The PTZ camera in a circular economy

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DIVISION OF PRODUCT DEVELOPMENT | DEPARTMENT OF DESIGN SCIENCES
FACULTY OF ENGINEERING LTH | LUND UNIVERSITY
2022

MASTER THESIS

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Published by

Department of Design Sciences
Faculty of Engineering LTH, Lund University
P.O. Box 118, SE-221 00 Lund, Sweden

Subject: Product Development (MMKM05)
Division: Division of Product Development, Department of Design Sciences,
Faculty of Engineering LTH, Lund University
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Examiner: Per Kristav

Abstract

Circular economy is a solution for how to achieve sustainable development in the world. A circular economy involves the recirculation of products and materials, and aims to avoid the creation of waste. For a product to be recirculated, the recirculation needs to be considered already in the design phase. This thesis is performed in collaboration with Axis Communications and explores how to design a visionary camera concept for circular economy in the year 2030.

The thesis has followed a product development process based on the Double Diamond design method. The development process began with an extensive exploratory phase by collecting research on the topic and through interviews discover opportunities for circularity at Axis. In a defining phase, requirements for the circular concept and the future scenario were established. The project followed through an iterative development phase where several concepts were generated and examined. The concepts were then assessed based on how they complied with the requirements. After a final concept was selected, it was further improved by iterations of prototyping.

The result is a concept for a PTZ camera where the key features are developed for the ease of repairing and reusing parts. The concept can be disassembled easily by having few fasteners. Through a modular interface, the parts in the camera can be exchanged and upgraded. The materials in the concept have been selected with the aim of being both durable as well as they contribute to clean material streams. The features in the concept would allow the camera to be looped back into the economy again and again.

Keywords: Circular economy, Product development, Design for circularity, Circularity guidelines, Mechanical engineering

Sammanfattning

Cirkulär ekonomi är en lösning på hur världen kan uppnå en hållbar utveckling. En cirkulär ekonomi innefattar att produkter och material cirkulerar i en cykel, och på så vis undviks skapandet av avfall. För att en produkt ska kunna cirkuleras krävs det att produkten har utvecklats med avseende på denna cirkulation redan i designfasen. Detta examensarbete har skrivits i samarbete med Axis Communications och undersöker hur ett visionärt kamerakoncept kan designas för en cirkulär ekonomi år 2030.

Examensarbetet har följt en produktutvecklingsprocess baserad på designmetodiken Double Diamond. Utvecklingsprocessen initierades med en omfattande undersökningsfas, där fakta samlades om ämnet och intervjuer genomfördes om möjligheter för cirkularitet på Axis. I en definierande fas listades krav för det cirkulära konceptet och ett framtida scenario byggdes. Projektet fortlöpte genom en iterativ utvecklingsfas där olika koncept genererades och undersöktes. Koncepten utvärderades därefter baserat på hur väl de uppfyllde de ställda kraven. Ett slutgiltigt koncept valdes och detta förbättrades ytterligare genom iterationer av prototypframtagning.

Resultatet är ett koncept för en PTZ-kamera där nyckelfunktioner är utvecklade för att möjliggöra reparation och återanvändning av delar. Konceptet kan monteras isär enkelt genom att det utnyttjar få fästen mellan delar. Ett modulärt gränssnitt underlättar för att delar i kameran kan bytas ut och uppgraderas. Materialen i konceptet har valts med syfte att vara slitstarka samtidigt som de bidrar till rena materialströmmar. Funktionerna i konceptet möjliggör för att kameran ska kunna cirkulera tillbaka in i ekonomin igen och igen.

Nyckelord: Cirkulär ekonomi, Produktutveckling, Design för cirkularitet, Riktlinjer för cirkularitet, Maskinteknik

Acknowledgements

This report is a master thesis in mechanical engineering performed at the Department of Design Sciences at Lund University and at Axis Communications in Lund. We would like to start off by thanking these two parties for their cooperation.

At Axis Communications, we first would like to thank our supervisor, Mikael Persson, for his support and guidance through this project. We would also like to thank Philipp Liljevall, and the whole PTZ mechanics team. Especially Jakob Holmquist for the assistance with the prototyping and Johan Widerdal for his feedback and knowledge. We would also like to thank all the people at Axis who happily answered all our questions at interviews or through email. Your expertise has given us invaluable insights for the project.

We would also like to thank our supervisor at LTH, Per-Erik Andersson, for his support throughout the project. Our meetings have always been encouraging and uplifting. We also would like to thank our co-supervisor Glenn Johansson for his knowledge and enthusiasm about the project.

Finally, we would like to thank our friends and family for the support not only during this project but also throughout our studies.

Lund, May 2022

Emma Malmström and Jakob Nilsson

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Introduction

This chapter introduces the project and presents the background for the thesis. The goal and scope are also established.

1.1 Background

“Development that meets the needs of the present without compromising the ability of future generations to meet their own”, is the definition of sustainable development described by the Bruntland Commission Report in 1987 [1]. Decades later, sustainable development is an ongoing challenge and one initiative for shifting into a sustainable development is Agenda 2030. Agenda 2030 is a plan developed by the United Nations (UN) to achieve a sustainable development for people, planet, and prosperity. The plan lists 17 goals that are to be achieved to fulfill economic, social and environmental sustainable development. The goals issue the importance of ensuring sustainable consumption, production patterns and management of natural resources to stop climate change [2].

The Ellen MacArthur Foundation describes circular economy as a solution framework to overcome the global issues of climate change, waste, and pollution. The current economy is described as linear and is based on the take-make-dispose process. Resources are taken from the Earth, made into products and, after usage, disposed as waste. On the contrary, a circular economy avoids the creation of waste and recirculates products and materials [3]. This recirculation is made possible by designing products with circularity in mind and considering the aspects of reuse and repair during product development [4].

To design a product to be recirculated, companies need to explore new development strategies. This thesis is performed together with Axis Communications (Axis). The thesis will focus on one of their products, the PTZ (pan, tilt, zoom) camera, to examine how it can be developed to fit into a circular economy.

1.2 Company description

Axis Communications provides network solutions such as video surveillance solutions, access control solutions and intercoms. Their products and services contribute to improving the security for a variety of industries [5]. Axis was founded in 1984 and at the time focused on developing technology to connect network printers. In 1996, Axis launched their first network camera, and the company now has its core business based on network solutions [6].

Sustainability is an important part of Axis and the company works towards the goals in Agenda 2030. One approach is to protect the planet by minimizing the environmental impact [7]. This includes the aspect of circular development and green design. The green design approach at Axis considers conscious material selection as well as optimizing product design [8].

1.3 Product description

The focus of this project is on one of the products in the network camera category: the PTZ camera. Its key functions are to pan, tilt and zoom the camera which enables a large area coverage for security surveillance. There are currently eleven different PTZ camera series in the product range, where the camera series has different attributes and features [9].

The project uses the PTZ camera model Q6075-E as a product reference. The camera model is presented in figure 1.1. The camera consists of a chassis in aluminum (nr 1 in figure 1.1) and a transparent dome (2) that protects the camera sensor. The camera sensor is mounted in a module that can rotate and tilt, thus it is called the PT-module (3). The motion required for these maneuvers are produced by two motors also attached in this module. Above this are two fans and two printed circuit boards (PCB). In order to install the product, a mount is needed to attach it to the desired surface (4).

Figure 1.1 PTZ Q6075-E with a mount, from [10].

1.4 Project goal

The goal of the thesis is to design a visionary concept for a PTZ camera at Axis that is developed for a future circular economy. The concept will be developed with the help of existing design guidelines for sustainable product development, and with regards to expected business models and recycling possibilities in the year 2030. The key features of the product concept will be developed with regards to circularity.

1.5 Research questions

Several research questions were constructed in order to specify what the thesis would strive to answer. The research questions were established at the beginning of the project and were considered throughout the development process. The questions were formulated and revised together with supervisors at Axis and at Lund University, to ensure their accuracy and fit to the project goals. The research questions are listed below.

- How should a PTZ camera be designed to be compliant with a circular economy?
- How should a specification of a circular PTZ camera be defined?
- Which design guidelines benefit a circular product development?
- What obstacles and conflicts occur when different design guidelines are combined and what trade-offs are made in order to prioritize guidelines for a PTZ camera?

1.6 Scope and delimitations

During this project, a concept of a PTZ camera will be developed based on existing design guidelines. The guidelines will cover areas such as material selection and mechanical design. The camera concept will be developed as a concept where key features are designed for circularity. However, the project will not provide a detail-level design of the concept.

The PTZ concept will be discussed and assessed based on the existing design guidelines. Life cycle analyses (LCA:s) are tools that can be used to assess the environmental performance of a product, however LCA:s will not be used in this project and are therefore outside of the scope of this thesis. The thesis will not consider the packaging solution of the PTZ camera nor investigate the energy consumption of the product during usage.

The concept will be designed for future business models that embraces a circular economy. However, no business model suggestion or logistic solution will be developed.

2 Methodology

This chapter details the methodology and how different methods were adapted for the project.

2.1 Methods used for this project

The methodology for the project is based on two methods: the Double Diamond design process and the Framework for Strategic Sustainable Development (FSSD). Double Diamond is used for creating the project outlines while the FSSD is used for creating a mindset and tools. The two methods are explained in the following sections along with their adaption to this project.

2.2 Double Diamond

The Double Diamond is a design process model proposed by the British Design Council. The process has the benefits of being versatile and simple to use, which makes it suitable for a variety of design projects [11]. Double Diamond consists of four phases: Discover, Define, Develop and Deliver. The phases are considered either divergent or convergent, which is visualized by the diamonds in figure 2.1. In the diverging phases, the focus lies on expanding one’s understanding or ideas. While in the converging phases, the focus lies on narrowing down the problems or the solutions to their core. Discover and Develop are the diverging phases while Define and Deliver are the converging phases. The Deign Council emphasizes that the process is not linear, and iterations between the phases are necessary during the design process [12]. The phases along with their purposes are further explained in the following sections.

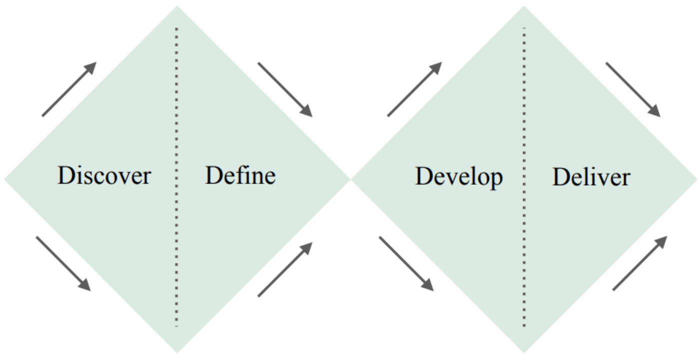

Figure 2.1 Illustration of the Double Diamond design process, adapted from [12].

2.2.1 Discover

The first diverging phase is called Discover. In this phase, the user focuses on widening the understanding of the problem. This can be done with both qualitative and quantitative methods, E.g., literature studies, interviews, or physical examination of a product. Note that no issues are to be solved in this phase, instead the focus lies on trying to get a grip of the problem to move on to the next phase [12].

2.2.2 Define

Once the user has obtained enough information and knowledge of the product and situation to get a good understanding of the problem, they can start to sort the information. This is done in the Define phase. The user has developed a clear understanding from the Discover phase, and they can then start to identify the opportunities and problems that follows. From there, it is possible to formulate some key questions, needs, and criteria that the user can work with in the next step [12].

2.2.3 Develop

The Develop phase is the third phase of the Double Diamond process. During this step the user, with the help of the formulated questions in the previous phase, starts working on one or more concepts. Specifically, the concepts are generated to fulfill the needs and criteria set up in the Define phase. This is done in an iterative manner where one tests and refines until they are ready for the final step of the development process [12].

2.2.4 **Deliver**

The final step of the Double Diamond is the Deliver phase. In this step, the concept developed in the previous step is evaluated and tested. The user also checks if the concept addresses the questions and issues raised in both the Discover and Define phase. It is also possible to improve concepts [12].

2.3 Framework for Strategic Sustainable Development (FSSD)

In addition to the previously explained Double Diamond method, a second method is used for the project. The method is known as the Framework for Strategic Sustainable Development. As the name implies, the method provides a framework for how companies and organizations can implement sustainability into their business in a structured manner [13].

The FSSD includes a tool called the ABCD-procedure. Step A is about building a shared vision and understanding of a successful, future scenario for the business regarding sustainability. During step B, the current reality is assessed. Step C is about brainstorming actions to close the gap between the vision and the current reality. Finally, step D is about prioritizing the actions. The process is interpreted as in figure 2.2, where the arrows describe the different possible actions [13].

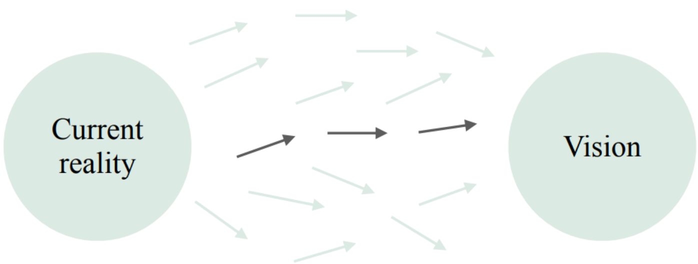

Figure 2.2 Visualization of the ABCD-procedure, adapted from [13].

2.4 Methodology adaption

For this thesis, the Double Diamond is used as the main method and the project follows the four different phases of Discover, Define, Develop, and Deliver. To incorporate the sustainability approach in the project, the FSSD is partly used in the methodology by including the idea of a future vision for the concept. The ABCD-procedure is applied briefly in the project, by using the idea of creating a vision during the Define phase of the project.

3 Discover

During the first phase of the Double Diamond process, Discover, research was gathered through a literature review, journey mapping and by interviews.

3.1 Literature review

The Discover phase of the project began with a literature review. The purpose of the literature review was to gain a broad understanding about the topic of design for a circular economy. The research was made by reading articles, books, and design guidelines on the topic. Literature was gathered from different sources. Some of the literature had been provided by the supervisor from Axis and some had previously been provided as course literature through Lund University. Additional literature was gathered through websites and by using the search databases LUBsearch and Google scholar. Keywords such as “circular economy”, “circular design” and “design guidelines” were used.

The main findings and conclusions of the literature were summarized in a document. This made it easier to keep track of relevant literature and how it would be useful for the project. Aside from gathering knowledge, the document was also used to note key questions that arose during the research. These key questions indicated what topics would require further research and investigation.

The literature review resulted in a basic knowledge of opportunities and obstacles regarding circular design strategies. This included knowledge about what circular economy is and what this will require for a manufacturing company. The following sections present research from the literature that built the foundation for the project.

3.1.1 **Circular economy**

The concept of circular economy differs from the current economy. The current economy can be described as linear and built on the take-make-use-dispose approach [3]. Linear business models make profits from the selling of products, whereas the strategy in circular business models is instead to make profits from the flow of materials and products [14]. This circular flow of products aims to close resource loops. By closing these loops, the economic and environmental value of products is preserved [15].

The Ellen MacArthur Foundation describes circular economy as a framework to solve issues like climate change and waste. According to the foundation, circular economy is based on three principles: eliminating waste and pollution, circulating products and materials, and regenerating nature [3]. The first principle about eliminating waste and pollution focuses on how waste can be avoided by designing product for recirculation [16].

The second principle is circulating products and materials, either in a biological cycle or in a technological cycle. The biological cycle consists of biodegradable materials that can be recirculated by methods such as composting. The technological cycle describes how a product can be recirculated by reuse, repair, remanufacture, and recycle [4]. The cycles, or loops, are visualized in figure 3.1.

