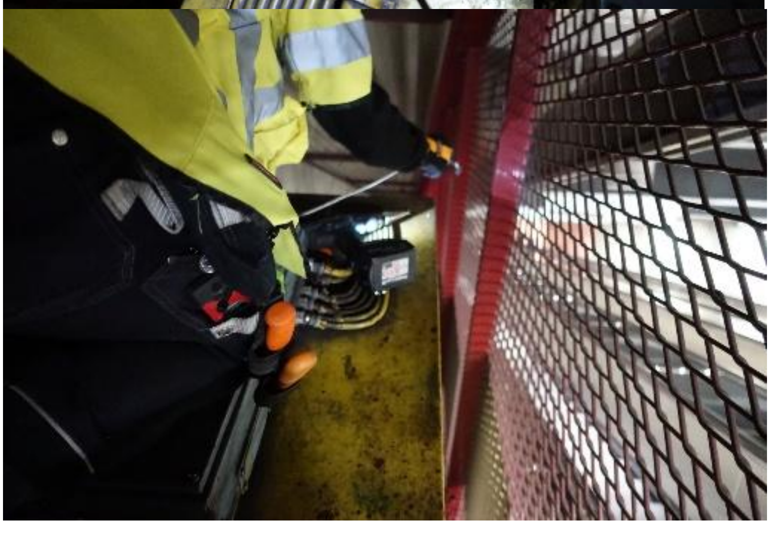
[F.2] The Engineering ToolBox. IP - Ingress Protection Rating. Retrieved December 17, 2017, from http://www.engineeringtoolbox.com/ip-ingress-protection-d_452.html

[F.3] European Standards. (1995). *Degrees of protection provided by enclosures for electrical equipment against external machanical impacts (IK code).* (CSN EN62262)

[F.4] Wikipedia. (2017). EN 62262. Retrieved December 17, 2017, from https://en.wikipedia.org/wiki/EN_62262

Appendix G Pictures from camera installation at SL

This appendix presents pictures from the installation of the camera AXIS M3044-V in an elevator at a metro station in Stockholm.



