BL0.0M

Enhancing Perceived Safety: A Transformation of the Visual Impact and Design Aesthetics of Camera Sensors in the Public Space.

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Responsible Sensing Lab

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Preface

A special thanks goes out to everyone that has helped me, guided me and supported me throughout this graduation project.

To my supervisory team, Sofie and Luce, for pointing me in the right direction on multiple occasions, constantly being available for feedback and being completely honest when improvements could be made.

To Anouk and the team at the RSL for their expertise in smart sensing technology, openness in communication and willingness to help in any way they could throughout the project.

To the experts at the PMB for their interest, assistence and patience during the prototyping phase, in which Murphy's law was truly put to the test.

To my friends in Delft who provided comic relief and fresh perspectives, and especially Jordan, who inspired me to set a certain standard for this thesis.

To my physiotherapists, who literally kept me up on my feet after I tore my ACL in a rugby match, 2 days after the project Kick-Off.

Finally, to my family and my girlfriend, Tess, for the constant support and enthusiasm they displayed during the last 5 months. This thesis would not be what it is now without you all.

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Abstract

This graduation project emerged from an existing collaboration between the Delft University of Technology and the Responsible Sensing Lab; a project of the Amsterdam Institute of Advanced Metropolitan Solutions.

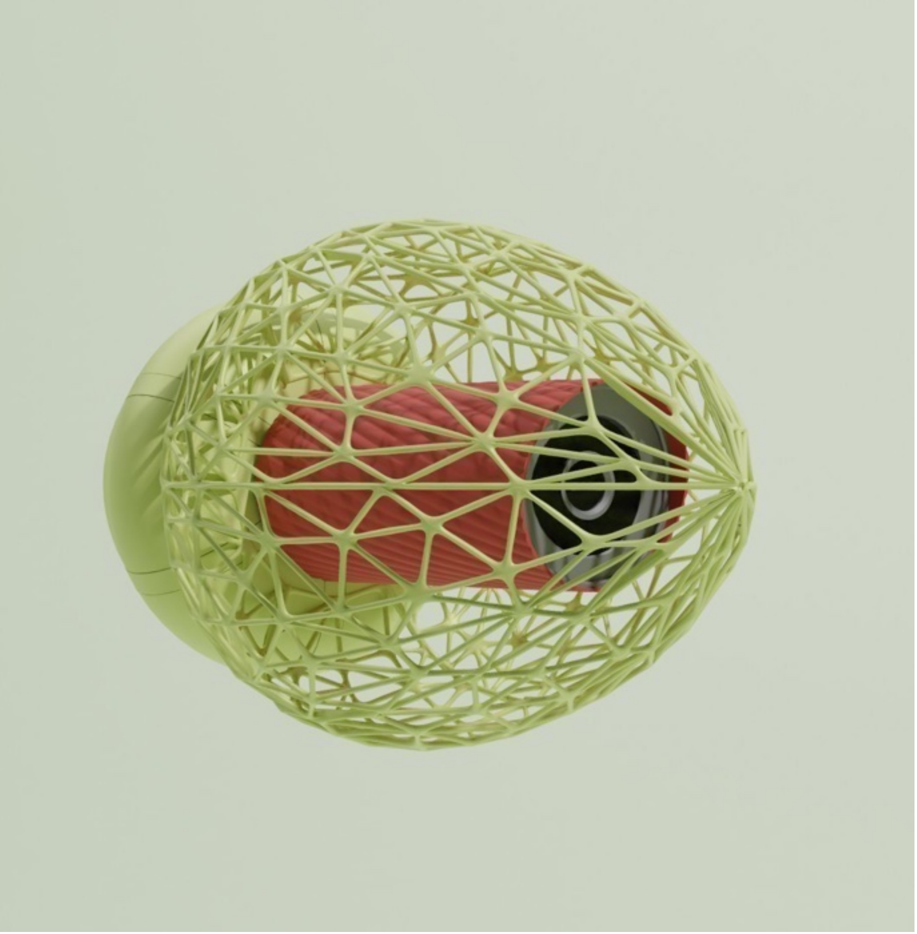
The Initial Assignment had the goal of enhancing the feeling of safety in public environments through the use of responsible sensing. Following the method of Value Sensitive Design and its 3 core aspects, contextual research was conducted into 1) perceived safety as the value, 2) smart sensors as the technology, and 3) public spaces as the context of use. Subsequently, the project was narrowed down to focus on improving the design aesthetics and visual impact of camera sensors in public spaces, with the intended end result of enhancing the perception of safety with the Target User Group of heterosexual women, aged 15-25.

Through the involvement of this Target User Group in 2 co-creation sessions, multiple informal feedback sessions and a Product Usability Evaluation in the Concept Development and Product Design phases of this project, a final design was created.

The final design, BL0.0M, is a reconception of the design, use and perception of current camera sensors. Compatible with both dome- and bullet camera sensor types, BL0.0M takes inspiration from a flower to serve both a functional and visual purpose to its public environment. Upon activation of the camera sensors, BL0.0M's petals open up–clearly communicating its functionality to passers by, and can be adjusted to convey different product expressions. Its modularity extends to its petal modules, which can easily be interchanged to allow for further customisation and variety.

The reception of the Target User Group was both critical and auspicious. Future recommendations primarily include further design iterations in petal design and positioning, as well as looking into the internal- and external validity of the user group involved. From both informal feedback and the Product Usability Evaluation, BL0.0M elicited a high level of intrigue and enthusiasm. Its functional and aesthetic contrast with current camera sensor designs is one of the main drivers for this response.

BL0.0M is a visionary design with an eye to the future, serving as the version 0.0 and a blank canvas for the next big steps and innovations in smart sensor design and implementation. For now, this is only the first step.