The third principle, regenerating nature, promotes the way of letting the nature rebuild itself and not extracting resources in a way that leads to degradation. In a circular economy, renewable materials are used instead of extracting fossil materials [17].

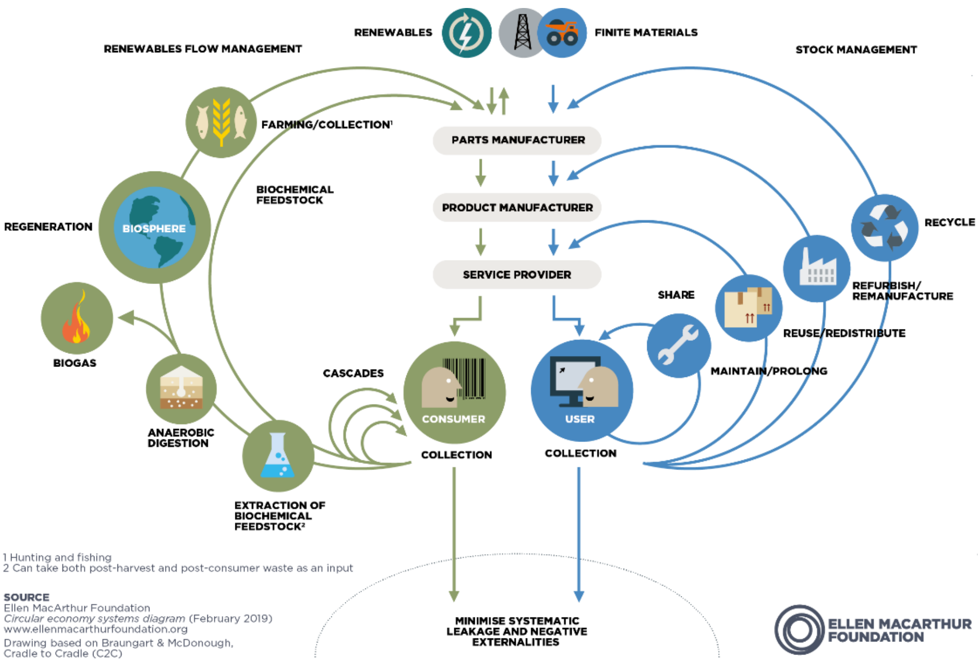

Figure 3.1 Circular economy systems diagram, from [4].

3.1.2 Strategies for implementing circular economy

3.1.2.1 Circular economy and the strategy for the transitioning in Sweden

In the report about circular economy and the strategy for the transitioning in Sweden, the Swedish government aims to achieve environmental goals and the goals in Agenda 2030 by implementing circular economy [18].

The strategy includes four different focus areas. The first focus area is about sustainable production and product design. It explains the importance of promoting the access of information about the origin and contents of products and how they can be recycled. Another aspect in the focus area is the way of designing products for a longer life by making them easy to reuse and repair. The focus area also includes that the Swedish government will promote the use of recycled material in products by developing requirements on recycled content.

The second focus area is about sustainable ways of consuming and using materials, products, and services. Leasing and sharing products are examples of this. The third focus area is about nontoxic material flows. Fossil resources should be avoided, and renewable and biobased resources should be prioritized. Products should also be reused rather than recycled. The area also aims to develop the recycling capacity so that more waste can be sorted and recycled mechanically. This will also increase the demand and use of recycled materials.

Finally, the fourth focus area is about promoting innovation and circular business models, such as providing incitements for companies to have circular business models. It also includes the promotion of research on digitalization and traceability.

The strategy also includes plans for different material streams that needs to be prioritized in a circular economy. The plan focuses on developing recycling of plastics and the sorting of plastic waste. Other prioritized material streams are materials that are considered critical for innovation such as rare metals. The plan highlights the need for recirculation of these materials by collecting material from previously used products. By considering a deposit for electronics, it is possible to increase the recycling rate of electronic devices [18].

3.1.2.2 EU's circular economy action plan

The European Union (EU) has developed an action plan for circular economy, that consists of new strategies on how to include the circular mindset in the entire product lifecycle [19]. One of the strategies in the plan is about sustainable product design. This includes increasing the ability to reuse, repair and upgrade products, as well as increase the share of recycled material in products. The strategy also includes promoting service-based products where the producers own the product, and to use digitalization as a tool for storage of product information. Another part of the strategy is to promote sustainability in products by providing incitements and rewards to products that are sustainable.

The use of plastics is another topic that is included in the action plan. The plastics strategy strives to reduce the amount of plastic waste generated and the EU lists several goals for implementing this. One goal is that by 2030, half of all plastic waste generated in the EU will be recycled. Another goal is to develop the recycling possibilities for plastics and by 2030, the sorting and recycling capacity will be four times greater than it is today. The strategy also addresses the demand for recycled plastic material and by 2030, the demand for recycled plastics will be four times greater than it is today. The production of recycled plastics will have advanced, and it will be possible to recognize when it is more sustainable to use renewable material rather than nonrenewable material [19].

3.1.2.3 Right to repair (R2R)

A key aspect of adopting a circular economy is prolonging the lifespan of the product. One way to do this is to repair products when they brake, instead throwing them away, as in a linear economy. This have led to lawmakers pushing for laws that makes it easier for the consumer to get their products repaired. In the United States, bills concerning this have been put forward. The bills require that products that are repairable can be repaired by more than the producer. In so making sure that the producer does not have a monopoly on repairing the product. Also assuring that it is easier for the consumer to repair their product [20]. The European Union have also put forward directives, though these are instead aimed towards making sure that products actually can be repaired and making it beneficial to do so. This concerns both the right to have a professional repair the product and the right for the consumer to be able to repair the product on their own. This would also apply after the legal guarantee has expired, unlike today when repairs are only covered during this period [21].

3.1.3 Circular product design

The recirculation of products and materials is made possible by making smart design choices for a product. Designers need to consider recirculation already in the design phase during product development [4]. This is highlighted through the Ecodesign directive, which is a directive developed by the EU that lists how the environmental impact of energy-using products can be reduced by product design [22].

There are different design approaches when designing a product for a circular economy. Bakker et al [15], describes circular product design from two different aspects: designing for product integrity and designing for recycling. The aspect of product integrity includes keeping the product in the loop for a long time, by designing for long use, upgradability, or repairability. The aspect of designing for recycling considers the recirculation of materials rather than recirculation of products or parts [15]. Recycling causes loss of value of the material compared to if a product is reused or repaired [23]. Recycling is therefore considered the final step for keeping materials in the loop in a circular economy [4].

There exists a variety of guidelines and tools for when designing products with these different approaches in mind, such as the CIRCIt guidelines. CIRCIt lists guidelines for different approaches such as upgrade, repair, reuse, remanufacture, and recycle. It is emphasized that some of the design guidelines can benefit multiple strategies, while some guidelines can instead create conflicts between strategies [23].

3.1.4 **Recycling**

One principle in circular economy is the elimination of waste [3]. By the recirculation and looping of products and materials, the concept of waste no longer exists in a circular economy [15]. Recycling is considered the final step in the life of a product for avoiding the creation of waste. By recycling materials, they can circulate back in the economy instead of ending up as waste. Even though recycling is the last step for a material, it is still considered a necessary one in a circular economy [4].

3.1.4.1 Recycling of e-waste

As Earth's population increases and modern technology becomes widely available as does the waste from technology. E-waste includes everything that has some sort of electrical component, whether it is a cord, batteries or a processor. According to Global E-waste Monitor 2017, 44.7 million metric ton of E-waste was generated. Most of that waste was generated in Europe and the US. Global E-waste 2017 also make the prediction that by 2050, 120 million metric ton will be generated, making it the fastest growing waste stream in the world. Where all of this waste ends up is hard to tell, though it is believed that the majority ends up in landfills or handled by workers in poor conditions. Some of the materials which is often found in e-waste are gold, platinum and cobalt. Materials which are becoming scarcely available as the demand for components in new electrical products keep raising. By implementing "urban mining", where resources are mined from e-waste rather from the crust of the earth, companies could save both money and energy. Combine this with the previous statement that the stream of e-waste is predicted to increase over the coming decades, thus making it a largely untapped and steady stream of materials [24].

The e-waste that reaches a recycle center are normally handled in a process that involves both sorting done by humans and by machines. Humas usually do the coarse sorting and the machines the finer sorting. Humans start out by removing objects that cannot go into the disintegrator, like batteries or harmful materials. The materials are then crushed into smaller parts and human sorting is once again used to separate out parts that should be placed in a different sorting stream. After this, the waste is grinded into even smaller pieces and magnets are used to sort out ferrous material. Other materials can then be sorted based on their different physical attributes, like density or optical properties [25].

The e-waste usually consists of electrical components incased in some sort plastic housing. In all the grinding processes described above, the plastic also gets milled down to pellets, which can then be reused in other products. The problem with plastics is that it can only be mechanical recycled a limited number of times, unlike aluminum which can be recycled numerous of times. It is also required to mix the recycled plastic with new, virgin plastic, in order to maintain its physical properties. The plastic used in these products are can often be treated with flame retardants. Flame retardants are substances that can make the process of recycling harder whilst also being harmful [26].

There are different ways to tackle the problem with e-waste. One proposed way to increase recyclability is to equip the product with a QR code or RFID signal that would disclose the materials in the product, how to recycle it and other valuable information [23]. The choice of material is also of great importance in order to make a product more recyclable. As mentioned above, aluminum can be recycled a vast number of times without degrading. This is achievable due to the fact that the aluminum does not lose its atomic structure when melted [27]. Another way to tackle the problems of e-waste is through feedstock recycling. This is a process where the collected material is split into small elements through chemical processing. This a process that is well suited for products where the materials are entangled or in other ways where the mechanical recycling is insufficient. [26] One feedstock process is pyrolysis, which is the process of heating the sample to high temperatures in a vacuum. The product of the process is gases and liquids of different materials [26]. One area where pyrolysis can be particularly useful is within handling of PCB:s. PCB:s contains many different materials, especially many different metals. Pyrolysis can be used here to sort out the different materials and enable the recycling of these materials [28].

3.2 Journey mapping

One tool used in the Discover phase was journey mapping. As the name implies, journey mapping can used to map the user’s journey through a service or in this case, a product’s journey [29]. The purpose of this to get a deeper understanding of the possible stages of a product’s lifecycle. The chosen stages for the journey mapping of the PTZ camera were design, material, manufacturing, usage, repair, reuse, discard, recycle, and miscellaneous. The final category, miscellaneous, was created for containing information not suited into other categories. The nine stages were assumed to illustrate the possible journey of a PTZ camera. The stages of the journey mapping are visualized in figure 3.2.

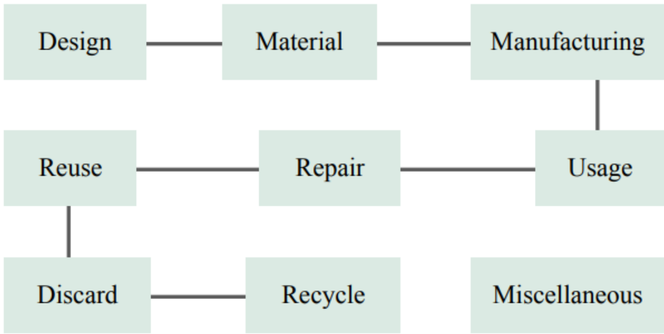

Figure 3.2 Stages of the journey mapping.

With these stages in mind, questions were attributed to each of the stages. The questions mainly concerned areas where the authors lacked knowledge, but also in areas that were believed to be of certain interest for opportunities regarding further research. The journey mapping process was carried out in a brainstorming manner where all questions were written on post-it notes and posted under the corresponding stage. The post-it notes were revised and duplicates were removed, only to keep relevant notes. The journey mapping resulted in a timeline for the product, consisting of findings and questions that needed further research. This research was gathered through additional reviews of the literature, and by conducting interviews.

3.3 Interviews

Interviews were held as a part of the Discover phase. The purpose of conducting interviews was to gather information about the different processes at Axis that could affect a circular product. This required contacting employees with different knowledge, such as materials, repair offerings, manufacturing, recycling, and usage of cameras. The interviews also provided the opportunity to ask questions about topics that had been identified to need further research.

The interviews were constructed as semi-structured interviews (SSIs). SSIs are held with one person and combine open-ended questions with closed-ended questions. One key benefit of this mixture of questions is the possibility of receiving unforeseen answers. With the ability of asking follow-up questions such as “how?” or “why?”, the interviewers can steer the conversation in new directions. [30] The benefits related to SSIs complied with the project purpose of gaining a broad understanding of circularity and the PTZ camera in the Discover phase, which was why this interview structure was selected. The interviews could therefore provide new perspectives on topics from experienced employees at Axis.

Interview guides were prepared for each interview with the procedure as suggested by Adams [30]. First, a few simple and straight-forward questions were asked in order to make the interviewee comfortable. The main part of the interview consisted of a mix of open- and closed-ended questions. Finally, the interview guide ended with a positive question about future possibilities regarding circularity. The full interview guides are gathered in appendix B.

4 Define

This chapter presents how the research was sorted and processed. The Define phase resulted in a define brief that functioned as a specification for the concept.

4.1 Sorting of research

After the Develop phase was completed there was a vast amount of accumulated research. In order to proceed, this research needed to be processed and sorted. This meant that all findings that had been discovered during the Discover phase (from literature, interviews etc.) would have to be processed. The purpose of sorting information was to create a loosely based design brief to use as a specification in the latter phases of the project.

The method for sorting all findings from the research was to gather all information on post-it notes on a wall, see figure 4.1. Visually sorting and grouping information is a useful tool for when reviewing a lot of information and ideas [31]. By adding all information up on a wall, relationships between different ideas could be discovered and the post-it notes were sorted into categories. The sorting of research resulted in a base for making relevant assumptions for the concept and what design guidelines would be used for concept generation. This is presented in the design brief.

Figure 4.1 Sorting of research.

4.2 Define brief

The Define phase resulted in a define brief. The goal of a define brief is to create rough outlines for key areas such as timelines, budget, and goals. These outlines are then used to communicate the project outcomes. The brief should be constructed in a loosely defined manner and not too specific in order to remain open to new ideas [29].

The design brief was discussed at two separate meetings: one with supervisors from Axis and one with the supervisors from Lund University. The purpose of the meetings was to receive feedback and comments on the content and project direction before moving into the next phase of the project. The content of the design brief is presented in the following sections.

4.2.1 **Future scenario**

Some assumptions were established regarding the future scenario for which the concept would be developed. These assumptions are based on the strategies for implementing circular economy described in section 3.1.2 and on discoveries from the interviews described in section 3.3. The assumptions are explained below and summarized in table 4.1.

Table 4.1 Assumptions for a future scenario.

Assumptions
Axis business model will comply with a circular economy
Axis will take responsibility for their products after usage
There will be an increased availability for renewable and recycled materials
REACH and RoHS will continue to apply
Axis current restrictions of PVC and chlorinated substances will continue to apply
Right to repair (R2R) will be in effect 2030 and the concept will fulfill the requirements for R2R, both the USA and EU version
The product will be used in the same way as today
The product will be situated in the same places as it is today
The product will have a warranty of at least 5 years
The product will be used for 10 years
The concept will be designed for estimated recycling processes in year 2030

The first assumption is that Axis business model will comply with a circular economy in a way that allows for take-back of their products. In a take-back system, the company takes back a product after it has been used, which allows for reuse of parts and products. In a circular economy, there will be incitements for companies to have circular business models that are profitable.

Another assumption is that there will be an increased availability in recycled and renewable materials and that the Axis products will consist of materials from these resources when possible. According to interviews held with Axis employees regarding material selection, the company currently has goals regarding the weight volume of renewable plastics in plastic components. In the future scenario, there will be further requirements on recycled content in products.