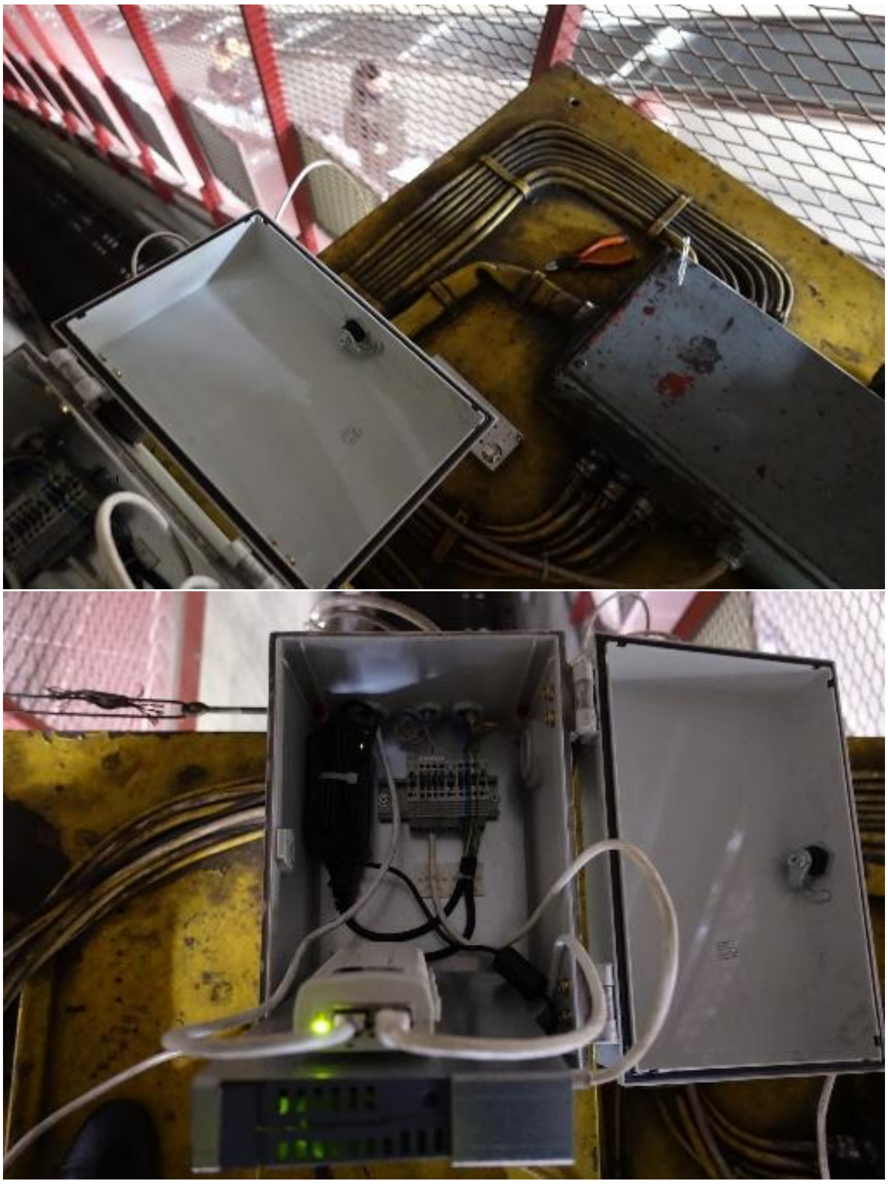


Figure G.1 Pictures of the installation taken from the elevator roof. Shows the connection solution made during the first installation and how the wires are drawn down to the elevator car. The converter and other electrical connections are placed in the white dust- and waterproof box seen on the lower pictures. [G.1]

Figure G.2 The installed AXIS M3044-V camera in the elevator. [G.1]

Appendix G References

[G.1] Pictures taken by Marie Bye Løken and Michel Chen

Appendix H Drawings of Final Concept

This appendix presents the drawings of each part of the final product concept.

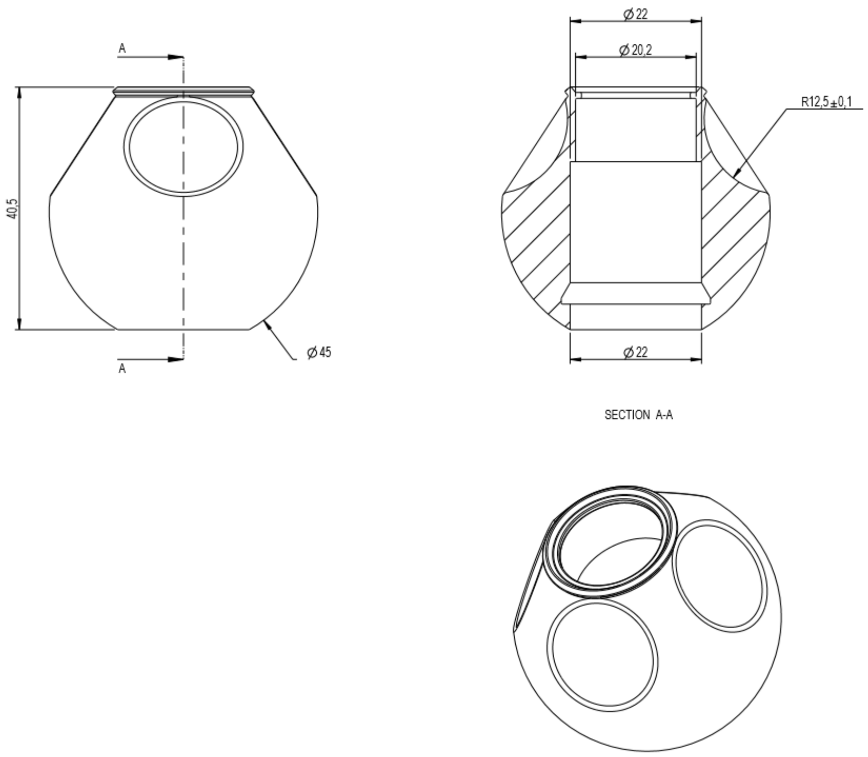


Figure H.1 Drawing of the silicone ball with some main measurements.