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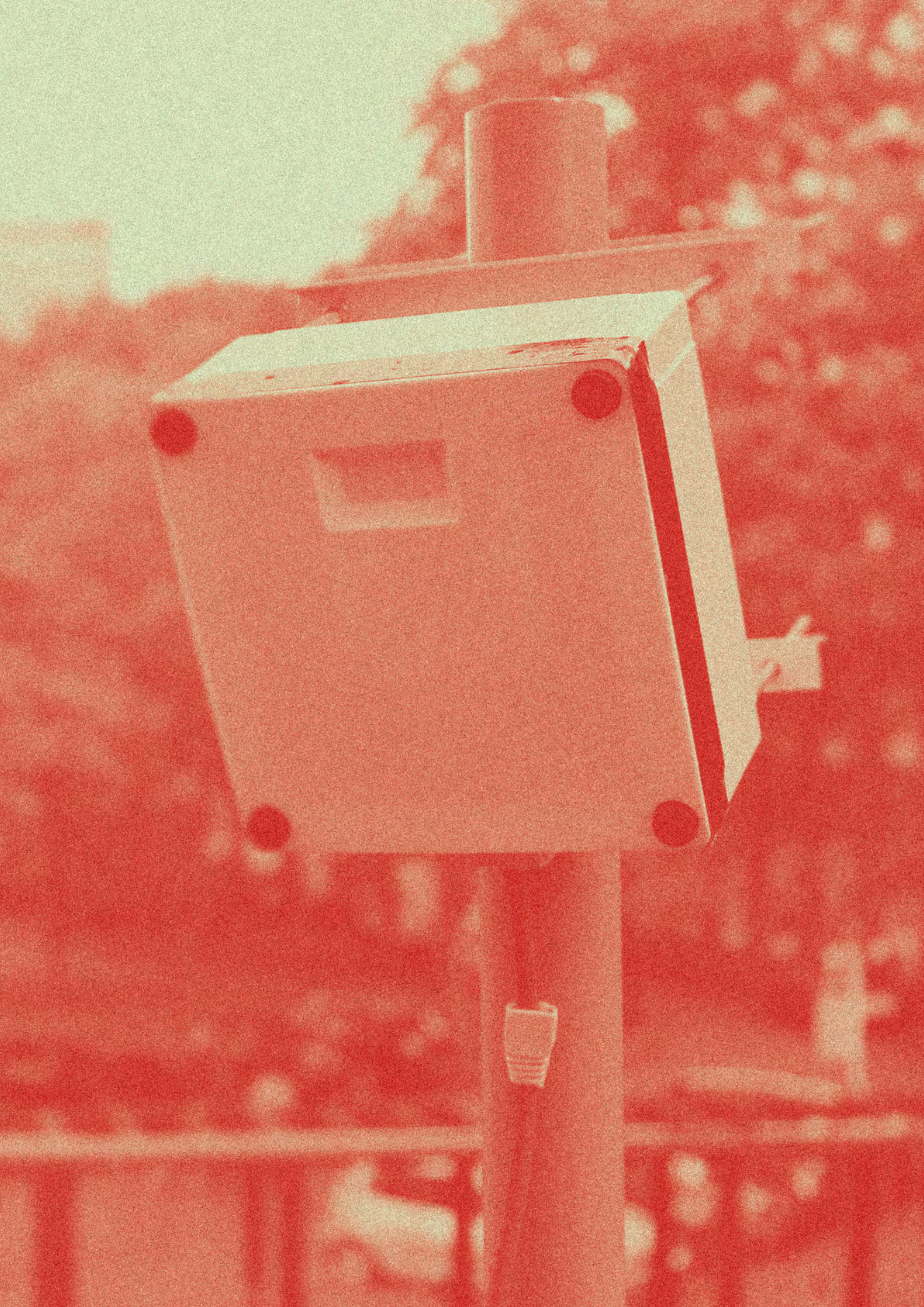
List of Abbreviations

3D	3-Dimensional
A	Autonomy
A'dam	Amsterdam
AMS	Amsterdam Insititute for Advanced Metropolitan Solutions
AS	Actual Safety
AVG	Algemene Verordening Gegevensbescherming
BLE	Bluetooth
CCP	Co-Creation Participant
CCTV	Closed-Circuit Television
CMS	Crowd Monitoring System
CNC	Computer Numerical Control
CPTED	Crime Prevention Through Environmental Design
CRL	Combined Readiness Level
CV	Computer Vision
DDP	Double Diamond Process
DJN	Design Justice Network
DPIA	Data Protection Impact Assessment
HRL	Human Readiness Level
I	Inclusiveness
IP	Interview Participant
LGBTQ+	Lesbian, Gay, Bisexual, Transgender, Queer, etc.
LoR	List of Requirements
MAYA	Most Advanced Yet Acceptable
MCU	Mobile Camera Unit
MoA	Municipality of Amsterdam
NS	Nederlandse Spoorwegen
P	Privacy (LoR)

P	Proportionality (Value Principle)
PETG	Polyethylene Terephthalate Glycol
PLA	Polylactic Acid
PMB	Model Making and Machine Lab
PUE	Product Usability Evaluation
PUEP	Product Usability Evaluation Participant
PrEmo	Emotion Measurement Instrument
QR Code	Quick Response Code
RQ	Research Question
RSL	Responsible Sensing Lab
RST	Responsible Sensing Toolkit
R&D	Research & Development
SE	Socioeconomic
SST	Smart Sensing Technology
T	Trust
TA	Takeaway
TADA	Anagram of ‘data’
TRL	Technology Readiness Level
TU Delft	Delft University of Technology
TUG	Target User Group
UX/UI	User Interface / User Experience
VSD	Value Sensitive Design
ViP	Vision in Product
WOT	Weighted Objectives Table
mmWave	Millimeter Wave
n	Sample size

(AMS Institute, n.d.-b)



1_0_0 Introduction

In this chapter, the Initial Assignment as given by the Responsible Sensing Lab and TU Delft is introduced alongside a definition of the Problem to be solved. This is followed by an overview of the Research Questions, design approach and methodologies used within this project.

1_1_0
Problem Definition

Fig. 1: The Public Space (Studler, 2016)
The use of SST has sharply increased with the goals of improving quality of life and making city operations more efficient.

1_1_1
Problem

As our lives are becoming increasingly urbanised and digital, so has the use of smart sensing technology in cities and public areas sharply increased, with the goals of improving quality of life and making city operations more efficient (AMS Institute, 2021).

Modern day smart sensing technology and specifically camera sensors, focus excessively on physical safety–referred to throughout this project as 'actual safety', as a metric for success and effectiveness. The relative subjectivity of perceived safety; whether people actually 'feel' safe, is a much harder metric to use, and does not always correlate to the level of actual safety (Syropoulos, 2018).

A problem occurs when a public space has a high level of actual safety but the people within the spaces experience low perceived safety, a problem that can be perpetuated by the utilitarian, 'form-follows-function' design approach of current camera sensors that focus solely on actual safety. Moreover, this 'tunnel vision' of actual safety as a metric and the related neglect of perceived safety can lead to an over-reliance on data collection and 'surveillance state' tendencies, which arguably has the potential to even harm the actual safety of citizens in the future. Consideration of perceived safety is therefore necessary in the design and use of smart sensors.

1_1_2
Initial Assignment

The original brief for this graduation opportunity was titled 'Enhancing the feeling of safety in public environments through the use of responsible sensing' and was already presented as a collaboration between the Delft University of Technology (TU Delft) and the Responsible Sensing Lab (RSL). Preliminary statistics on the feeling or perception of safety in public spaces were provided as a basis of the initial design problem, describing a downward trend in the overall feeling of safety, a higher likelihood for women to feel unsafe compared to men, and a higher likelihood for young people to feel unsafe compared to older people.

Presented as a very broad starting point for a graduation project, the brief did specify a few directions and desired outcomes. The assignment was to start off with both primary and secondary research into the influence of public spaces on people's perception of safety within them. The subsequent design phase would explore potential solutions that would improve this perception of safety and develop these solutions in the form of concepts and a physical prototype. As a final note, it was emphasised that the design solution should not involve the shifting of any action or responsibility on the end user.

1_1_3
Company Involvement

The Responsible Sensing Lab (RSL) is a project of the Amsterdam Institute for Advanced Metropolitan Solutions which was set up to address the urban challenge of Responsible Urban Digitisation by exploring how smart sensors can be used and implemented responsibly within the public spaces of cities.

According to the RSL, 'responsible' use and design of such technologies requires the integration of public and democratic values. The Responsible Sensing Toolkit (RST) was therefore developed to serve as a step-by-step guide for responsible smart sensing.

For this graduation project, the Responsible Sensing Lab was involved in providing valuable research and expertise in the technical, legal, political and societal aspects of smart sensing technology.

As an integral member of the RSL team, Project Leader at the MoA department of CTO and having previous experience in collaborations with TU Delft, Anouk Wieleman was the main contact person and Company Mentor of this graduation project.