Through interviews, it was discovered that Axis products currently comply with material legislations that aims for nontoxic material streams. Examples of such legislations are REACH (Registration, Evaluation, Authorization and Restriction of Chemicals) and RoHS (Restriction of Hazardous Substances in Electrical and Electronic Equipment). In addition to this, Axis has goals to phase out PVC and chlorinated flame retardants [32]. These restrictions are assumed to continue to apply in the future.

Right to repair will apply in the scenario. The concept will be developed to comply with R2R.

It is assumed that the concept will be used in the same way as it is today and at the same locations. The warranty of the product will be five years and it is assumed to be used for ten years.

For the scenario in year 2030, it is assumed that recycling processes will have advanced and that it is possible to recover materials to a higher degree through both mechanical and chemical recycling.

4.2.2 **Circularity requirements**

The concept is developed based on design guidelines that benefit product design for a circular economy. These guidelines are derived from the research gathered in the Discover phase, both from the existing design guidelines [23] : [33] : [34] : [35] : [36] and from the interviews held at Axis. In this thesis, the guidelines are named circularity requirements. The circularity requirements are grouped into four categories: Reduce, Repair, Reuse, and Recycle. These categories were selected as they strive to represent the different phases in the life of a circular product. The requirements describe how a product can be optimized for circularity in each category. The circularity requirements are presented in table 4.2 and each category is described further below.

4.2.2.1 Reduce

The first category of circularity requirements is Reduce. The requirements in this category focus on resource efficiency by reducing the number of parts and materials. It also includes designing the product for a long life, thus reducing the risk of breakage and need for the product to be replaced by a new one. By making it easy to maintain the product, such as cleaning it, it can stay in a good condition for a longer time.

4.2.2.2 Repair

The second category of the circularity requirements is Repair. By repairing the camera, the life of it is prolonged. During interviews held at Axis, it was identified that it needs to be easy to exchange parts in the product, such as the PCB:s. This information was therefore included in the circularity requirements. Another requirement derived from interviews was the wish for standardized parts in the product, which reduces the variety of different spare parts.

4.2.2.3 Reuse

Reuse is the third category of circularity requirements. This category aims to create possibilities for the camera to be used again after one use-cycle, either by refurbishment or the reuse of parts. The interviews revealed the wish for upgradability options in camera. By utilizing the same camera but exchanging only parts of it, the product can be upgraded with new functions. Other requirements in the category of Reuse are to create parts that can be used for many use-cycles. Examples of such requirements are having a timeless design of the product, along with selecting materials that keeps their original appearance or having the opportunity to remove the traces from previous use-cycles.

4.2.2.4 Recycle

The fourth and final category is Recycle. The requirements in this category focus on the ability of being easy to disassemble in a recycling facility, along with selecting materials that contribute to clean material streams.

Table 4.2 Circularity requirements.

Category	Nr	Requirement
Reduce	1	The number of parts in the product is minimized
	2	The weight of the product is minimized
	3	The number of materials in the product is minimized
	4	It is easy to maintain the product during the whole life cycle
	5	The product is designed for long life and components are chosen with similar expected lifetime
Repair	6	Components and parts are standardized throughout the product
	7	No special equipment is needed to repair the product
	8	The product is easy to access for repair
	9	The orientations of the connector are aligned to make it easier to open up the product
	10	The product is compliant with “Right to repair” laws
	11	It is easy for the customer to repair the product on their own
	12	Repair guides are provided, both for professionals and consumers
	13	The product enables self-diagnosis of repair issues
	14	The product uses IoT for service log
	15	It is easy to exchange components within the product, E.g., power PCB
Reuse	16	The product consists of materials that age well and contribute to maintaining its original appearance throughout the entire lifespan
	17	The product has a timeless design
	18	The design promotes upgradeability
	19	It is easy to reach components that are going to be reused or that contain hazardous substances
	20	It is easy to reset the product, both hardware and software
	21	The product is designed for multiple cycles by removing traces of use
	22	The product uses IoT to enable tracking of products and materials
Recycle	23	The product is designed for expected recycling processes in the year 2030
	24	The design enables toxic and nonrecyclable materials to be grouped together within the product

	25	The design makes it easy to recirculate valuable materials
	26	Nonrecyclable materials are avoided
	27	Thermosets are avoided
	28	Banned substances are avoided
	29	The design considers the grinding process of e-waste recycling
	30	It is easy to remove electrical components
	31	It is easy to distinguish the different materials to enable easy sorting
	32	The design does not mix plastics that cannot be separated in easy ways or be distinguished by their physical attributes
	33	The design relies on common plastics such as ABS, MABS, PE, PP, PA, PC/ABS and HIPS
	34	The design avoids mixing of materials such as 2k molding, composite materials, and different plastics
	35	The design avoids permanent fixtures such as gluing
	36	It is easy to disassemble the product
	37	Surface treatments are avoided to ensure that the physical properties of the materials are not altered and hinder the recycling process

4.2.3 **PTZ camera requirements**

Along with the circular requirements, the PTZ camera concept itself has a list of specifications. As a reference, the Q6075-E specification was used to define what requirements were necessary for the concept. The content of this specification lists properties such as operating temperatures, materials and weight for the camera. The specification is visible in appendix C.

As the aim of the project was to create a visionary concept for a circular PTZ camera, the current specification was used only briefly. Several key requirements for the concept were established based on the features and specifications for the current Q60 camera, and these are listed in table 4.3. This list was used as a complement to the circular requirements. The PTZ camera requirements list was also discussed with the supervisor at Axis to ensure that the requirements were suitable for a future PTZ camera.

Table 4.3 PTZ requirements.

Nr	Requirements
1	The usability of the product is similar to the current Q60 model
2	The design of the product is similar to the current Q60 model and includes camera module, PCB:s, motor, dome and appearance
3	The product has the same requirements as the Q60 model

4.2.4 **Vision**

The vision is a circular PTZ camera as a future product concept for Axis that complies with a circular economy in the year 2030. The camera is designed for a product system that aims to minimize the creation of waste. Waste is minimized by designing the concept around four strategies: Reduce, Reuse, Repair and Recycle. The strategies represent loops in which the product can recirculate for multiple cycles. This recirculation is possible by Axis taking responsibility of the product during its entire life cycle.

5 Develop

This chapter presents the process for the Develop phase. During Develop, ideas and concepts were generated to explore possible solutions for the circular camera concept. In the beginning of the phase, the focus was on producing many different ideas and concepts. These were then refined and improved throughout the process.

5.1 Idea generation

The Define phase resulted in a project vision and circularity requirements for the concept. The circularity requirements functioned as a base for the next phase of the project: Develop. The first part of Develop was the idea generation. The purpose of generating ideas was to discover features for the circular camera concept, without the need to develop full concepts just yet. The aim of the idea generation was to generate a lot of ideas and to keep an open mind, free of judgment [37]. To ease the process and to stimulate creativity, a couple of methods were chosen. The methods are described in the sections below.

5.1.1 **Brainstorming based on the circularity requirements**

The idea generation began with sketching and exploring ideas for solutions to the circularity requirements. Several ideas were developed for each requirement in mind. The sketching was performed both in a brainstorming manner and by individual sketching by both team members. Brainstorming is used for generating a lot of ideas without the need to consider feasibility [37]. By developing ideas both by brainstorming together and by individual sketching, many possible ideas could be explored.

5.1.2 **Best- and worst-case scenarios**

Another method used to generate ideas was creating best- and worst-case scenarios for each category in the circularity requirements. Different concepts were sketched for the categories of Reduce, Repair, Reuse, and Recycle and the goal was to detect what features are desirable or unwanted for each category. The purpose of this exercise was not to think realistically, but rather to focus on extreme scenarios in order to detect unexpected features. After the best and worst-case scenarios had been sketched for each category, they were discussed to discover how they fulfilled the different circularity requirements.

5.1.3 **XYZ-method**

Another method used during the idea generation was the so called XYZ-method. This method was used to produce many different ideas by taking turns refining each other's ideas. The procedure is that a team of X participants sketches Y ideas during Z minutes [38]. For this project, the two team members sketched three ideas during five minutes. After the five minutes had passed, the concepts were presented and discussed. The papers (with the concepts) were then passed around and the participants continued to work on their given concept, again with a time limit set to five minutes. This was then repeated one more time.

5.1.4 **Idea selection**

The ideas that had been developed were revised during an idea selection. The methods that had been used for idea generation had resulted in many ideas and the purpose of the selection process was to quickly identify ideas that showed potential and needed be furthered developed. The ideas were grouped under corresponding category of the circularity requirements, see figure 5.1. The ideas were then revised together with the supervisor at Axis, and each participant selected two ideas each that they considered interesting for continued developing.

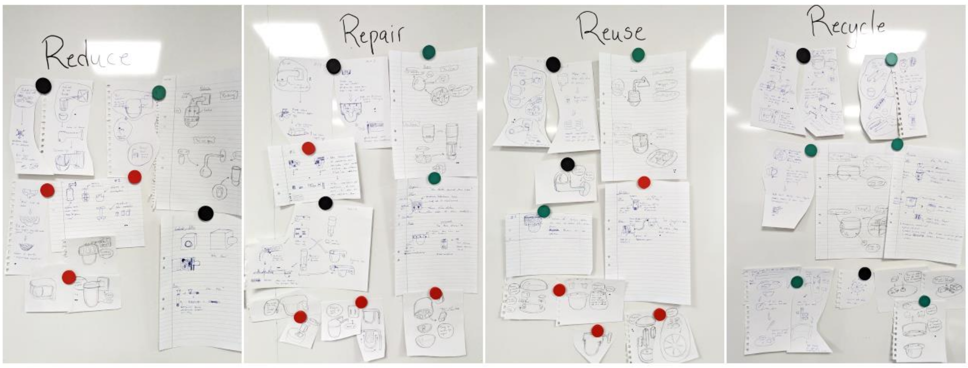

Figure 5.1 Idea selection.

5.2 Concept generation

The idea generation had resulted in several ideas for features in the circular camera and these features built a foundation for the concept generation. As opposed to the idea generation, the aim of the concept generation was to create concepts in which the product is further specified.

5.2.1 **Concepts for each R**

The first part of the concept generation focused on creating four concepts that were developed individually for Reduce, Repair, Reuse and Recycle. The purpose of this was to discover how a concept could be optimized for each category of the circularity requirements and how such extreme cases would be designed. The extreme concepts for each category were then compared to the other concepts to discover what features could create conflicts or synergies between the different circularity requirements.

5.2.1.1 Reduce

The concept developed for Reduce is presented in figure 5.2. The concept strives to minimize the total number of parts and materials by extending the dome (5) and attaching it directly onto the mount (3). The types of fasteners were selected with the aim of minimizing the number of parts in the product. The dome is attached onto the mount using snap-fits (6) that are integrated in the parts. Glue is used to fasten parts that need to be secured further. The mount has an angle of 45 degrees to create a versatile mount that can be flipped depending on if the camera will be attached on the wall (1) or on in the ceiling (2). The profile of the concept for each scenario is visible in the lower area of figure 5.2 and shows the tilted shape of the dome. The versatile solution reduces the need for two different mounts in the product portfolio, which benefits the goal of reducing the total number of parts. The structure of the mounting solution has also been optimized for weight reduction. The electronic parts are connected to a rack (4) that attaches onto the mount, also by using integrated snap-fits.

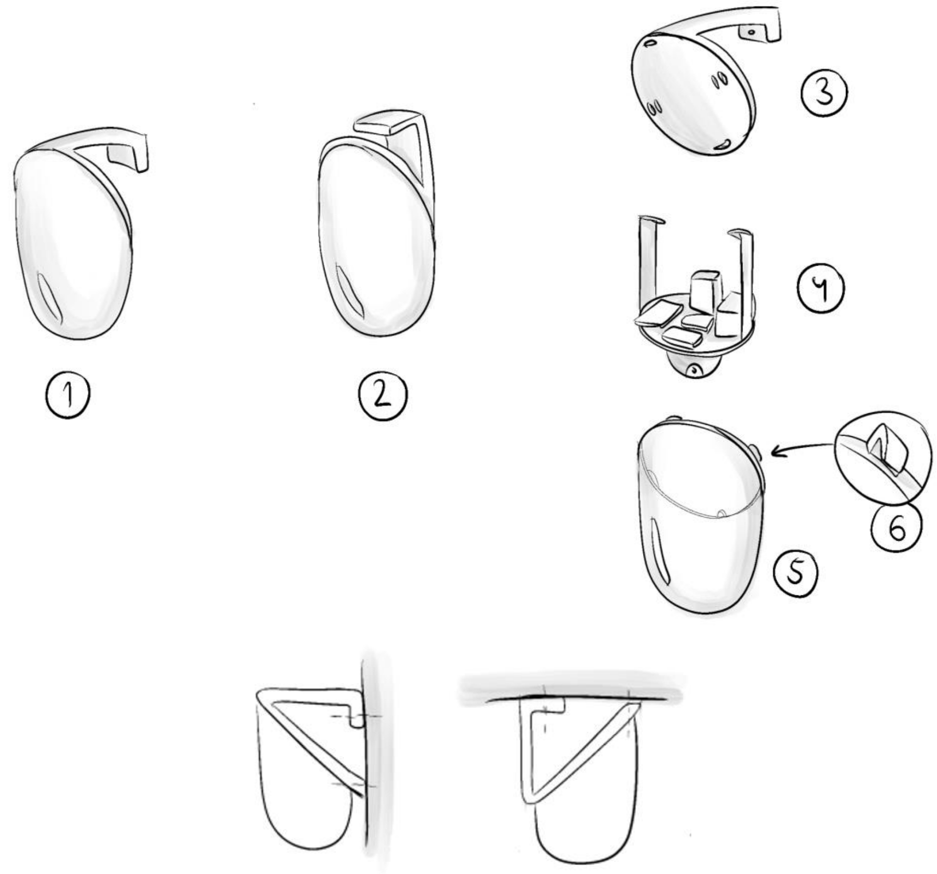

Figure 5.2 Concept optimized for Reduce.

The concept optimized for Reduce was discussed and compared against the other categories in the circularity requirements. The synergies and conflicts between the concept and the other circularity requirements from other categories are presented in table 5.1. It was noted that the concept benefits the category of Repair by being easy to access (nr 8). The dome can easily be snapped off the mount and allow access into components that need repair. Another synergy is that the number of materials is minimized which benefits the recyclability of the product (nr 25) since it easier to separate materials when they are fewer.

The fasteners in the concepts consist mainly of snap-fits. The integration of snap-fits in the different parts can lead to conflicts with the category of Reuse and Repair, and the requirement regarding the standardization of parts (nr 6) and upgradability (nr 18). Some parts in the concept are secured with glue which causes a conflict with the Recycle category, both with the requirement of avoiding permanent fixtures (nr 35) and the requirement of the product being easy to disassemble (nr 36).

Table 5.1 Identified conflicts and synergies, Reduce.

	Nr	Circularity requirement	Comment
Synergies	8	The product is easy to access for repair	Dome can be snapped of easily
	25	The design makes it easy to recirculate valuable materials	Fewer parts and materials benefit recyclability. Easier to separate materials when they are fewer
Conflicts	6	Components and parts are standardized throughout the product	Integrated structure with snap-fits
	18	The design promotes upgradeability	Integrated structure with snap-fits
	35	The design avoids permanent fixtures such as gluing	Some parts in the concept are secured with glue
	36	It is easy to disassemble the product	Some parts in the concept are secured with glue

5.2.1.2 Repair

The concept for optimizing Repair is seen in figure 5.3. One main feature in this concept is the hatch (1) that allows for easy access into the camera and to its components. The camera can be opened without the need to remove it from the mount on the wall or ceiling. Once the hatch is opened, the components that are critical for repair are visible. The components have been divided into modules (2) that allows for easy identification of parts and their status.