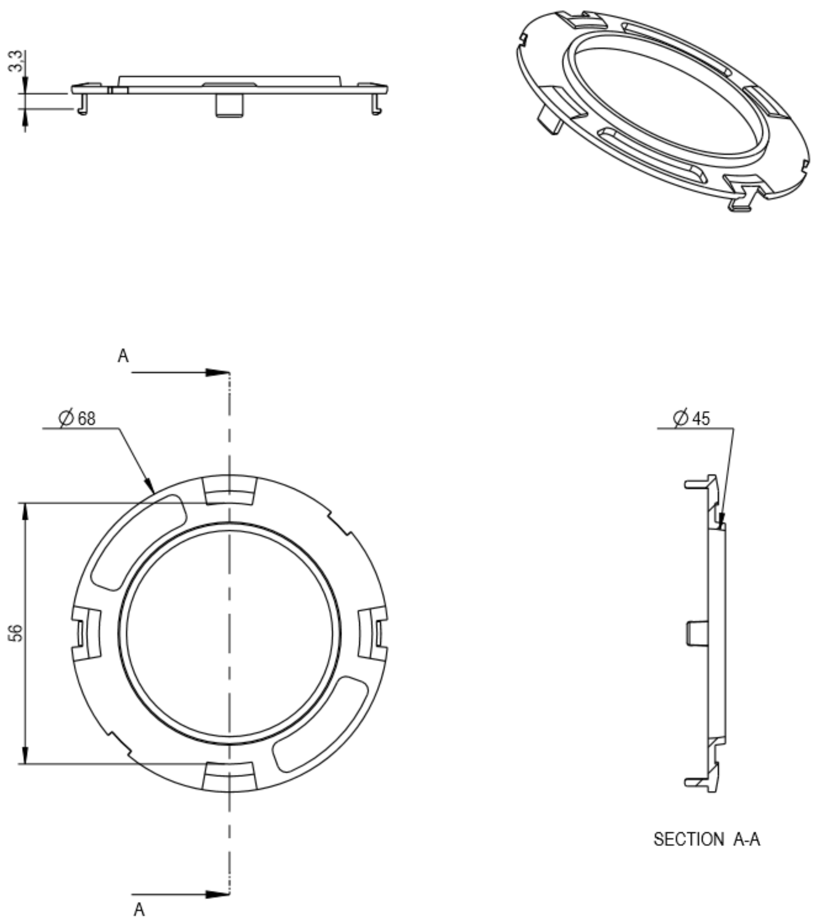


Figure H.2 Drawing of the top bracket with some main measurements.

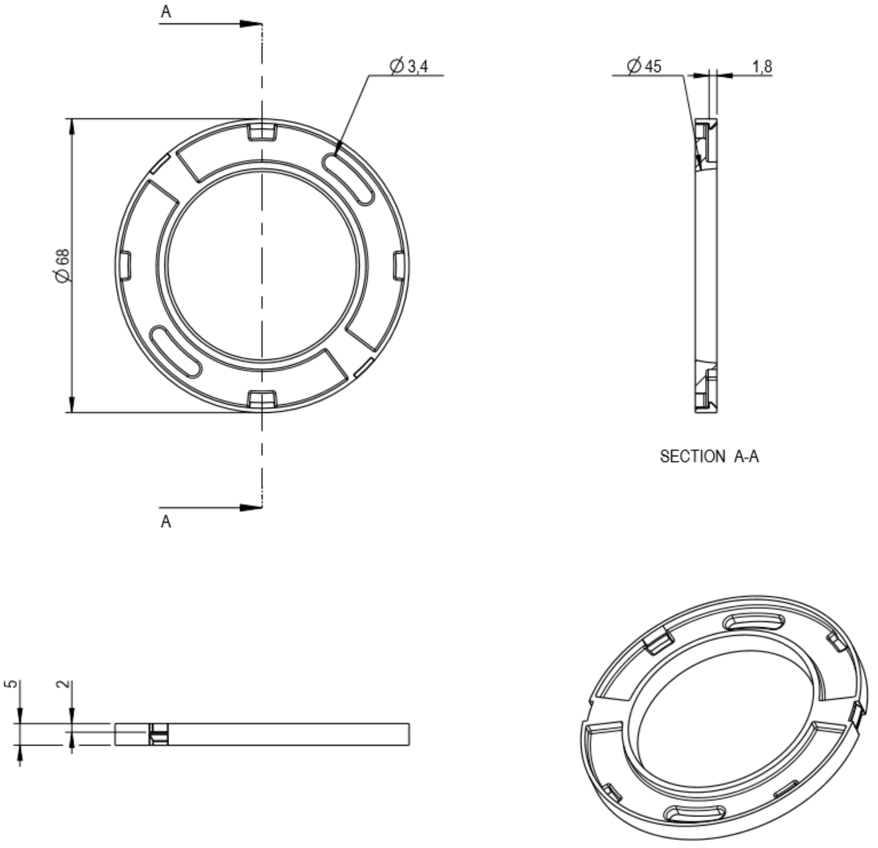


Figure H.3 Drawing of the bottom bracket with some main measurements.