1_2_0
Research Direction

1_2_1
Scope

The Research & Analysis phase of this project is structured according to the Value Sensitive Design (VSD) method (further explained in 1_3_2). The first 3 general research questions; RQ_1_0, RQ_2_0 and RQ_3_0, therefore shift the research focus on the project value, technology, and context of use, respectively.

The 4th general research question, RQ_4_0, represents the transition from the Research & Analysis phase of the project to the succeeding Design Vision, Concept Development and Product Design phases. Here, the insights and findings gained from the previous research questions is used to make a start at defining and developing the final design.

1_2_2
Research Questions

RQ_1_0	**Who are the main stakeholders and how are they involved?**
RQ_1_1	Who are the direct and indirect stakeholders in the context of smart sensing technology?
RQ_1_2	What potential harms and benefits can be identified for each stakeholder in the context of smart sensing technology?
RQ_1_3	How do identified harms and benefits correspond to key social and individual values?
RQ_1_4	How can a value hierarchy be implemented to resolve present value conflicts considering different stakeholders?

RQ_2_0	**What is the current state of smart sensing technology regarding public safety?**
RQ_2_1	What types of smart sensors are currently deployed throughout the city?
RQ_2_2	What determines the current location and application of smart sensors?
RQ_2_3	How is smart sensing used systemically to safeguard citizens in public space?
RQ_2_4	What alternative smart sensing solutions have been explored?
RQ_2_5	How does the municipality envision future public space?

RQ_3_0	**What influences perceived safety in public spaces?**
RQ_3_1	What situational factors can affect perceived safety?
RQ_3_2	How do certain aspects of urban design influence perceived safety?
RQ_3_3	How do citizens view public safety in the context of social and individual values?
RQ_3_4	How can demographic factors influence perceived safety?
RQ_3_5	How do citizens currently perceive and interact with smart sensors?

RQ_4_0	**How can smart sensors be designed to contribute to perceived safety in public space?**
RQ_4_1	How can the human-product interaction be redesigned to contribute to perceived safety?
RQ_4_2	How can the embodiment be redesigned to contribute to perceived safety?
RQ_4_3	How can it be integrated into the design of public space to contribute to perceived safety?

How can **smart sensing technology** be (re)designed to contribute to **perceived safety** in **public spaces?**

Main Research Question

1_3_0
Approach & Methodology

1_3_1
Double Diamond Process

Based on the initial assignment, the process of this project was structured according to the Double Diamond Process (DDP), in which the research- and design phases of this project are each represented by a respective 'diamond'. These diamonds are further subdivided into a divergence- and subsequent convergence stage.

In the 1st divergence stage, broad, contextual research is conducted to generate a 'big picture', to then be converged and sharpened into a design direction and vision. The 2nd divergence stage then explores different design solutions and concepts, of which 1 is selected to be developed and refined in the concluding convergence stage.

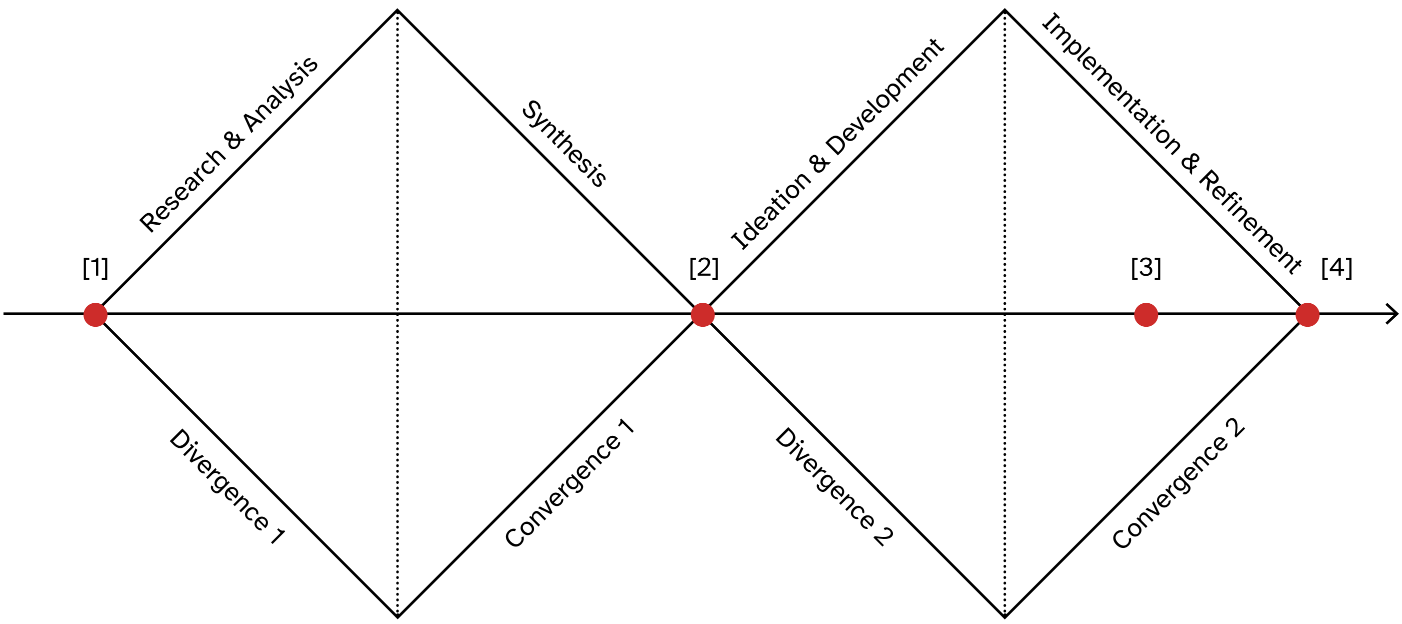


Fig. 2: Double Diamond Process
The 4 stages of the Double Diamond Process with project milestones highlighted in red.

[1]: Kick-Off Meeting, 02_03_2023
[2]: Mid-Term Evaluation, 03_05_2023
[3]: Green Light Meeting, 30_06_2023
[4]: Graduation Ceremony, 28_08_2023