On the inside of the camera, the modules are attached onto a rail (3). The rail provides room for additional upgrade modules in the camera. The rail is also connected to the dome (4), which is fastened underneath the rail. The dome can be exchanged by sliding it on and off the rail.

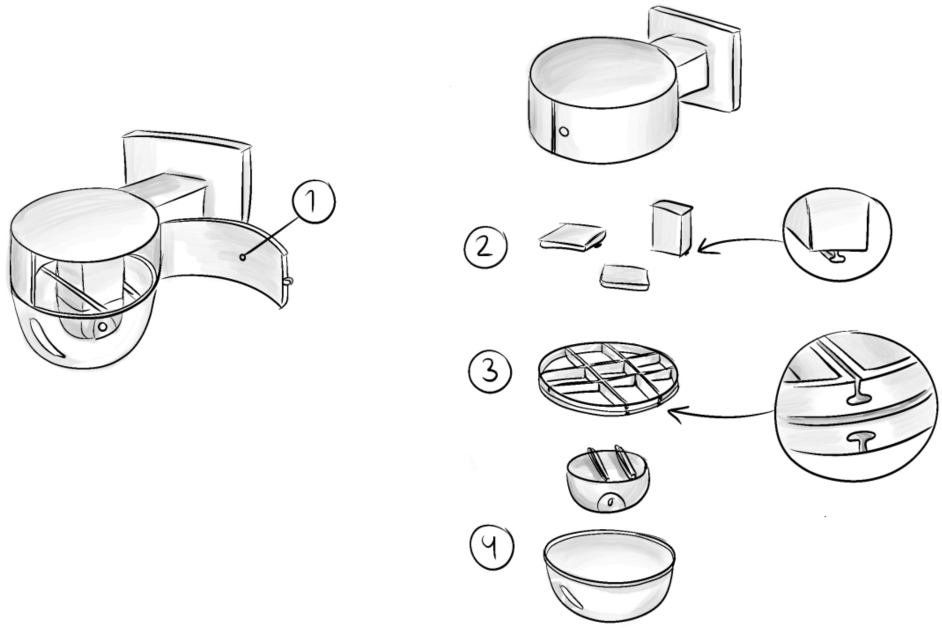

Figure 5.3 Concept optimized for Repair.

Identified conflicts and synergies are listed in table 5.2. The modules in the concept along with the rail not only benefit Repair, but also Reuse since the modules promote upgradability (nr 18). The electrical parts are all connected to the rail which benefit Recycle and how nonrecyclable materials are grouped within a product (nr 24).

There is a possible conflict between the concept and the requirement of designing components for a long life (nr 5). This is due to the moving parts in the hatch mechanism, that can lead to sensitive parts that are less durable.

Table 5.2 Identified conflicts and synergies, Repair.

	Nr	**Circularity requirement**	**Comment**
Synergies	18	The design promotes upgradeability	The modules in the rail can be exchanged and upgraded
	24	The design enables toxic and nonrecyclable materials to be grouped together within the product	All electrical parts are connected to the rail
Conflicts	5	The product is designed for long life and components are chosen with similar expected lifetime	Moving parts in the hatch mechanism creates parts that are less durable

5.2.1.3 Reuse

The third concept is developed for Reuse and is presented in figure 5.4. The concept is designed with a modular approach with the aim of simplifying exchange of parts and upgrades for the product. According to Ulrich [39], modular product architecture can be described by the linking of one function to one physical part of the product. It aims to de-couple the interfaces of parts. Two coupled components are dependent on each other, meaning that when one of the components is changed, the other one must also be changed be in order for the product to function. De-coupled components do not have this dependency. [39]. The concept of Reuse aims for a modular approach by connecting the parts to functions.

The outlines of the product structure are shown in figure 5.4. A rail (3) functions as a base for components to be attached onto. The components are fastened using a solution similar to a belt (2). The belt secures the components and attaches onto the rail with screws. The rail offers the opportunity of placing components wherever on the rail by having many screw holes placed across the rail. Screws are used as the main connectors for all parts in the concept.

The surface of the exterior parts, excluding the dome, is texturized (1). The texture has the function of hiding scratches or other aesthetic defects that can occur. By having lowered the demands on surface finish, the parts can be reused in another use-cycle. Additionally, the camera can be provided with an extra case (5) that covers the exterior. The purpose of the case is to remove traces of use from previous use-cycles and to provide an option of upgradability related to appearance, e.g., choosing a new color for the camera.

Each part in the camera is provided with a marking (4) that is used to connect it to a system. The system contains information about the part such as material data and the number of use-cycles it has been in.

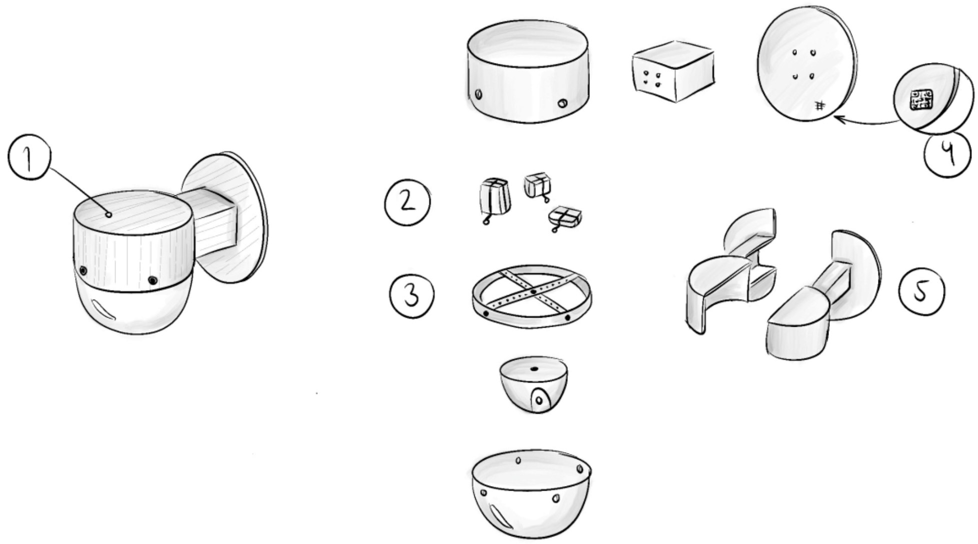

Figure 5.4 Concept optimized for Reuse.

The identified conflicts and synergies for the Reuse concept are presented in table 5.3. The modularity in the concept can benefit the category of Repair and that it is easy to exchange components within the product (nr 15). The scanning of parts can also be an advantage in Recycle and makes it easy to recirculate valuable materials (nr 25), since this provides information about materials that can be used during sorting.

On the other hand, the modular system can create a conflict between Reuse and Reduce. Modularity can increase the number of parts in the product (nr 1). Having screws as fasteners can increase the time to disassemble the product which creates disadvantages both during Repair (nr 8) and Recycle (nr 36).

Table 5.3 Identified conflicts and synergies, Reuse.

	Nr	Circularity requirement	Comment
Synergies	15	It is easy to exchange components within the product, E.g., power PCB	Modularity creates interfaces between parts that benefits upgrades
	25	The design makes it easy to recirculate valuable materials	Scanning parts to receive information about materials
Conflicts	1	The number of parts in the product is minimized	Modularity can increase the total number of parts
	8	The product is easy to access for repair	Many screws in the concept
	36	It is easy to disassemble the product	Many screws in the concept

5.2.1.4 Recycle

The concept that has been developed to optimize Recycle is illustrated in figure 5.5. The concept consists of three main parts: the mount (1), the dome (3), and the electronics (2). The parts are disassembled by pressing a button (6) on the mount. This action releases the snap-fits (4 and 5) that connects the dome and the electronics from the mount, and the product is split into three parts. The purpose of this is to easily separate the different materials in the camera as it enters a recycling facility. The materials can therefore continue in different materials streams without contaminating one another. The parts are provided with markings that are scanned in the recycling facility which allow identification of the materials.

The electronic components in the camera consist of multiple parts with different materials that are challenging to recycle. These components are therefore connected into one electronic part (2) that is later sorted further to collect valuable materials.

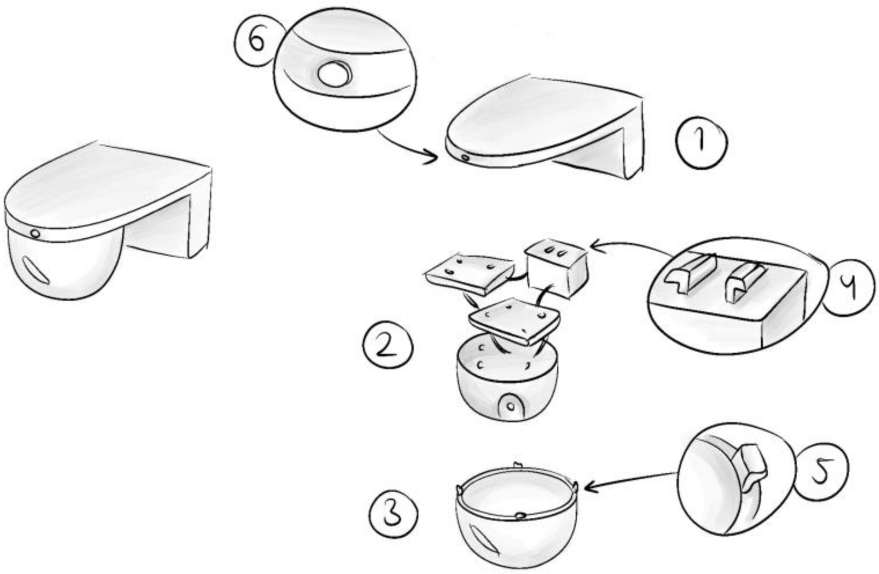

Figure 5.5 Concept optimized for Recycle.

Finally, the conflicts and synergies for the Recycle concept was discussed and listed, see table 5.4. The concept consists of few parts which is an advantage from the perspective of Reduce (nr 3). The button in the concept benefits Repair due to that it is easy to access (nr 8).

One possible obstacle with Reduce pair is the gripping mechanism with the button. The mechanism includes moving parts which can be less durable and lead to a shorter life of the product (nr 5). The snap-fits create a conflict with Reuse and the upgradability of the product (nr 18).

Table 5.4 Identified conflicts and synergies, Recycle.

	Nr	Circularity requirement	Comment
Synergies	1	The number of parts in the product is minimized	The product consists of few parts
	8	The product is easy to access for repair	The product is disassembled by pressing one button
Conflicts	5	The product is designed for long life and components are chosen with similar expected lifetime	Snap-fit mechanism creates parts that are less durable
	18	The design promotes upgradeability	Integrated structure with snap-fits

5.2.2 **Concept combination**

For the PTZ camera to be developed for a circular economy, the concept needs to consider all four categories in circularity requirements, i.e., Reduce, Repair, Reuse, and Recycle. The extreme cases for each category had been explored in the previous phase of the development process and the features of these concepts were combined for the creation of the full concepts.

5.2.2.1 Concept A

Concept A is presented in figure 5.6. One main feature in the concept is the button (3) that, when pressed, triggers a mechanism (4) that divides the product into three parts. The three parts consist of the mount (5), the basket (6), and the dome (7). The basket contains the electronic parts, that are considered as modules. The modules are fastened with a flexible fastener (8) that can be used for all modules, similar to a belt. Depending on if the camera will be mounted in the ceiling or on the wall, two different mounts are provided (1 and 2).

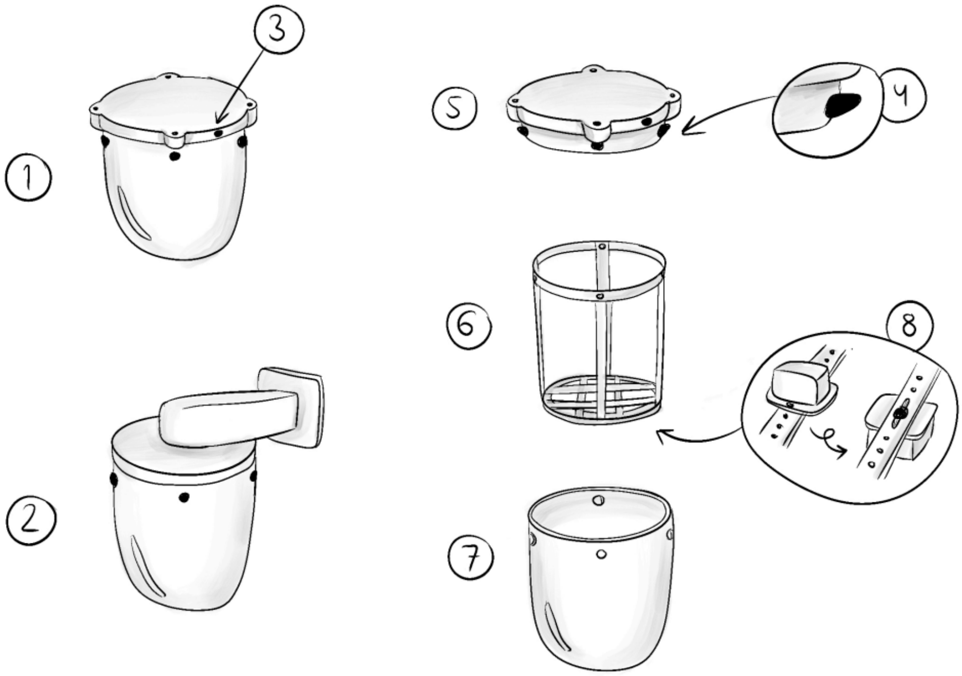

Figure 5.6 Concept A.

5.2.2.2 Concept B

Concept B is visible in figure 5.7. Similar to concept A, concept B groups the electronics as one part to which all electronic parts (5) are connected. With the aim of reducing the number of fasteners and to make it easier to disassemble the product, the electronics are clamped into place by the two crosses (4). The crosses are secured together by screws. The plate is modular to enable all parts to be easily exchanged and upgraded inside of the product. The concept has two different mounts depending on if the camera will be placed on the wall (2) or in the ceiling (1). A seal (3) provides protection against moisture from entering the camera.

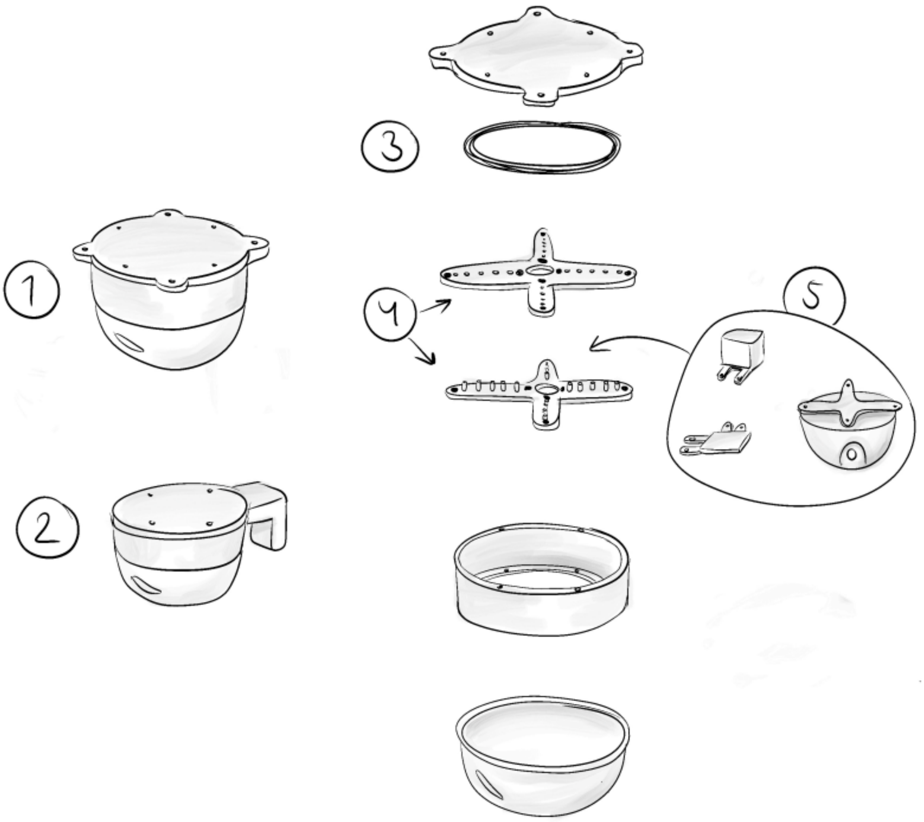

Figure 5.7 Concept B.