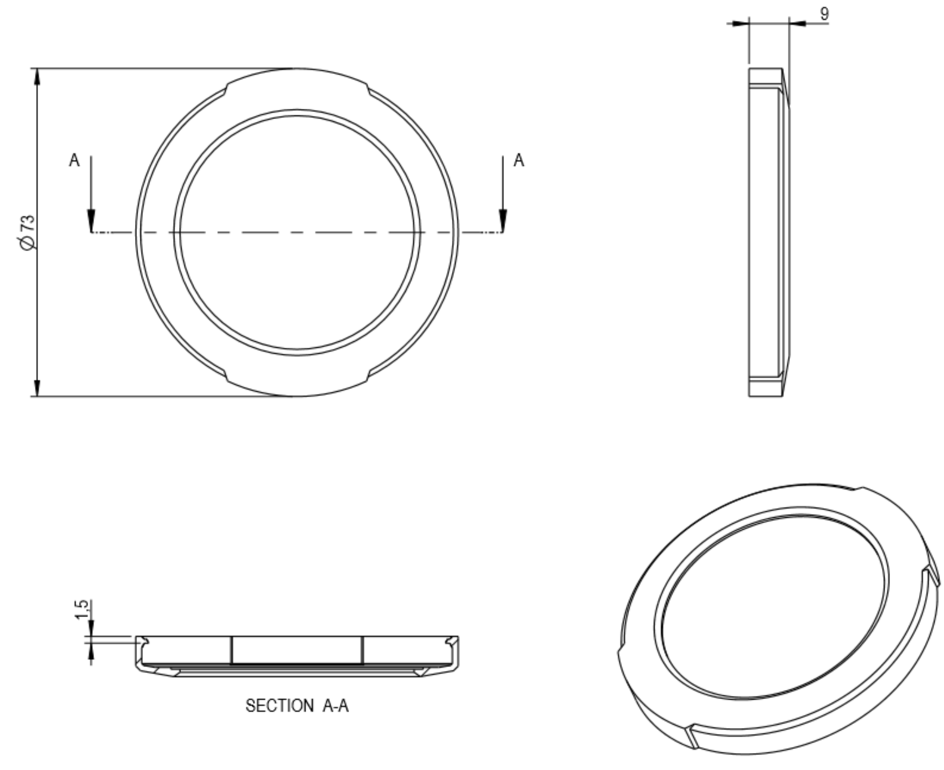


Figure H.4 Drawing of the cover ring with some main measurements.