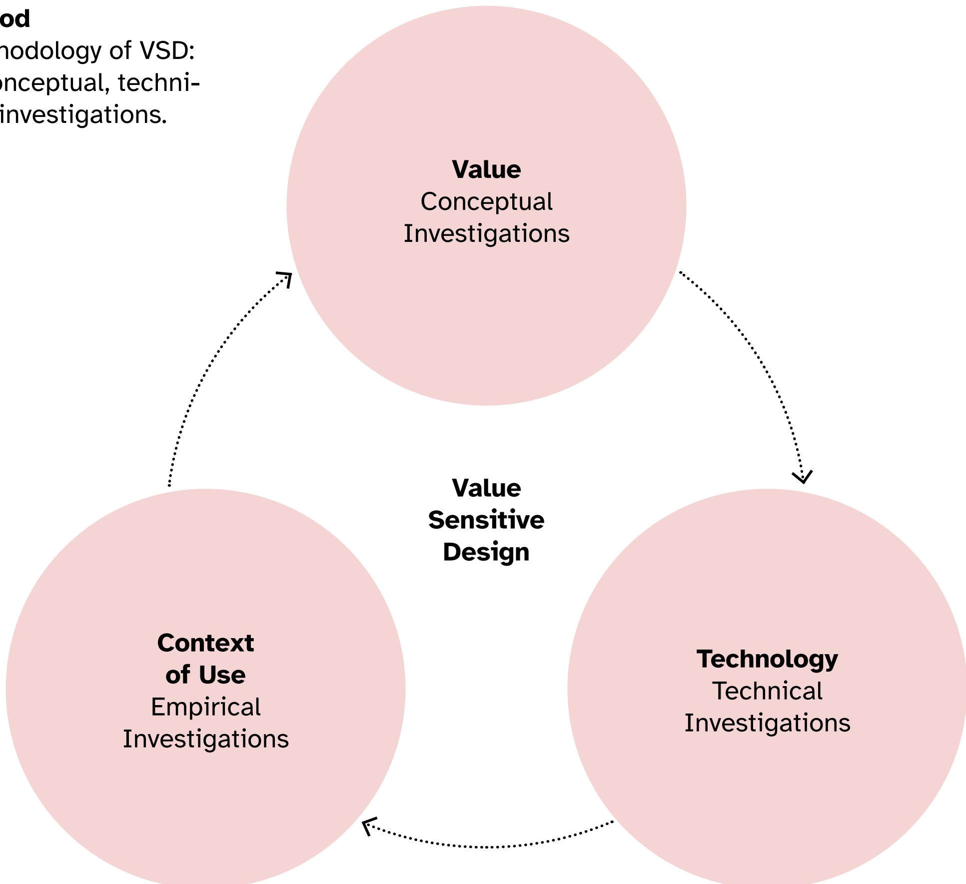
1_3_2
Value Sensitive Design

As stated before, the initial assignment read; 'enhancing the feeling of safety in public environments through the use of responsible sensing'. For this objective, Value Sensitive Design seemed to be a perfect method, as the very formulation of the objective already contained the description of a 1) value, 2) technology and 3) context of use.

Having identified the 3 core aspects of the VSD method (Friedman et al., 2013), the value of perceived safety was identified as the most central to this project. This would serve as the starting point of the project and the Research & Analysis phase, from which research into the technology and context of use followed.

Besides the framework of these 3 core aspects, Value Sensitive Design also describes a 'tripartite methodology in which research is structured into conceptual, technical and empirical investigations. Following the tripartite methodology, the Research Questions in 1_2_2 were set up, with each type of investigation being loosely associated with a core aspect of VSD, as shown in Fig. 3.

Fig. 3: VSD Method
The tripartite methodology of VSD: cycling through conceptual, technical and empirical investigations.



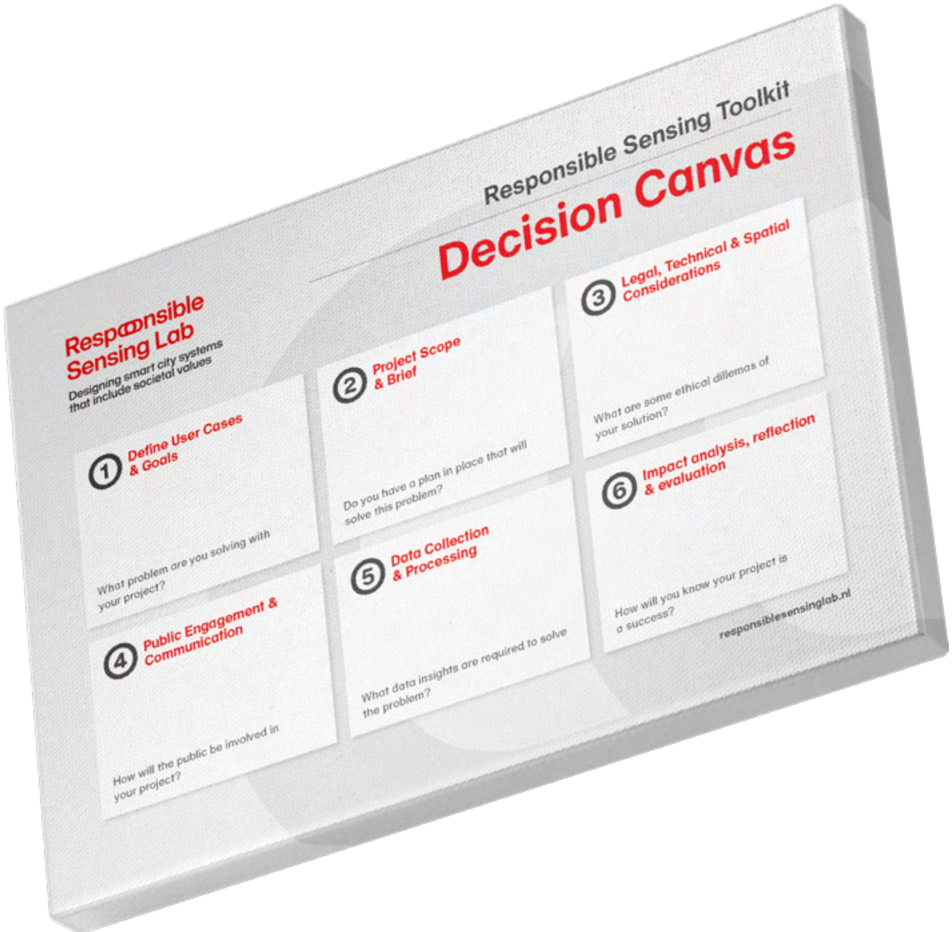


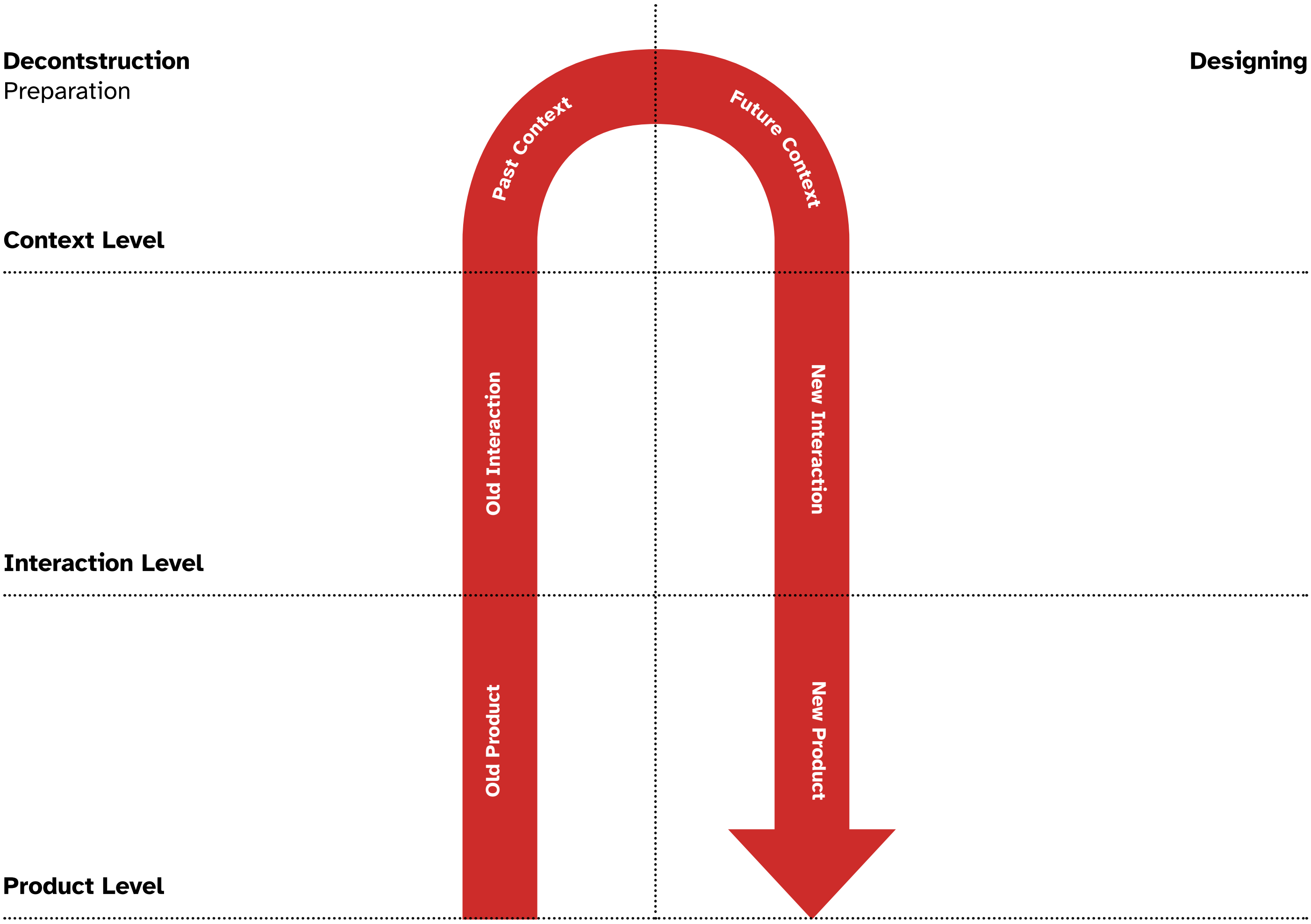
Fig. 4: RST Decision Canvas (AMS Institute, n.d.-b)
The 6 main decisions to consider during smart sensor design and implementation