5.2.2.3 Concept C

The third concept, concept C, is presented in figure 5.8. One main feature in the concept is the versatile mount (3). By having an angle of 45 degrees, the mount can be used both for when the camera is placed on the wall (1) or in the ceiling (2).

A basket (4) for the electronics is fastened inside of the mount. The different electronics modules are secured onto the bottom of the basket with screws (7). The bottom of the basket is provided with rows of many screw holes, to create opportunities for upgrades and exchanges of modules inside the camera.

The dome (6) is extended upwards and is angled 45 degrees. A seal (5) is added between the dome and the mount to protect the camera from moisture to enter.

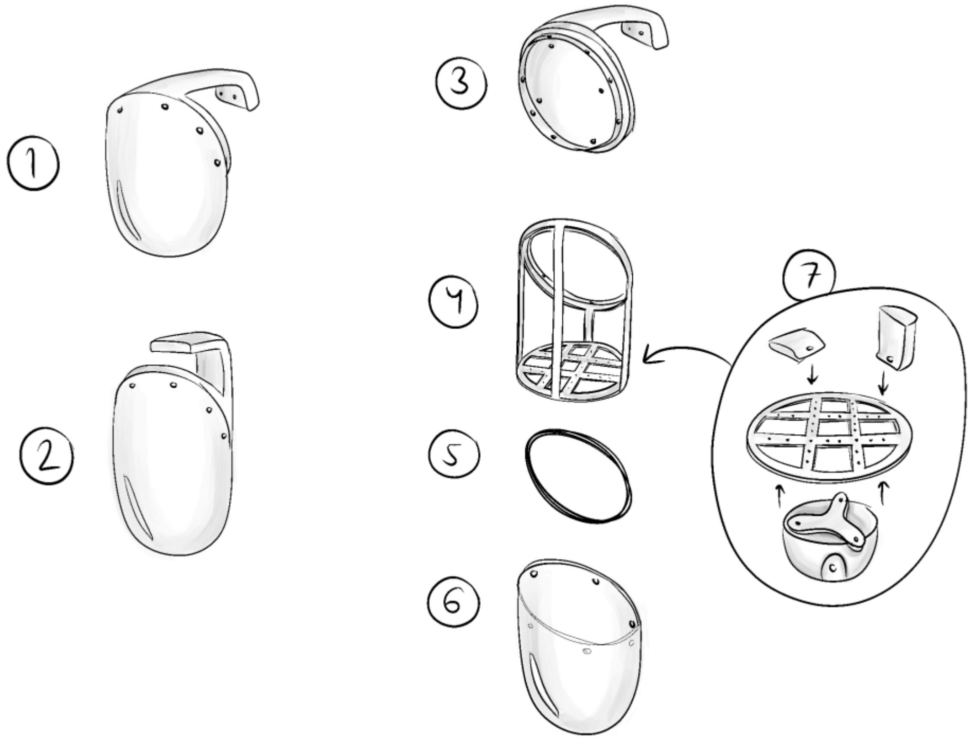

Figure 5.8 Concept C.

6 Deliver

Presented in this chapter is the finale step in the double diamond process, Deliver. This process handles the evaluation of the concepts developed in the previous stage. It also details how the chosen concepts are further refined and which methods are used to do so. The chapter ends with a presentation of the final concept.

6.1 Concept evaluation

The first task during the Deliver phase was the concept evaluation. The Develop phase had resulted in three different concepts for the circular PTZ camera. For the selection of one final concept, the three concepts needed to be evaluated and compared to each other. The concept evaluation was executed by the students, but both the scoring matrix and the outcome was presented to the supervisor at Axis and discussed to ensure the reasoning behind the evaluation.

6.1.1 **Scoring matrix**

The three concepts were evaluated and compared using a concept scoring matrix. Concept scoring is useful when assessing and comparing different concepts by assigning weights to each selection criteria based on their importance. The final scores for the concepts are the weighted sum of each rating [37].

The concept scoring matrix used in this project is based on the circularity assessment tool, proposed by CIRCit. The circularity assessment tool is developed with the purpose of assessing the circularity potential of product designs and concepts. The assessment was performed based on the previously established circularity requirements, which the concepts have been developed with regards to. The concept scoring therefore aims to compare the circularity potential of the concepts with each other and identify what improvements can be made [40].

6.1.2 **Assigning weights to selection criteria**

The scoring matrix was prepared by assigning a weight to each selection criteria in the matrix, i.e., each circularity requirement. The weight correlates to the importance of each requirement. The weight ranges from 0-3 and the weights for each requirement are presented in table 6.1. 0 indicates that the requirement is not important when rating the concepts. Either the requirement is fulfilled by all concepts, or it has not been highlighted through the concepts and are not to be assessed upon. A weight of 1 indicates that the requirement is slightly important for circularity. A weight of 2 means that the requirement is moderately important and a weight of 3 means that the requirement is really important.

In the category Reduce, the weight of 1 has been assigned to requirement 2. This requirement is about minimizing the weight of the product. It has been weighted low and therefore considered less important in terms of circularity. This is based on the identified conflict between material usage and durability. With the motivation of designing a product durable enough for keeping many use-cycles, the weight and material usage of the product is considered less important in terms of circularity. With the same motivation, requirement 5 about designing a product for long life is given a weight of 3.

For the category of Repair, a weight of 3 have been assigned to the requirements that were identified as important during interviews. These requirements are the need for standardization, along with the ability for the customer to repair the product on their own and that parts can be exchanged easily in the product. The requirement of having connections aligned in the same direction is considered less important for the sake of circularity.

The most important requirement in the Reuse category is that the design promotes upgradability. The requirement of timeless design is considered less important and is therefore assigned a 1 in weight.

In the final category, Recycle, the requirement about avoiding nonrecyclable materials is assigned a weight of 3. Two other requirements that are considered very important are to avoid permanent fixtures and to make it easy to disassemble the product. This are considered very important for circularity since they can benefit both Reuse and Repair.

6.1.3 **Outcome**

The results of the concept scoring are presented in table 6.1. Each concept was rated with a score between 1-5, and the weighted sum was calculated. In addition to the concept scoring table 6.1, the sums for each requirement were presented through a graph, see figure 6.1. The graph shows the circularity potential scores according to the CIRCit circularity assessment tool and graphically highlights the differences between the concepts [40].

Table 6.1 Concept scoring.

Category		Circularity requirement	Weight	A	B	C	Sum A	Sum B	Sum C
Reduce	1	The number of parts in the product is minimized	2	4	3	5	8	6	10
	2	The weight of the product is minimized	1	3	3	5	3	3	5
	3	The number of materials in the product is minimized	2	2	4	4	4	8	8
	4	It is easy to maintain the product during the whole life cycle	2	4	4	3	8	8	6
	5	The product is designed for long life and components are chosen with similar expected lifetime	3	2	4	4	6	12	12
Repair	6	Components and parts are standardized throughout the product	3	2	2	5	6	6	15
	7	No special equipment is needed to repair the product	2	5	4	4	10	8	8
	8	The product is easy to access for repair	2	5	1	4	10	2	8
	9	The orientations of the connector are aligned to make it easier to open up the product	1	2	5	3	2	5	3
	10	The product is compliant with “Right to repair” laws	0				0	0	0
	11	It is easy for the customer to repair the product on their own	3	4	2	4	12	6	12
	12	Repair guides are provided, both for professionals and consumers	0				0	0	0
	13	The product enables self-diagnosis of repair issues	0				0	0	0
	14	The product uses IoT for service log	0				0	0	0
	15	It is easy to exchange components within the product, E.g., power PCB	3	4	5	3	12	15	9
Reuse	16	The product consists of materials that age well and contribute to maintaining its original appearance throughout the entire lifespan	2	3	3	3	6	6	6
	17	The product has a timeless design	1	4	4	3	4	4	3
	18	The design promotes upgradeability	3	5	4	5	15	12	15
	19	It is easy to reach components that are going to be reused or that contain hazardous substances	2	3	4	4	6	8	8
	20	It is easy to reset the product, both hardware and software	2	4	3	5	8	6	10

	21	The product is designed for multiple cycles by removing traces of use	2	3	3	3	6	6	6
	22	The product uses IoT to enable tracking of products and materials	0				0	0	0
Recycle	23	The product is designed for expected recycling processes in the year 2030	2	0	0	0	0	0	0
	24	The design enables toxic and nonrecyclable materials to be grouped together within the product	2	5	2	5	10	4	10
	25	The design makes it easy to recirculate valuable materials	2	3	4	5	6	8	10
	26	Nonrecyclable materials are avoided	3	3	3	3	9	9	9
	27	Thermosets are avoided	0				0	0	0
	28	Banned substances are avoided	0				0	0	0
	29	The design considers the grinding process of e-waste recycling	1	3	4	3	3	4	3
	30	It is easy to remove electrical components	2	4	5	3	8	10	6
	31	It is easy to distinguish the different materials to enable easy sorting	2	3	5	5	6	10	10
	32	The design does not mix plastics that cannot be separated in easy ways or be distinguished by their physical attributes	2	3	3	3	6	6	6
	33	The design relies on common plastics such as ABS, MABS, PE, PP, PA, PC/ABS and HIPS	2	3	3	3	6	6	6
	34	The design avoids mixing of materials such as 2k molding, composite materials, and different plastics	0				0	0	0
	35	The design avoids permanent fixtures such as gluing	3	5	5	5	15	15	15
	36	It is easy to disassemble the product	3	5	4	2	15	12	6
	37	Surface treatments are avoided to ensure that the physical properties of the materials are not altered and hinder the recycling process	1	3	3	3	3	3	3
Total score							**213**	**208**	**228**

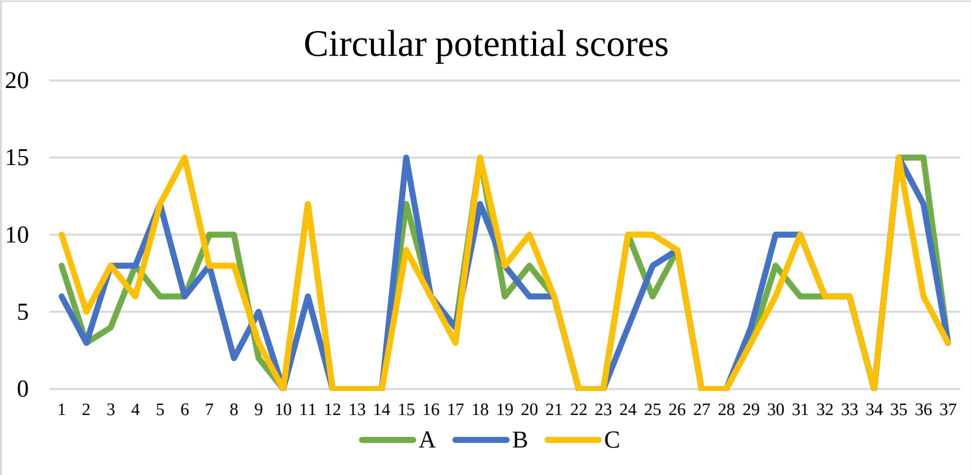

Figure 6.1 Circular potential scores.

In the category of Reduce (requirement 1-5), Concept C scores the higher points. Concept A and concept B scores higher than concept C in requirement 4, but only by one point. The reason for this is that the designs in concept A and B would make it easier to maintain the products. This is mostly because their design relies on mounting the product directly in the ceiling, while concept C has the angular shape that can cause the collection of dust in this area. Overall, concept C receives most of the points due to the minimization of weight, materials and parts.

When scoring the concepts based on the requirements in Repair (requirement 6-15), concept C again receives high scores. Concept C scores especially high on requirement 6 regarding standardization and requirement 11 regarding if the customer can repair the product on their own. This is due to that C relies on screws as securing mechanisms and that does not need to be taken down in order to access its inner parts, e.g., for repairs. For requirements nr 15, it scores significantly lower than the other concepts. This is also because of the screws, but here it is deemed that they require more time to remove than the connectors used in concept A and B. Here it is clear that the screws are an advantage in certain regards but a disadvantage in others.

C scores high on most requirements in the Reuse category (requirement 16-22). All concepts are based on the principle of an electronics module onto which all electronic parts are connected with the same types of fasteners. This results in that all concepts score high on the requirement on promoting upgradability. However, concept B receives a slightly lower grade due to that the modules need to be customized to fit the electronics module. Both B and C has a product hierarchy that makes it easy to reach components.

The concepts receive very similar results in the category of Recycle (requirement 23-37) which is mostly due to that the materials are similar. A and C groups the electronic parts well by having the electronics module onto which all components are attached. B scores a little higher when rating the ability of removing the electrical components. This is due to the joined fastener that, when unfastened, releases all components simultaneously. The button mechanism in concept A causes some mix of materials in the mount which leads to lower points on the ability to distinguish different materials when sorting during recycling. Concept C scores low on the ability of disassembling the product with ease, which is due to the screws. Compared to concept A and B, the screw connections in concept C are more time-consuming when disassembling.

6.1.4 **Conclusions of concept scoring**

The concepts scoring resulted in that concepts C received the highest score. The concept had several advantages regarding material efficiency and product architecture. The electronics module is beneficial from the aspect of upgradability and the exchanging of parts. However, concept C could be improved by incorporating the attachment solutions from the other concept instead of utilizing screws. This would be an advantage when disassembling the product, which can benefit Repair, Reuse and Recycle as well.

6.2 Prototyping

Concept C was chosen to be explored further. This was done by prototyping the concept. The purpose of prototyping was to detect possible obstacles and improvements with the concept.

6.2.1 **CAD modelling**

The concept was first prototyped by creating CAD models. By creating models, different issues with the design could be discussed and solved. There were several issues regarding the mount and how it would be designed for it to be mounted both on the wall or in the ceiling. Other issues were how cables would supply the camera with power. Several CAD models were created to iterate towards better solutions. Two iterations of the CAD modelling are visible in figure 6.2.

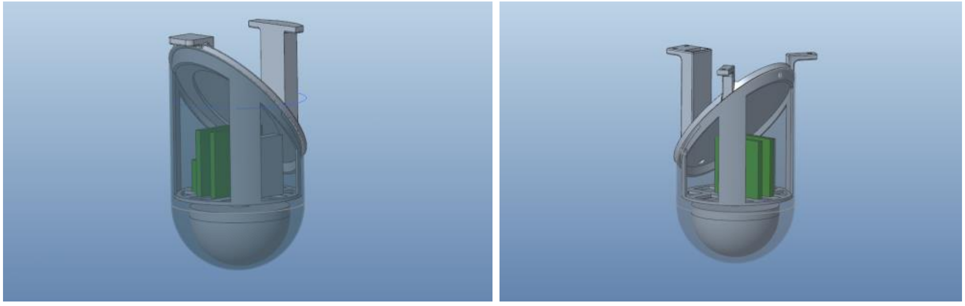

Figure 6.2 Iterations during CAD modelling.