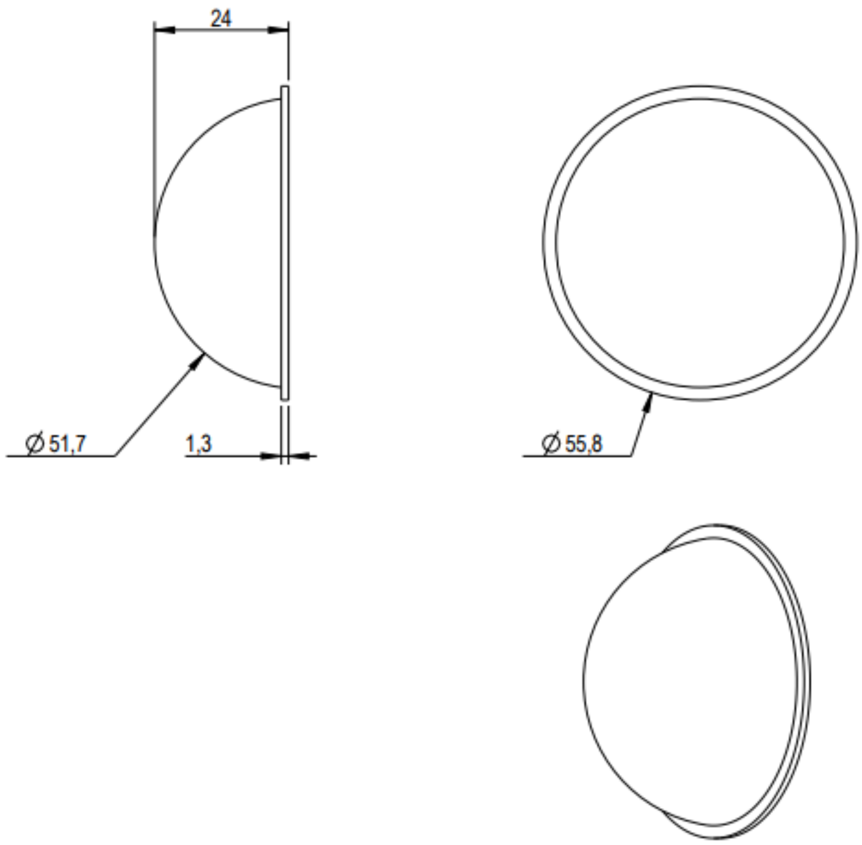


Figure H.5 Drawing of the dome with some main measurements.

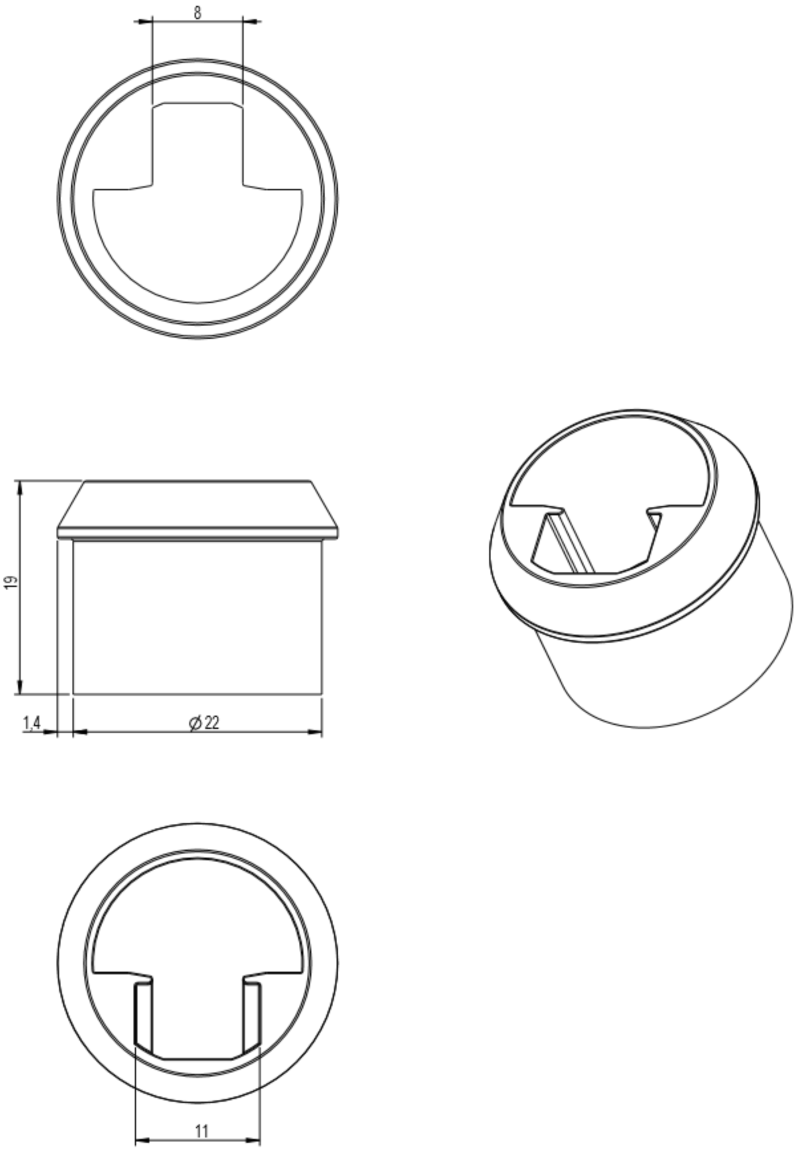


Figure H.6 Drawing of the stopper with some main measurements.