1_3_3
Responsible Sensing Toolkit

According to Responsible Sensing Lab, the RST is designed "to help identify dilemmas rather than provide solutions so municipal innovators can make decisions responsibly and ethically within a simple framework" (AMS Institute, 2023). Within the research & analysis phase of this project, the RST was therefore used to quickly and efficiently gain a broad insight of all of the considerations, challenges and dilemmas associated with responsible smart sensing, to ultimately build upon the experience and expertise of the Responsible Sensing Lab.

Within the RST, the Decision Canvas (see Fig. 4) splits the toolkit up into 6 main steps or 'decisions' to consider during the design and implementation of smart sensing technology:

1. Define user cases & goals
2. Project scope & brief
3. Legal, technical & spatial Considerations
4. Public engagement & communication
5. Data collection & processing
6. Impact analysis, reflection & evaluation



1_3_4
Vision in Product

Developed by Hekkert and Van Dijk (2016) the Vision in Product (ViP) method was chosen to be used to in the Synthesis phase of this project because of 1) my personal experience using the method in previous design projects and 2) its focus on an envisioned future and underlying 'raison d'être'. Here, both the 'now' and this envisioned future are analysed through a product–, interaction–, and context level, in which the past is deconstructed in preparation for the subsequent design phase.

Because ViP forces the designer to think outside of the proverbial problem box, new pathways to solutions can be explored. In the case of this project, where smart sensing technology is currently viewed and used as the only solution to the problem of maintaining actual safety, such an approach can prove quite valuable.

1_3_5
TRL and HRL

Fig. 5: ViP Model
The 'now' and the envisioned future are analysed through a product–, interaction–, and context level.

Technology Readiness Level
The Technology Readiness Level (TRL) scale, or Technology Readiness Assessment, is a "systematic, evidence-based process that evaluates the maturity of [a given] hardware, software, or process" (Persons & Mackin, 2020). From its originial application in the aerospace industry, the 9-level scale has been modified and put to use in many other contexts, including software– and industrial design.

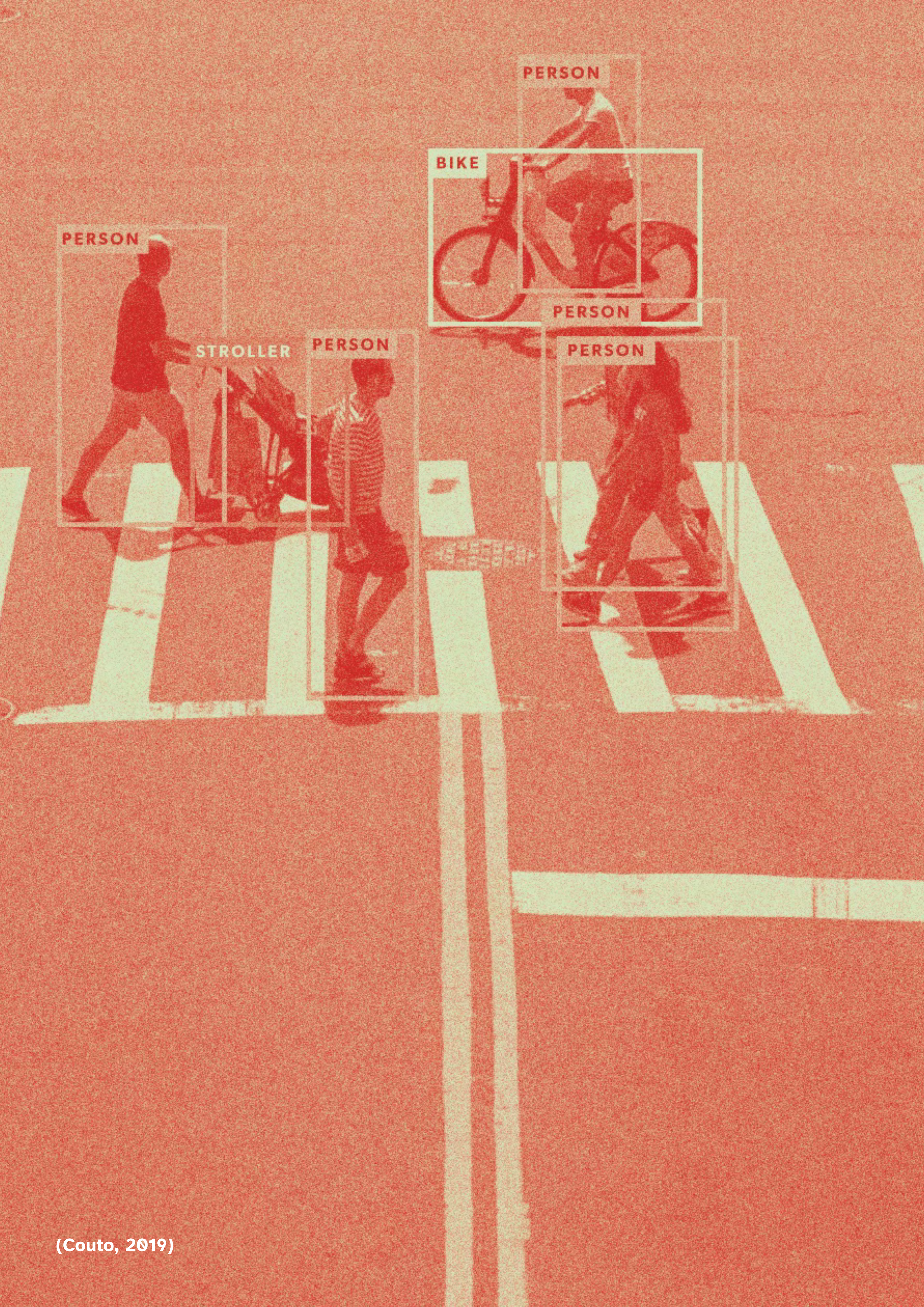
Especially during the Concept Development and Product Design phases, the TRL scale can prove useful in providing both a structure and measure for progress. For this project, the goal is to achieve at least TRL of 5 with the final design.