6.2.2 3D printing

In addition to CAD modelling, the concept was also prototyped by 3D printing. By 3D printing, the parts in the concept could be tested and assembled by hand. The purpose of this was to get a feeling for the concept and to ensure that the concept could be assembled in the intended way. One iteration of the 3D printing is visible in figure 6.3.

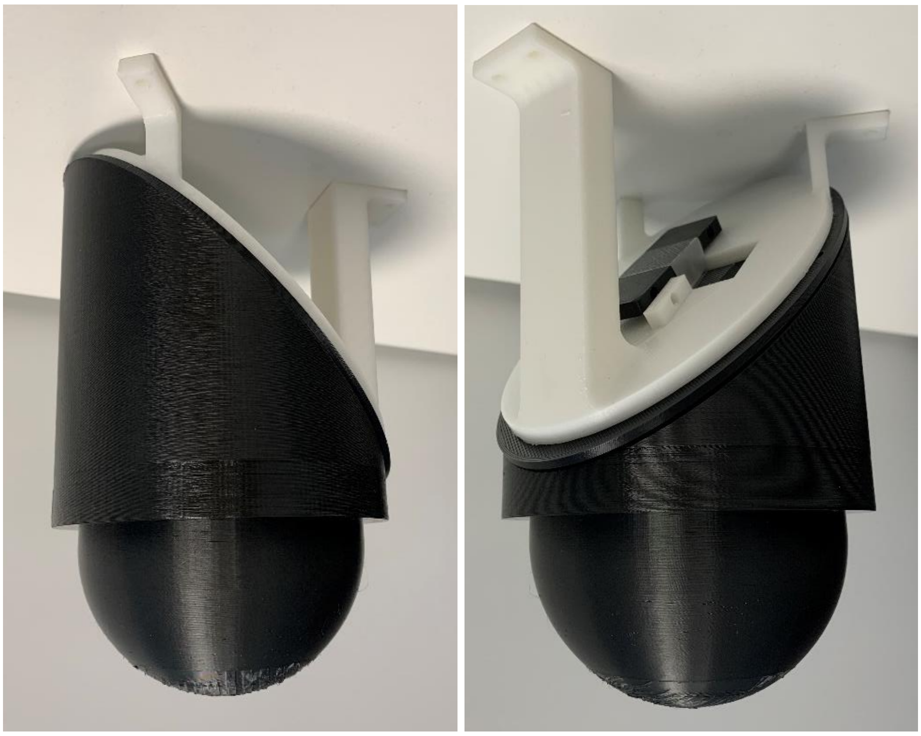

Figure 6.3 3D printing of concept.

6.2.3 Input from supervisor

The concept was revised together with the supervisor at Axis to discuss possible issues and requirements that needed to be addressed. This information was then included in the concept and further iterations were made in prototyping process.

Some of the requirements were regarding the cable management and how cables running in to and within the camera would cause problem when installing or entering the camera for reparation or upgrading. If one for example would open the lid to change a PCB, one would have to do it carefully and detach the cable, without causing problems to the fragile electronics on the inside. This was a less than ideal solution that created an additional barrier for Repair and Reuse. In order to maintain a design that would be easy to enter it was decided that the final concept would involve electrical connectors that could be easily connected and unconnected. Pogo pins are spring loaded contacts that only relies on force in order to connect. The pins can also be exchanged for balls, creating a connection that can be rolled into place [41]. These type of connectors were deemed to be suitable for this concept.

It was also noticed that the PCB:s would require further protection. In the concept, the camera is fully enclosed only when it is installed on the mount, which causes a risk for the PCB:s during installation. Finally, the upgradability of the dome was discussed. The dome is a part that can get scratched and needs to be exchanged. It was therefore established that the dome would not be extended upwards but instead kept in the shape of a half sphere, to minimize the total amount of material that would need to be exchanged if the dome gets scratched.

6.3 Final concept

The final concept for the circular PTZ camera is visible in figure 6.4 and 6.5. The features in the concept have been developed with the aspects of Reduce, Repair, Reuse and Recycle. The concept and its features are presented in the following sections.

Figure 6.4 Concept mounted in the ceiling.

Figure 6.5 Concept mounted on the wall.

An exploded view of the parts in the concept is visible in figure 6.6. The camera consists of six main parts: a mount (1), a lid (2), a grid (3), a dome (4), a gasket (5) and a chassis (6). All components, excluding the mount, makes up what is referred to as the camera body (2-6). The grid, dome and gasket are all stacked and are kept in place by the lid and the chassis. The grid is where the electrical components, such as PCB:s and the PT-module, attach onto.

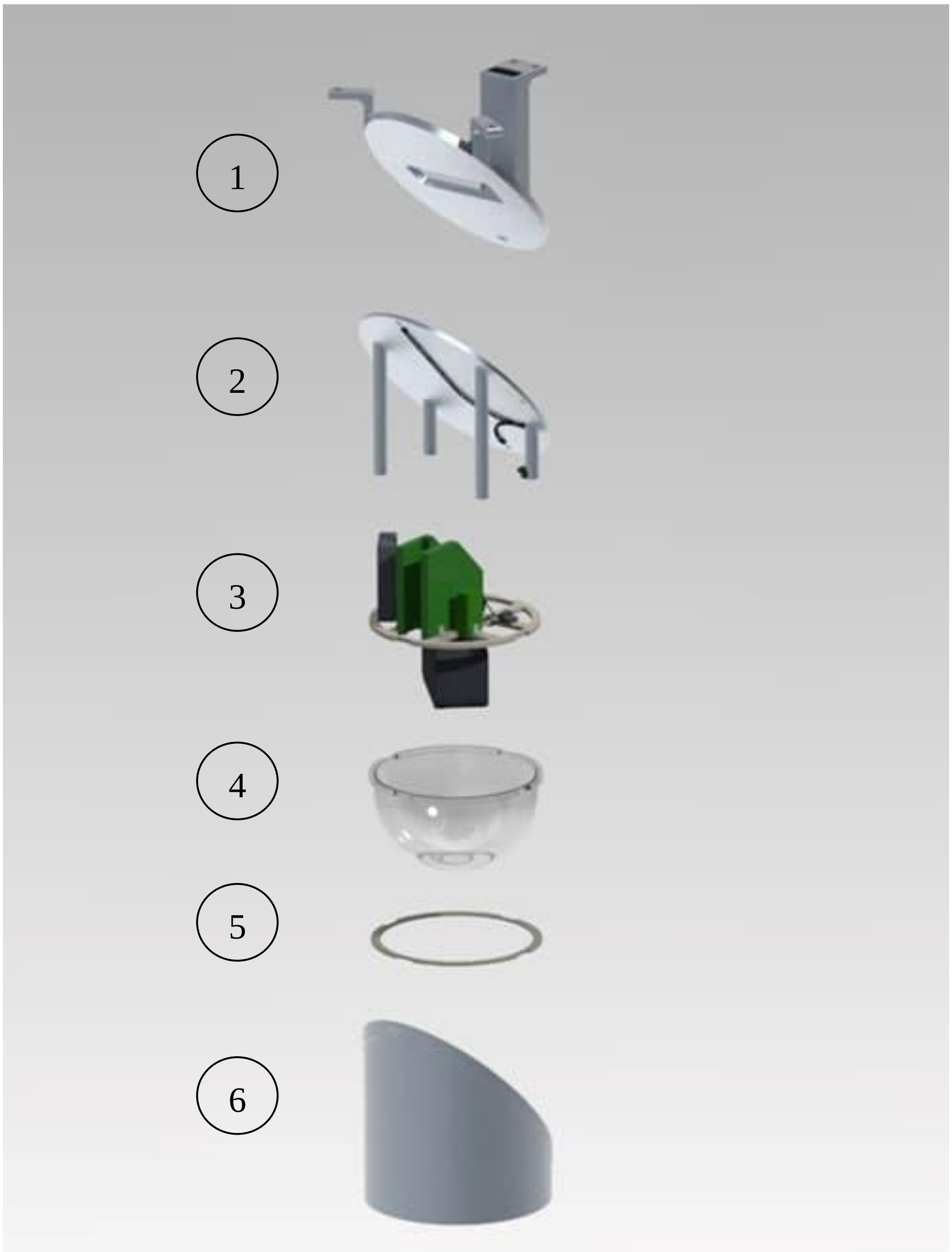

Figure 6.6 Exploded view.

The chassis and the mount are connected with a 45-degree angle. This creates a solution that can be used for both ceiling and wall hanging with the same mount, see figure 6.8. This also makes the dome be directed downwards in both constellations. The mount has a rectangular hole and the lid for the body has a latch with the same dimensions. By inserting the latch in the hole and then turning it 90 degrees, it locks the body and the mount together, see figure 6.7. The lock is then secured by screws form both sides. This locking mechanism aims to make it easy to access the camera, e.g. for repairs. By allowing the user to remove the camera from the mount with only two screws, the user can bring the camera to an environment where it is safe to open the camera.

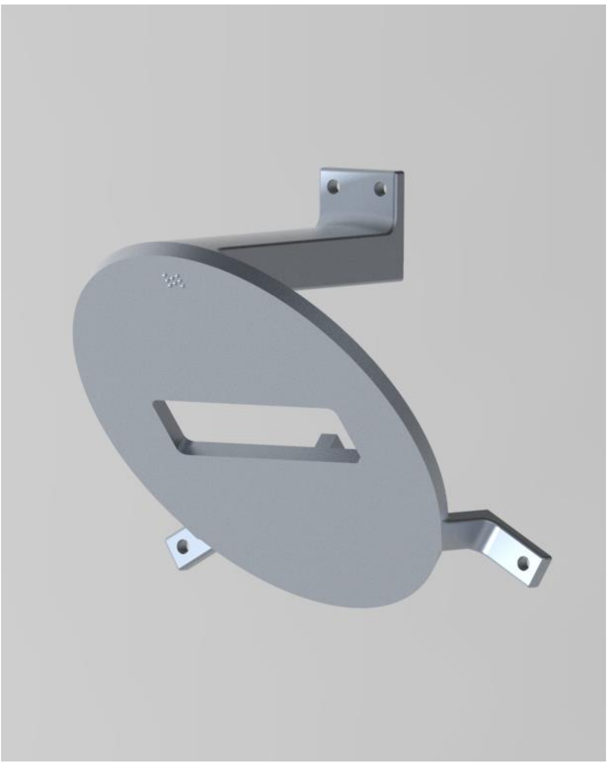

Figure 6.7 Mount.

Figure 6.8 Connection between mount and lid.

The concept also envisions that the mount can be used for different camera bodies with different sizes, as long as they rely on the same locking mechanism. As mentioned, pogo pins were chosen in order to keep the concept easy to access and install, thus they are used to connect the mount and the camera body see figure 6.9.

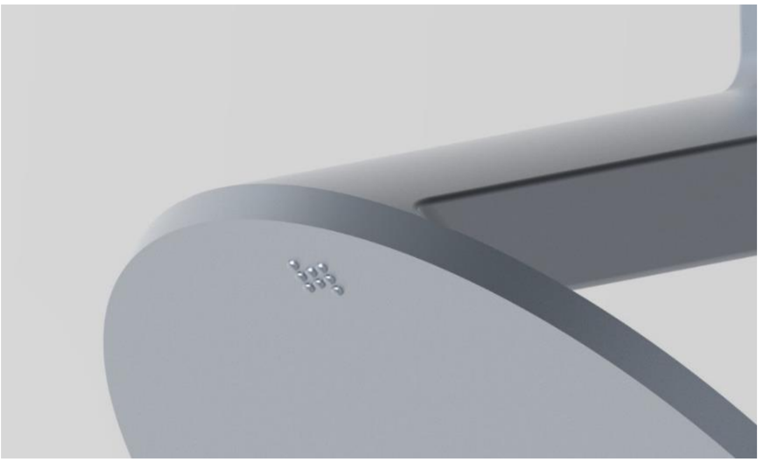

Figure 6.9 Pogo pins.

When the camera is removed from the mount, it consists of the camera body, see figure 6.10. The camera is then fully enclosed and protects the components that are located on the inside. By protecting the fragile components, such as the PCB:s, the life of the camera can be prolonged. At the same time, only four screws needs be removed to access the inside in order to exchange or repair components.

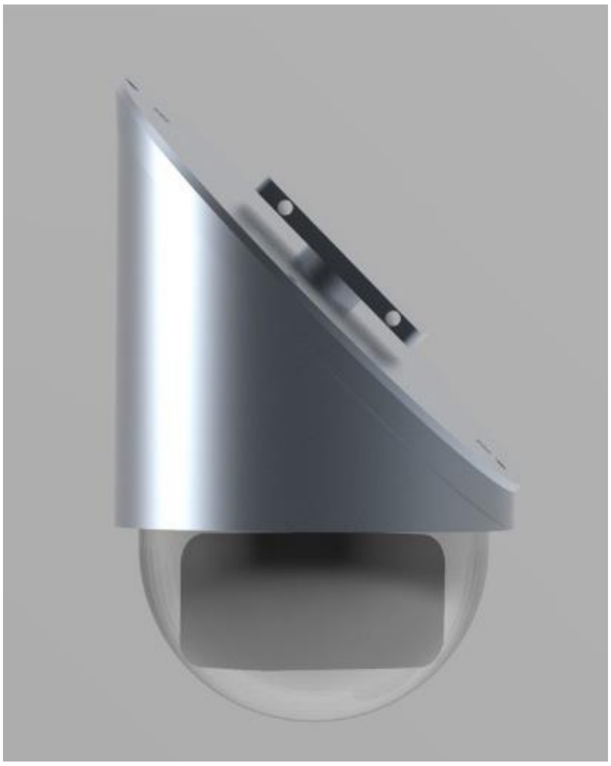

Figure 6.10 Camera body.

The lid is assembled onto the chassis by four screws, see figure 6.11. The top of the lid consists of the latch, which attaches the camera body onto the mount.

Figure 6.11 Lid.

The design of the lid aims to reduce the number of parts and fasteners in the concept. The lid is provided with four bars, see figure 6.12. When the lid assembled, the four bars press the dome, gasket and grid into the chassis, and this mechanism locks all parts. No additional fasteners, e.g. screws, are therefore needed. The mechanism utilizes gravity as the camera will always hang downwards.

In figure 6.12, the cables for power and image transferring are visible. The cables are connected to the electronic components through pogo pin connectors that allows for easy separation and disassembly.

Figure 6.12 Lid.

The chassis in the concept is visible in figure 6.13 and 6.14. The chassis holds the dome, gasket and grid. These parts are assembled by being placed upon an edge in the chassis, see figure 6.13. The parts are locked rotationally by the four tracks in the chassis, further assisting the locking mechanism by the lid.

Figure 6.13 Chassis, inside.

Figure 6.14 Chassis, outside.

The dome is visible in figure 6.15. It is assembled into the chassis by being locked rotationally by the four bars. The lid locks the dome vertically. If damaged, the dome can be exchanged by being lifted out of the product after the removal of the grid.

The chassis and the dome have diameters that are larger than what the current PT-module requires. This spacious design allows for future upgrades where the PT-module is designed to be larger.

Figure 6.15 Dome.

One central part in the concept is the grid for the electrical components. The grid is assembled inside the chassis, see figure 6.16. Similar to the dome, the grid is locked rotationally by the four tracks and locked vertically by the bars in the lid.