Human Readiness Level
Even though the TRL scale has many useful applications, including within this project, its sole focus on the technology is eerily reminiscent of how smart sensing technology is currently designed, used and assessed.

The Human Readiness Level (HRL) scale was developed with the aim of levelling the progress of a certain technology with the "usability and its refinement to be used by humans" (Salazar & Russi-Vigoya, 2021). As such, the design phase of this project will be structured according to elements from both the TRL and the HRL, as seen in Tab. 1.

Tab. 1: TRL and HRL
The Technology Readiness Level scale, used as a foundation for the Human Readiness Level scale.

Level	Technology Readiness	Human Readiness
9	Actual system proven through successful mission operations	Postdevelopment and sustainment of human performance capability
8	Actual system completed and qualified through test and demonstration	Human system integration tested in a representative environment
7	System prototype demonstration in a space environment	Human performance using system equipment fully tested, validated
6	Subsystem prototype demonstration in a relevant environment	System design fully matured through performance analysis and prototyping
5	Component and/or breadboard validation in the relevant environment	Human system integration demonstration and early user evaluation
4	Component and/or breadboard validation in the laboratory environment	Analysis of human performance applied within system concept
3	Analytical and experimental critical function proof of concept	Mapping of human interaction to proof of concept
2	Technology concept and/or application formulated	Human capabilities and limitations applied to conceptual designs
1	Basic principles observed and reported	Human-focused concept of operations (human use scenario) defined



(Couto, 2019)


PERSON
TAXI

2_0_0
Context

In this chapter, the context of the assignment is analysed through the 3 main starting points of Value Sensitive Design. Using the VSD method, perceived safety, smart sensing technology and the public space are researched as the value, technology and context of use of this project, respectively.

2_1_0
Perceived Safety
Values

2_1_1
Perceived and Actual Safety

Actual Safety
Public safety or 'actual' safety can be defined as "the risk [a member of the public has] of becoming a victim of crime and disturbance of public order" (Jansson, 2019). Actual safety is an absolute priority in our everyday lives. Said by Syropoulos (2018) to be a "prerequisite for societies to prosper and flourish", the fulfilment of any other human goal or acitivity can be strongly argued to be conditional to actual safety. If a person is not safe, their number one priority at that moment is to be safe again, and fulfilment of any other goal or value is secondary. On Maslow's hierarchy of needs (Eller & Frey, 2019), only physiological needs like hunger, thirst and fatigue fall lower on the pyramid. In other words: safety comes first.

Perceived Safety
If actual safety refers to the risk of becoming a victim of crime and disturbance of public order, then perceived safety can be thought of the perception of this risk. The assumption is often made that these two perspectives are always in line with each other. Zhang et al. (2021) point out that this is not the case, finding a significant mismatch between crime rates and the perception of safety, which they refer to as 'perception bias'. According to Zhang et al., this perception bias represents severe under- or overestimation of crime and safety in certain neighbourhoods. This paradoxical association is further reinforced by Syropoulos (2018), who points out that despite historically unprecedented low levels of crime, perceived safety is continually challed by public awareness of unsafe occurrences like terrorist attacks or mass shootings–primarily through media exposure.

2_1_2
Safety as a Value

According to Value Sensitive Design, a value is subjectively determined and depends on human wants within a certain cultural or societal context (Friedman et al., 2013). Looking at the two perspectives of safety in the context of values further reveals the discrepancy between them.

The Authorities

For the authorities, a stakeholder group loosely representing the government and its municipalities, the police and other emergency services, the assurance of actual safety for its citizens is a key value. In the context of this project, the authorities mainly refer to the municipality of Amsterdam and its police. From the perspective of the authorities, 'safety' applies to a general population, requiring a degree of objectivity and quantifiability–usually in the form of crime statistics, to be able to measure and maintain a level of actual safety. The ability to maintain a society as free as possible from the risk of becoming a victim of crime and disturbance of public order is a direct reflection of the capability and competentness of the authorities, as well as the resultant public trust in them.

The Public

For the public–or citizens of Amsterdam, safety is seen not from the perspective of a whole population, but by the individuals within it. Safety is experienced and valued subjectively, based on the conceptions and perceptions of the individual, hence perceived safety. Where one citizen might enjoy walks in the park at 3:00 a.m., another might regard the situation as unsafe. Although perceptions can therefore differ depending on demographic and situational factors, the desire to feel safe can be thought of as a universal value, placed with even importance to actual safety on Maslow's hierarchy of needs according to Eller & Frey (2019).