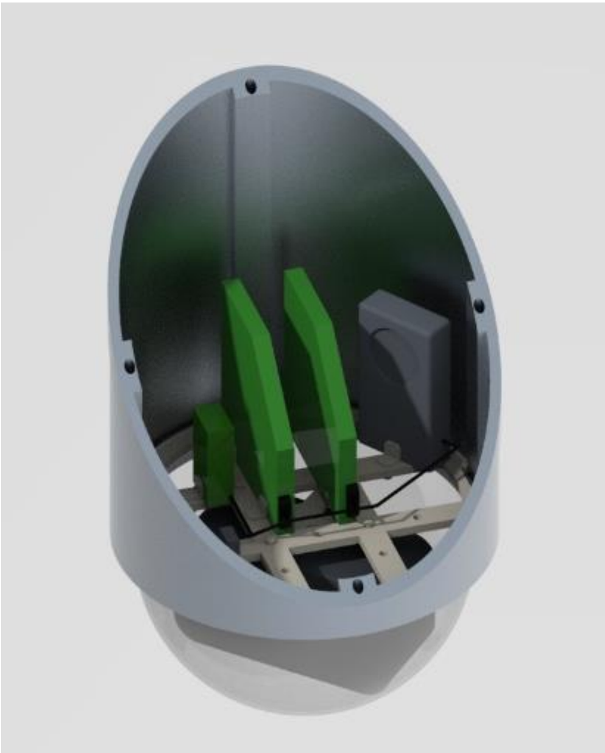

Figure 6.16 Grid assembled in the chassis.

All electronic parts are connected to the grid, see figure 6.17. The components connected to the grid in the figure are three PCB:s, one fan, a pogo pin connector and the PT-module. The PCB:s are visualized as green blocks. To reduce the amount of material used, the use of plastic covers for the components has been limited. For example, the PT-block, visible underneath the grid, is not provided with an additional plastic cover for the sake of aesthetic reasons.

Connecting these parts onto one grid is beneficial from many aspects in the circularity requirements. The grid allows for easy access to components that need repair, e.g. the PCB:s. It is also an advantage during recycling, since the grid groups all electronics within the product. The grid promotes upgradability through its modular design, by providing the same types of holes that components can be attached into.

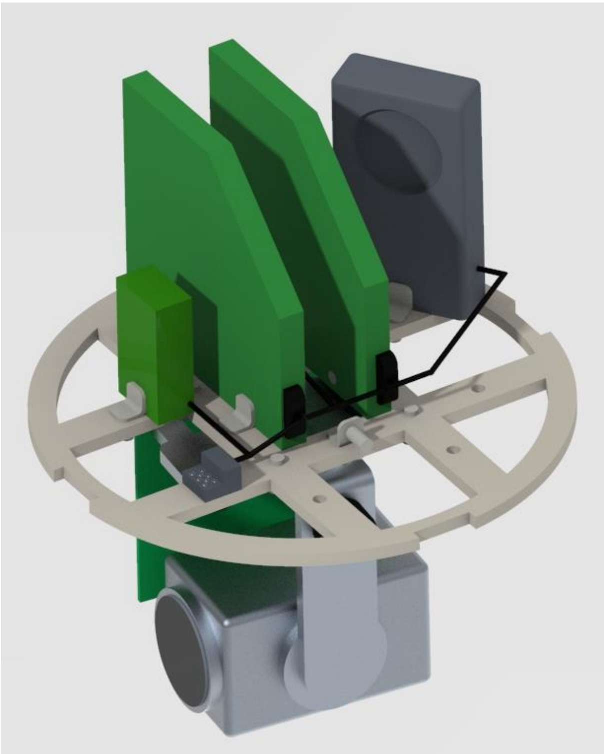

Figure 6.17 Grid.

The components are connected to the grid using snap-fits, see figure 6.18. The snap-fit solution aims for non-permanent connections that are easy and quick to disassemble. The snap-fits themselves are designed to be modular in such way that one type will work on all the different components that need to be attached to the grid. The snap-fits have a circular cross-section that enables parts to be oriented in

360 degrees, which provides many possibilities for how parts can be placed onto the grid.

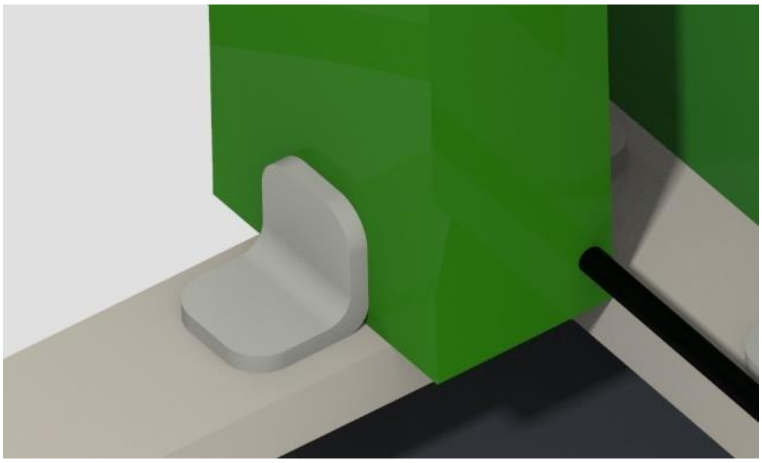

Figure 6.18 Snap-fit.

To avoid moisture from entering the camera, the concept is provided with a gasket, see figure 6.19. The gasket can also be used for compression for the force on the stacked components, creating a tight fit.

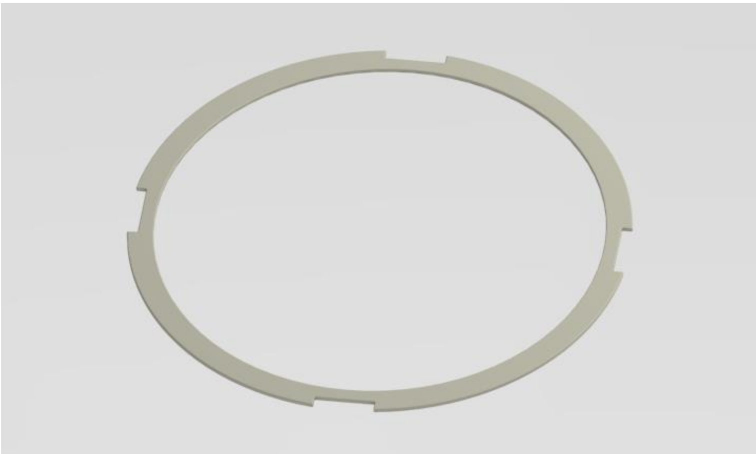

Figure 6.19 Gasket.

The main parts in the concept are marked with a code that can be scanned, see figure 6.20. The code is connected to a system would contain information about the part. Examples of such information could be material data, repair history, previous use-cycles and recycling instructions. The code could also be used to find manuals on how to use and repair the camera.

Figure 6.20 Scannable code in the mount.

The materials selected for the main parts in the concept are listed in table 6.2. The materials are selected to be recyclable and aim for clean material streams in order to optimize for mechanical recycling. When mechanical recycling is not an option, chemical recycling such as pyrolysis is used to loop back the materials into the cycle.

Table 6.2 Material selection.

Part	Material
Mount	Aluminum
Chassis	Aluminum
Lid	Aluminum
Dome	PC plastic
Grid	PA plastic
Snap-fit fasteners	PA plastic
Gasket	TPE

The mount, chassis and lid are made of aluminum. These parts are designed to be durable and to last for many use-cycles, as well as they protect the contents in the camera. Aluminum is recyclable and its properties does not degrade during the recycling process [27]. To avoid the use of coatings that can cause issues during recycling, the aluminum is anodized. Anodizing creates a strong surface on the metal that is also corrosion resistant, without creating obstacles during recycling [42]. By having anodized aluminum, the protective surface properties can be obtained without the need to add extra surface coatings. Another way of avoiding the use of surface treatments and printing on the camera, is that the Axis logo is engraved in the body part.

The dome is made of the thermoplastic polycarbonate (PC). PC has high light permeability and is recyclable [43].

The grid along with the snap-fit fasteners are suggested to be made of the plastic polyamide (PA). With the aim of reducing the amount of additives in the polymer, no color additives have been added. Parts located in the camera are considered not to require color purely for aesthetic reasons.

The gasket is made of a thermoplastic elastomer (TPE). TPE:s are an alternative to rubber, and are ideal for material recycling [43].

The dome, grid, snap-fit fasteners and gasket are assumed to be made from renewable plastics. From a circularity aspect, it is beneficial to use drop-in plastics. Drop-in plastics have the same molecular structure and properties as their fossil alternatives but are developed from renewable resources, e.g. sugar canes or corn [26]. This avoids the use of fossil resources, as well as their properties allows for mechanical recycling similar to a conventional polymer. If reviewing the plastics in the concept, only PA can be manufactured as drop-in plastic today. For the future scenario, it is assumed that the technology will have progressed and will include the materials for the other plastic parts as well.

7 Discussion

In this section, the project is reflected upon. The final concept is discussed along with the future work for the project.

7.1 Circularity requirements

The concept was developed based on guidelines for circular design. Many different guidelines were found during the Discover phase, and some were adapted as circularity requirements for the concept. Some of the guidelines could be used exactly as they were while others were modified to apply for this project. Other guidelines found through the research were considered as too specific for this project. For the requirements to be easy to use, the circularity requirements were kept quite general and not too specific.

The circularity requirements were divided under the categories of Reduce, Repair, Reuse and Recycle. These categories aimed to represent the different phases for the life of a circular product. There are however additional categories and requirements that could have been selected when designing for circularity. Examples of additional categories are Rethink, Refurbish and Remanufacture. However, selecting more categories would have broaden the project scope even further and the choice was therefore made to select four categories.

During the Develop phase, it became clear that the circularity requirements could create both conflicts and synergies between each other. These conflicts and synergies have been discussed throughout the concept development and have affected the selected features for the concept. Examples of synergies that were detected was that grouping of electrical parts into one module can benefit both Repair and Recycle. From the Repair perspective, the electrical parts can be accessed and exchanged easily when grouping them. From the Recycle perspective, electrical parts contain materials that cause issues, so the grouping of electrical parts benefits the sorting of materials during recycling.

The circularity requirements were used as assessment criteria during the concept evaluation. The assigned weight for the criteria indicated which requirements were considered as more important in terms of circularity. When assigning weights to the criteria, it was discovered that some requirements were binary (yes/no) while others could be fulfilled to different degrees. The binary requirements could be applied to all concepts, and it was therefore decided to assign the binary requirements a weight of 0. Another way of constructing the circularity requirements could have been to divide the requirements into must- and want-requirements, where the must-requirements are binary. It was also discovered that some of the requirements overlapped with each other, and these were also weighed as 0. One example of this was the requirement for R2R as it overlapped with the other, more detailed, requirements for Repair.

7.2 Final concept

The concept used the current camera model Q6075-E as a product reference. The project purpose was to design a visionary concept and therefore use the requirements for the product reference only briefly. No full comparisons have been made regarding the material usage, weight or number of parts for the concept compared to the reference. For a full comparison, the concept would need to be developed further to obtain the required details for such a comparison. A comparison of the current concept and the Q6075-E model was therefore not expected to yield any relevant results.

The final concept has been developed on the categories of Reduce, Repair, Reuse and Recycle. As the project progressed, the focus shifted more into optimizing the concept for the two categories of Repair and Reuse. It was discovered that the features developed for these categories showed a larger importance when prolonging the life of the product. This resulted in a concept that could be taken down from the mount easily by only removing two screws. The camera can then be opened with another four screws. When opened, it is possible to exchange all the electrical parts without any additional tools. It also possible to remove all the main electronic components as one part, as they are grouped together via the grid.

Throughout the project, there has been ongoing trade-offs between the different circularity requirements and what design choices to prioritize. One example of this is the material selection, and the trade-off between reducing material and to design for durability. The concept could have been optimized further for weight reduction, however it was decided to focus on durability and the aim of keeping the product in the loop for a long time.

Snap-fits were utilized in the concept to fasten electronic parts. The concept evaluation had revealed improvement potential for the disassembling of the product. The solution was to exchange the screws for snap-fits but at the same obtain the modular grid. While screws are standardized components, snap-fits are considered easier to disassemble. They create a product where it is easy and intuitive to exchange parts inside the camera. However, screws were used to fasten the lid and the mount, as it was of importance that the camera was secured.

The concept suggest that pogo pins can be used as a flexible way of connecting different components in the design. Using spring loaded pins for this purpose requires that there is a tight fit between the connectors since the pins are sensitive for vibrations and movement. Though there in nothing that would make this method unfeasible, the technology is not used in these kinds of applications today.

The design utilizes three different PCB:s, separated by their functions. By having more PCB:s than this it would require more cables, material and a complex designs. While having less would make the camera hard to repair. If all the electronic components would be connected to one PCB it means that the whole PCB would have to be exchanged even if only one component is broken. Thus, having three makes a repair less wasteful.

7.3 Future work

The purpose of this project was to develop a visionary concept for circular economy in the year 2030. The features in the concept are based on assumptions for how such a future scenario would look like and there are therefore many aspects that needs to be further investigated before this concept can be realized. One aspect is the business model for Axis. The concept is developed to be a part of a circular product handling with focus on the repair and reuse of parts, which would require changes in the Axis business model. A business model suggestion was however outside the scope of this thesis.

Another aspect to consider is how to assess the sustainability of the circular concept. The term sustainability covers many areas, and the concept needs to be assessed from different perspectives. In this thesis, a concept has been developed with the aim of a circular product handling and to keep the product and materials in the loop for a long time. Other ways of assessing a concept is to construct LCA:s to calculate the environmental impact of a products lifecycle, e.g. carbon dioxide emissions or energy consumption. LCA:s were not included in the scope of this thesis but for future work, LCA:s could be used to investigate other aspects of sustainability for the concept.

As the concept is visionary and developed for a future scenario, the concept has not been provided with a detailed-level design and there are therefore several areas that require future work. Examples of this are development of the connections between the different parts, such as the plastic snap-fits or the mechanism in the lid. In addition to this, the concept needs to review the feasibility and risks of the design choices to make sure they comply with the camera requirements, e.g. how the camera responds to external loads and vibrations.

7.4 Process

The project has followed the Double Diamond design process with the four phases Discover, Define, Develop and Deliver. This method was considered useful for the project process as the different project activities could be assigned for each of the phases. As the project scope was broad in the beginning of the project, the converging phase of Define was critical for narrowing down the research and to define the concept.

One challenge throughout the process was the project scope. The established research questions covered many areas and topics, and the purpose of this was to discover different opportunities regarding circularity and how it can be implemented in a product development project. Throughout the project, it has been challenging to determine the required level of detail for the thesis and to assess the feasibility of the concept. The main purpose of the project was to develop a visionary concept and to use the existing product requirements for the Q60 camera model only loosely. One way of limiting the scope could have been to establish additional requirements for the concept and therefore include a more detailed specification in the Define phase. However, this could have created a conflict with the purpose of creating a visionary concept.

8 Conclusions

The project has identified features for a concept for a PTZ camera in a circular economy. When designing for circularity, there are several different aspects to consider. This concept has been developed based on the aspects of Reduce, Repair, Reuse and Recycle. The main challenge in this project has been to tackle the different trade-offs that occur when considering these four aspects at the same time. It was discovered that the concept should prioritize the aspects of Repair and Reuse as they aim to prolong the life of the product, rather than focusing on design for Recycle. The key features in the concept therefore focus on repair possibilities and promotes the upgradability of parts. The concept is easy to enter and disassemble, as well as the product structure allows for the exchange of parts. This is highlighted through a modular interface inside of the camera, where components can be connected by the same types of snap-fit fasteners.

The project resulted in a visionary concept. Being designed for a future circular scenario in year 2030, the concept is not applicable in the company product range today. However, the concept hope to inspire how circular design strategies can be implemented in the product development.

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Appendix A Work distribution and time plan

This appendix presents the work distribution of the project along with the time plan. The project time plan is compared to the outcome and the differences are discussed.

A.1 Work distribution

The work was divided equally between both students. Both students participated in all main activities during the project and performed them together. When performing the activities, the students sometimes divided some tasks between them such as investigating different research areas individually during the Discover phase.