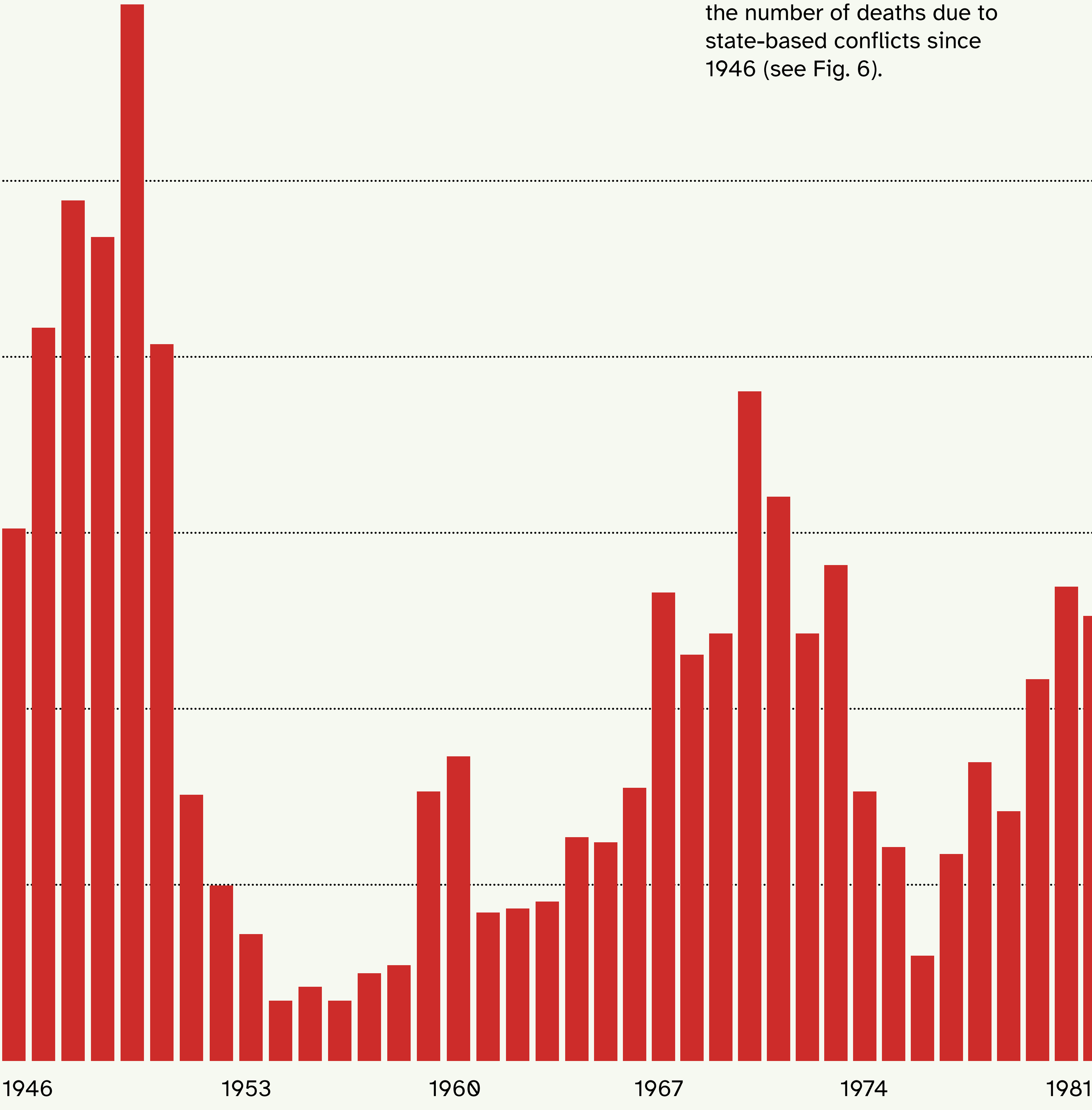
Next Steps

After analysing the current state of actual safety, the value of perceived safety will be dissected and analysed in the following Stakeholder Value Matrix, in which project-relevant values related to perceived safety are identified from the perspective of each stakeholder along with associated harms and benefits.

2_1_3
The Current State of Safety

Having established the difference between actual and perceived safety, it becomes useful to know what the current state of actual safety is and to what degree this warrants current perceptions of safety.

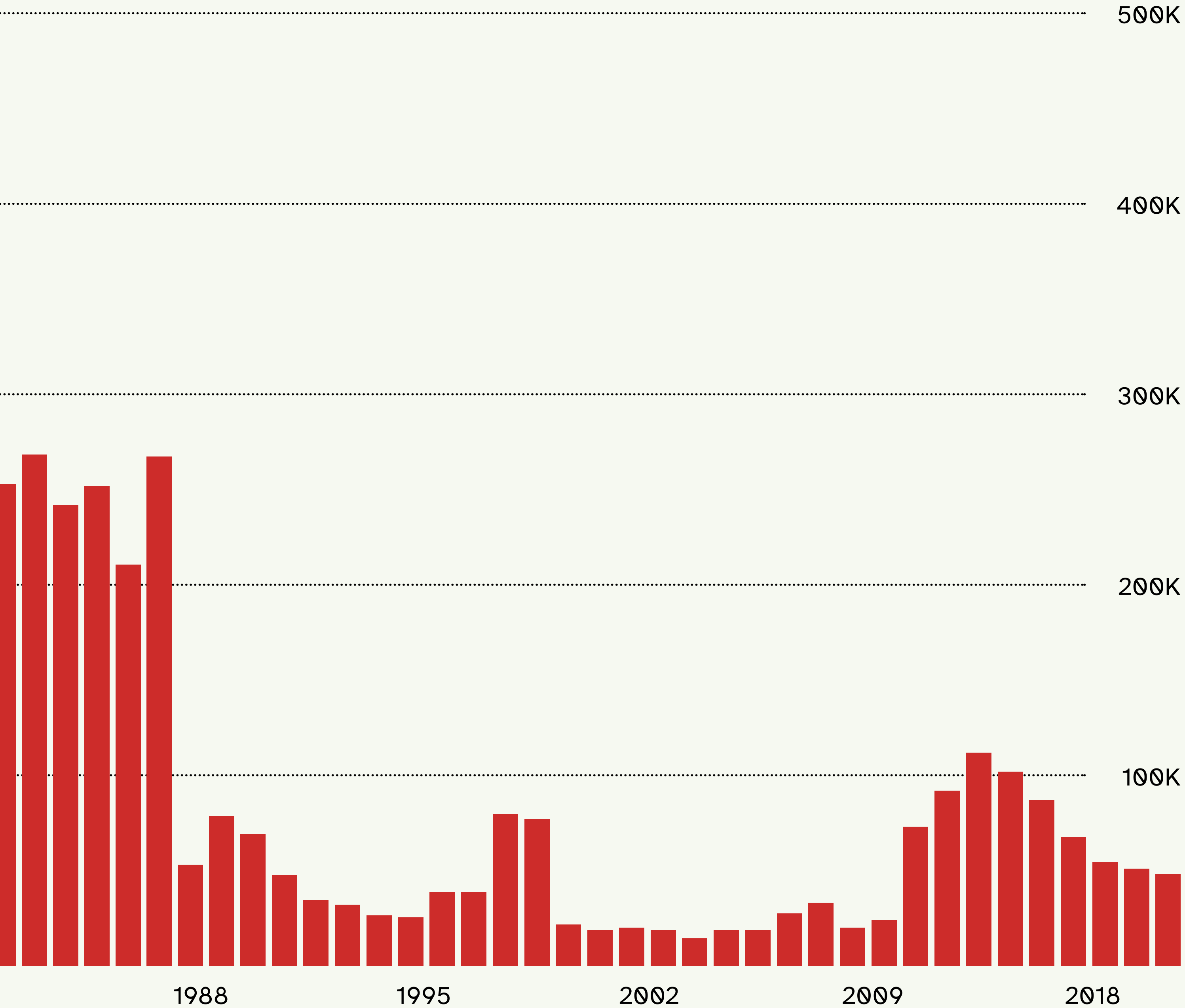
According to Syropoulos (2018), actual safety is arguably the highest it has ever been, although this is not reflected through constant media coverage of “mass shootings, racial issues and cross-national conflict”. Syropoulos’ claim is strongly supported by Roser et al. (2016), having reported a steady and significant decrease in the number of deaths due to state-based conflicts since 1946 (see Fig. 6).



Even so, new threats to actual safety have emerged as technologies advanced, especially regarding cyber safety and digital privacy. In 2012, 800,000 new malware variants were detected daily (Dumitras & Efstathopoulos, 2012). However, the simultaneous and continuous development of other technologies to counter these threats has made it possible to maintain actual safety in this domain.

Technology that advances and is implented in a rapid pace–specifically CCTV, has a definite and potentially negative impact on perceived safety, to be discussed in much more detail later in this report. Even so–this often excessively and unnecessarily invasive technology was found to reduce crime in public spaces by 24-28% (Alexandrie, 2017).

Fig. 6: Number of Deaths in State-Based Conflicts
Direct deaths of both military personnel and civilians. Deaths from disease or famine are not included.



2_1_4
Stakeholder Value Matrix

Value Sensitive Design

(Couzy, 2019)

Value Sensitive Design stems from the recognition and structured integration of human values throughout the design process (Friedman et al., 2013). Within the context of this project, VSD fits well in that it comes with a general list of human values with ethical import–often implicated in System Design, that can be used as a starting point. In this case, this list serves as a set of base values that are important to Amsterdam's citizens as a key stakeholder. The general nature and application in Systems Design also make this list universally relevant.