A.2 Project plan and outcome

The project plan and outcome are presented in figure A.1. The activities in the project are presented through a timeline, where the lighter color blocks describe the plan and the darker color blocks describe the outcome. The project plan was constructed in the beginning of the project to estimate the duration of each activity, and therefore create a rough timeline for the project.

The outcome differs somewhat from the plan. Some of the activities overlapped with each other and required some iterations, which was the case for Discover and Define. During the Define phase, the team needed to iterate back to Discover for the collection of additional research. There was also a large difference between the plan and outcome for Deliver. The initial plan was to overlap the Develop phase with the Deliver phase and iterate between the two phases. Instead, the students entered the Deliver phase later and spent more time than expected in this phase. There were also more iterations required during the prototyping in the Deliver phase, which was why this was activity was carried out longer than expected.

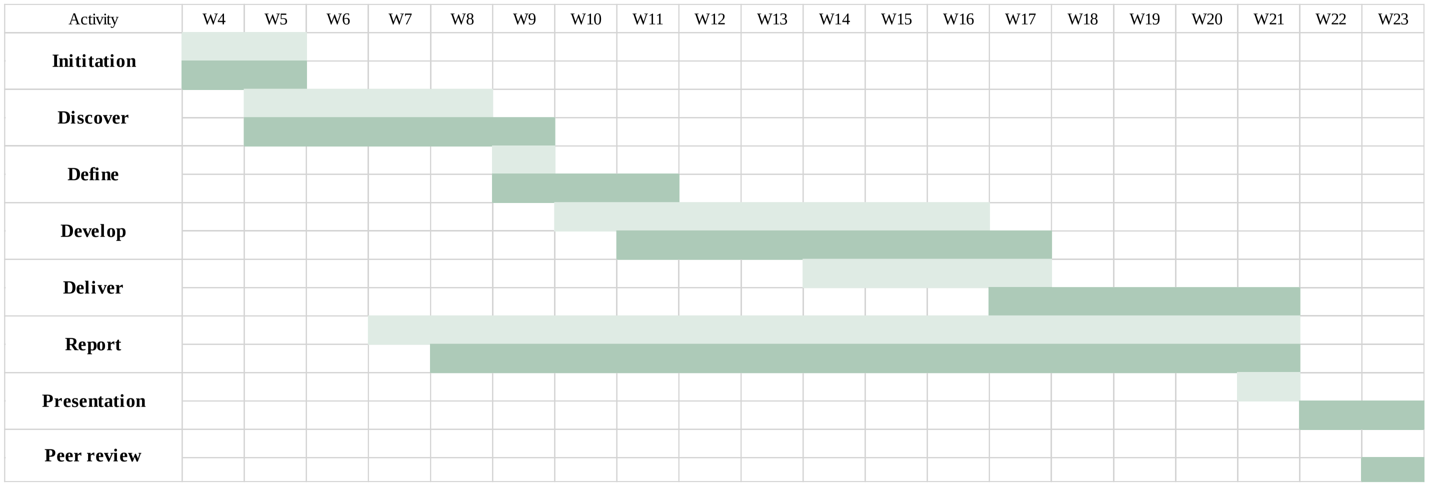

Figure A.1 Planned and performed activities.

Appendix B Interview guides

This appendix presents the interview guides that were used for the interviews held during the Discover phase.

B.1 Materials and recycling

- What is your role at Axis?
- Do you wot with recycling today and if so, how?
- What is the optimal way of recycling the products today?
    - What is the optimal way of disassembling the products today?
    - Is there a gap between how the products should be recycled and ow they are actually recycled?
- What are the different recycling processes for the materials in the cameras?
    - What processes are used?
- Are there materials in the cameras that creates complications during recycling?
    - Do the cameras contain hazardous substances?
    - What materials are nonrecyclable?
- What is the origin of the raw materials for the cameras?
- How does the process look like on how to include more recycled materials in the products?
- Does Axis currently have a collaboration with other partners about recycling possibilities?
    - E.g., recycling facilities
    - Why or why not?
- Could Axis do more to optimize the recycling process?
    - That products are being recycled?
    - That products are recyclable?
    - How?
- Are there any incitements for recycling of cameras today?
    - For Axis?
    - For customers?
    - Deposit? Take-back?
- Why is the camera disposed?

    - Why is it not recycled?
- What challenges exist today regarding recycling of cameras?
- What obstacles occur when using recycled materials in the products?
- What are the future possibilities for materials and circularity?

B.2 Product usage

- What is your role at Axis?
- Who are the customers?
    - How are the different customers using the cameras?
- Where are the cameras located?
- What is the lifetime of the cameras?
    - Guaranteed lifetime?
    - Expected lifetime?
    - Actual lifetime?
- What technological shifts has previously made the cameras out of date?
- Is there any strategy for how often customers should change camera?
- What are the current customer demands?
    - In general?
    - Regarding circularity?
- How is a camera upgraded with new software?
    - How long after the camera is released will it be upgraded?
- How do you think customer usage can or should be changed in order to think more in terms of circularity?

B.3 Manufacturing

Production

- Can you explain the production of a PTZ works, in a broad sense?
- What different kinds of manufacturing techniques are there for a PTZ camera?
- Are there any materials or substances used in the manufacturing process today that are worse from an environmental point of view?
- Are there any spillages in the production?
- Are there opportunities to use the spillage?
- When designing for circularity, there are a lot of changes one can make i.e., avoiding glue when securing parts or making the product easier to

disassemble. Do you think these kinds of changes would interfere with production?
    - Do you think it could have a positive effect on production?
- How do you think production can be optimized with a circular economy?

Sustainability and circularity at Axis today

- How is your view on the future and circularity?
- What are the incentives to recycle the camera today?
    - For Axis?
    - For the consumer?
- Deposit or take back?
- What are the challenges of recycling the cameras today?
- How does Axis business model comply with a circular economy?
    - What disadvantages are there?
    - What advantages are there?

B.4 Repair

- What can be repaired?
    - Can everything in the camera be repaired?
    - What is repaired today?
- How does the repair work today?
    - How does the RMA work?
    - How does the EMS work?
- Is the repair done at the site or is taken down and sent back?
    - Are the cameras sent back and forth a lot?
- What is stopping reparation today? What is not repaired?
    - What is stopping you from making more repairs?
- Downsides of repairing?
- How can you make it easier to repair the cameras?
- Can parts be exchanged? i.e., modular?
- How do you work with right to repair?
    - In the future?
- How do you identify what's wrong with the camera when it's broken?
    - How can you make it easier?
- What kind of problems relate to refurbishment?
- How can you use repair to incorporate circular economy?

Appendix C PTZ Q6075-E specification

This appendix presents the current specification for the PTZ Q6075-E, which is the camera model that was used as a reference for the concept.

Datasheet

AXIS Q6075-E PTZ Network Camera

Outdoor-ready PTZ with HDTV 1080p and 40x optical zoom

AXIS Q6075-E PTZ Network Camera offers HDTV 1080p and 40x optical zoom for great overviews and excellent details. This high-performance outdoor PTZ camera comes with autotracking 2 with click and track functionality, as well as an orientation aid for active object tracking and quick orientation. With Axis Lightfinder 2.0 the camera delivers low-light images with more saturated colors and sharper images of moving objects. Plus, enhanced security features such as signed firmware and secure boot ensures the integrity and authenticity of the firmware. Furthermore, Axis Zipstream with H.264/ H.265 significantly lowers bandwidth and storage requirements.

- > HDTV 1080p with 40x optical zoom
- > Axis Lightfinder 2.0
- > Autotracking 2 and orientation aid
- > Built-in analytics
- > TPM, FIPS 140-2 level 2 certified

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HDTV NETWORK VIDEO

AXIS Q6075-E PTZ Network Camera

Models	AXIS Q6075-E 50 Hz AXIS Q6075-E 60 Hz
Camera	
Image sensor	1/2.8" progressive scan CMOS
Lens	4.25–170 mm, F1.6–4.95 Horizontal field of view: 65.1°–2.00° (1080p) Vertical field of view: 39.1°–1.18° (1080p) Autofocus, auto-iris
Day and night	Automatically removable infrared-cut filter
Minimum illumination	Color: 0.1 lux at 30 IRE, F1.6 B/W: 0.002 lux at 30 IRE, F1.6 Color: 0.15 lux at 50 IRE, F1.6 B/W: 0.003 lux at 50 IRE, F1.6
Shutter speed	1/11000 s to 1/3 s with 50 Hz 1/11000 s to 1/3 s with 60 Hz
Pan/Tilt/Zoom	Pan: 360° endless, 0.05°–450°/s Tilt: 220°, 0.05°–450°/s Zoom: 40x optical, 12x digital, total 480x zoom E-flip, 256 preset positions, tour recording (max 10, max duration 16 minutes each), guard tour (max 100), control queue, on-screen directional indicator, orientation aid PTZ, set new pan 0°, adjustable zoom speed, focus recall
System on chip (SoC)	
Model	ARTPEC-7
Memory	1024 MB RAM, 512 MB Flash
Compute capabilities	Machine learning processing unit (MLPU)
Video	
Video compression	H.264 (MPEG-4 Part 10/AVC) Baseline, Main and High Profiles H.265 (MPEG-H Part 2/HEVC) Main Profile Motion JPEG
Resolution	HDTV 1080p 1920x1080 to 320x180
Frame rate	Up to 50/60 fps (50/60 Hz) in HDTV 1080p
Video streaming	Multiple, individually configurable streams in H.264, H.265 and Motion JPEG Axis Zipstream technology in H.264 and H.265 Controllable frame rate and bandwidth VBR/ABR/MBR H.264/H.265
Image settings	Manual shutter time, compression, color, brightness, sharpness, white balance, exposure control, exposure zones, fine tuning of behavior at low light, rotation: 0°, 180°, text and image overlay, polygon privacy masks, electronic image stabilization (EIS), freeze on PTZ, automatic defog, backlight compensation, scene profiles Wide Dynamic Range (WDR): Up to 120 dB depending on scene, highlight compensation
Network	
Security	Password protection, IP address filtering, HTTPS[a] encryption, IEEE 802.1x (EAP-TLS)[a] network access control, digest authentication, user access log, centralized certificate management, brute force delay protection, signed firmware, secure boot, protection of cryptographic keys with FIPS 140-2 certified TPM 2.0 module
Supported protocols	IPv4, IPv6 USGv6, ICMPv4/ICMPv6, HTTP, HTTP/2, HTTPS[a], TLS[a], QoS Layer 3 DiffServ, FTP, SFTP, CIFS/SMB, SMTP, mDNS (Bonjour), UPnP®, SNMP v1/v2c/v3 (MIB-II), DNS/DNSv6, DDNS, NTP, RTSP, RTP, SRTP, TCP, UDP, IGMPv1/v2/v3, RTCP, ICMP, DHCPv4/v6, ARP, SOCKS, SSH, NTCIP, LLDP, CDP, MQTT, Syslog, Link-Local address (ZeroConf)
System integration	
Application Programming Interface	Open API for software integration, including VAPIX® and AXIS Camera Application Platform; specifications at *axis.com* One-Click Cloud Connection ONVIF® Profile G, ONVIF® Profile S and ONVIF® Profile T, specification at *onvif.org*
Event conditions	Device status: above operating temperature, above or below operating temperature, below operating temperature, fan failure, IP address removed, network lost, new IP address, shock detected, storage failure, system ready, within operating temperature Edge storage: recording ongoing, storage disruption I/O: digital input, manual trigger, virtual input MQTT subscribe PTZ: PTZ malfunctioning, PTZ movement, PTZ preset position reached, PTZ ready Scheduled and recurring: scheduled event Video: live stream open
Event actions	Day/night mode, overlay text, video recording to edge storage, pre- and post-alarm video buffering, send SNMP trap PTZ: PTZ preset, start/stop guard tour File upload via FTP, SFTP, HTTP, HTTPS network share and email Notification via email, HTTP, HTTPS and TCP MQTT publish
Data streaming	Event data
Built-in installation aids	Pixel counter, leveling guide
Analytics	
AXIS Object Analytics	Object classes: humans, vehicles Trigger conditions: line crossing, object in area Up to 10 scenarios Metadata visualized with color-coded bounding boxes Polygon include/exclude areas Perspective configuration ONVIF Motion Alarm event
Applications	**Included** AXIS Object Analytics AXIS Video Motion Detection, autotracking 2, active gatekeeper Basic analytics (not to be compared with third-party analytics): object removed, enter/exit detector, object counter **Supported** Support for AXIS Camera Application Platform enabling installation of third-party applications, see *axis.com/acap*
General	
Casing	IP66-, IP67-, NEMA 4X- and IK10-rated Metal casing (aluminum), polycarbonate (PC) clear dome, sunshield (PC/ASA)
Sustainability	PVC free
Power	**Axis High PoE 60 W SFP midspan:** 100–240 V AC, max 66.1 W Camera consumption: typical 14 W, max 51 W
Connectors	RJ45 10BASE-T/100BASE-TX PoE, RJ45 Push-pull Connector (IP66/IP67) included
Storage	Support for SD/SDHC/SDXC card Support for SD card encryption Support for recording to network-attached storage (NAS) For SD card and NAS recommendations see *axis.com*
Operating conditions	**With 30 W:** -20 °C to 50 °C (-4 °F to 122 °F) **With 60 W:** -50 °C to 50 °C (-58 °F to 122 °F) Maximum temperature according to NEMA TS 2 (2.2.7): 74 °C (165 °F) Arctic Temperature Control: Start-up as low as -40 °C (-40 °F) Humidity 10–100% RH (condensing)
Storage conditions	-40 °C to 65 °C (-40 °F to 149 °F) Humidity 5–95% RH (non-condensing)
Approvals	**EMC** EN 55032 Class A, EN 55035, EN 61000-3-2, EN 61000-3-3, EN 61000-6-1, EN 61000-6-2, EN 55024, FCC Part 15 Subpart B Class A, ICES-003 Class A, VCCI Class A, RCM AS/NZS CISPR 32 Class A, KCC KN32 Class A, KN35 EN 50121-4, IEC 62236-4 **Safety** IEC/EN/UL 60950-1, IS 13252 IEC/EN/UL 60950-22, IEC/EN/UL 62368-1 **Environment** IEC/EN 60529 IP66/IP67, NEMA TS 2 (2.2.7-2.2.9), IEC 62262 IK10, ISO 4892-2, EN 50121-4, IEC 62236-4, IEC 60068-2-1, IEC 60068-2-2, IEC 60068-2-6, IEC 60068-2-14, IEC 60068-2-27, IEC 60068-2-60, IEC 60068-2-78, NEMA 250 Type 4X **Network** NIST SP500-267 **Midspan:** EN 60950-1, GS, UL, cUL, CE, FCC, VCCI, CB, KCC, UL-AR

T10139891/EN/M17.2/2111

Weight	3.75 kg (8.3 lb)
Dimensions	Ø232 x 271 mm (Ø9.13 x 10.7 in)
Included accessories	Axis High PoE 60 W SFP midspan 1-port, RJ45 Push-pull Connector (IP66), Sunshield Installation Guide, Windows decoder 1-user license
Optional accessories	Smoked dome cover AXIS T91 Mounting Accessories, AXIS T8415 Wireless Installation Tool, AXIS T90 Illuminators, AXIS T8310 Video Surveillance Control Board, multi-user decoder license pack
Video management software	AXIS Companion, AXIS Camera Station, Video management software from Axis' Application Development Partners available on *www.axis.com/vms*
Languages	English, German, French, Spanish, Italian, Russian, Simplified Chinese, Japanese, Korean, Portuguese, Traditional Chinese
Warranty	5-year warranty, see *axis.com/warranty*

a. *This product includes software developed by the OpenSSL Project for use in the OpenSSL Toolkit. (openssl.org), and cryptographic software written by Eric Young (eay@cryptsoft.com).*

Environmental responsibility:

axis.com/environmental-responsibility