Value	Project-Relevant Description
Human Welfare	Refers to people's physical, material, and psychological well-being
Ownership and Property	Refers to a right to possess an object (or information), use it, manage it, derive income from it, and bequeath it
Privacy	Refers to a claim, an entitlement, or a right of an individual to determine what information about himself or herself can be communicated to others
Freedom from Bias	Refers to systematic unfairness perpetrated on individuals or groups, including pre-existing social bias, technical bias, and emergent social bias
Universal Usability	Refers to making all people successful users of information technology
Trust	Refers to expectations that exist between people who can experience goodwill, extend good will toward others, feel vulnerable, and experience betrayal
Autonomy	Refers to people's ability to decide, plan, and act in ways that they believe will help them to achieve their goals
Informed Consent	Refers to garnering people's agreement, encompassing criteria of disclosure and comprehension (for "informed") and voluntariness, competence, and agreement (for "consent")

	Value	Project-Relevant Description
	Accountability	Refers to the properties that ensures that the actions of a person, people, or institution may be traced uniquely to the person, people, or institution
	Courtesy	Refers to treating people with politeness and consideration
	Identity	Refers to people’s understanding of who they are over time, embracing both continuity and discontinuity over time
	Calmness	Refers to a peaceful and composed psychological state

Municipality of Amsterdam

(Context Travel, n.d.)

Representing the stakeholder interests of the Municipality of Amsterdam, the following values were extracted from key goals and policies outlined on the municipality’s website (City of Amsterdam, 2021). It is important to note that the MoA’s values are primarily targeted towards Amsterdam’s citizens, and aimed to be achieved through the design and maintenance of Amsterdam’s public space.

Value	Project-Relevant Description
Personal Contact	Refers to interpersonal communication, in this context between citizens of Amsterdam
Recreation	Refers to the opportunity to enjoy activities outside of work, within this context in Amsterdam’s public space
Cohesion	Refers to the approach of fulfilling multiple, separate policy aims simultaneously and symbiotically, rather than in isolation from another
Attractiveness	Refers to the aesthetic appeal of the city of Amsterdam and its public space
Cleanliness	Refers to the sanitary waste-related conditions of the city of Amsterdam and its public space
Accessibility	Refers to the extent to which Amsterdam’s public space can be navigated by people of all abilities

Responsible Sensing Lab

(AMS Institute, n.d.-a)

The Responsible Sensing Lab at the AMS Institute aims to integrate important public and social values into the design and utilisation of smart sensors throughout Amsterdam (AMS Institute, 2021). In so doing, the RSL has identified the following values that play a key role in the integration of these values and responsible sensing as a consequence.

Value	Project-Relevant Description
Transparency	Refers to the ease of perceiving the use of smart sensing technology and its interaction with the public
Inclusiveness	Refers to the extent to which citizens and its various subgroups are involved equally in the use of smart sensing technology and collected data
Empowerment	Refers to the extent to which citizens are encouraged to act on their autonomy
Awareness	Refers to the extent to which smart sensing authorities actively inform the public about the use of smart sensing technology and its interaction with the public
Contestability	Refers to people's ability to criticise and engage in a discussion with an authority about alternative approaches or solutions

Project

(Metro Nieuws, 2020)

This project stems from the Initial Assignment of 'enhancing the feeling of safety in public environments through the use of responsible sensing', from which a distinction was made between actual– and perceived safety.

Value	Project-Relevant Description
Actual Safety	Refers to the risk a citizen has of becoming a victim of crime and disturbance of public order
Perceived Safety	Refers to a citizen's perception of the risk of becoming a victim of crime and disturbance of public order

2_1_5
Harms and Benefits

Harms

In to the Responsible Sensing Toolkit (AMS Institute, 2023), harms primarily relate to potential risks that have direct impact on the lives of Amsterdam's citizens, or any citizens that reside in a 'smart' city. Such risks include the erosion of citizen's rights and compromised freedoms through the 'chilling effect' unwaranted invasion of privacy through surveillance-state tendencies and the increasing collection and exploitation of personal data through social engineering and function creep. Only legal risks and the degradation of public trust are viewed from the perspective of government institutions.

Benefits

Potential benefits, however, are almost entirely viewed from the perspective of the government and any private institutions they might employ. Here, the Responsible Sensing Toolkit emphasises the importance to contribute to public health and safety, a crucial benefit to this project. Furthermore, the improvement of city services, public space and achievements related to policy, environmental quality and reducing overall costs are also mentioned.

Interesting, since benefits are viewed from the perspective of the government and the municipality, emphasis on a benefit like perceived safety is once again missed.

Tab. 2: Harms & Benefits, Values
Mapping of identified harms and benefits (AMS Institute, 2023) to relevant values

	ID	Relevant Value(s)
Harms	Rights erosion	Autonomy, Contestability, Accountability
	Public trust	Trust, Transparency, Awareness
	Invasion of privacy	Privacy, Identity, Trust
	Social engineering	Trust, Transparency, Informed Consent, Universal Usability
	Surveillance state	Privacy, Autonomy, Trust, Freedom from Bias
	Function creep	Informed Consent, Contestability
	Chilling effect	Autonomy, Contestability, Accountability
	Compromised freedoms	Autonomy, Contestability, Awareness, Ownership and Property
	Legal	Accountability, Contestability
Benefits	Public health and safety	Actual Safety
	Improve city services	Accessibility, Attractiveness, Cohesion
	Optimise public space	Accessibility, Attractiveness, Recreation, Personal Contact, Cleanliness
	Reduce costs	Cohesion, Ownership and Property
	Environmental quality	Human Welfare, Cleanliness
	Policy / Planning	Cohesion, Inclusiveness

2_1_6
Value Principles

Proportionality Principle
The concept of proportionality (AMS Institute, 2023) is often used as a tool to compare the benefit of fulfilling one value against the cost of neglecting another during a value conflict. Simply put, "is there an appropriate balance between the importance of the goal and the cost of the means?" (Wu et al., n.d.). According to the RSL, 'appropriate' means that costs do not exceed benefits. For example, the cost of infringed privacy can and should not exceed the benefit of improved, actual safety. A major challenge remains in how to quantify and measure the fulfilment or neglect of values, as these are often stripped of meaning when simplified down to mere facts and statistics.

Design Justice Network Principles
The Design Justice Network Principles, introduced by Costanza-Chock (2018), aim to resolve the value conflicts that emerge due to a lack of involvement and inclusion of those people who are most adversely affected by design decisions. Costanza-Chock describes how the pressure for innovation and a disconnect between designers and certain direct stakeholder groups can lead to technologically-over-dependent 'solutions' that can actually create additional, complex problems. By identifying the voices of those mist affected early on and considering exisiting solutions, such value conflicts can be avoided.

TADA Principles
Suggested by the Responsible Sensing Toolkit (AMS Institute, 2023) the TADA manifest serves as an ethical framework that can be applied when designing for smart sensing and data collection. The principles integrate values like inclusiveness, autonomy, transparency, accountability and contestability, to minimise the knowledge gap between citizens in front of–and authorities behind the smart sensors in the public space.

CMS Goals
The Crowd Monitoring System Goals (AMS Institute, 2023) describe a set of key objectives concerning the use of smart sensors for crowd monitor within the public space, thereby highlighting the importance and necessity of collecting data with a clear, communicated goal. Here values that align mostly with the interests of the municipality are emphasised, such as actual safety, accessibility, attractiveness, cleanliness and recreation.

Tab. 3: Value Principles
Value principles to aid in resolving potential value conflicts

	ID	Description
Proportionality Principle (AMS Institute, 2023)	P	The proportionality principle states that the degree of infringement of the individual interest must be proportionate to the intended legitimate purpose of the particular measure that is being used.
Design Justice Network Principles (Costanza-Chock, 2018)	DJN_1	We use design to sustain, heal, and empower our communities, as well as to seek liberation from exploitative and oppressive systems.
	DJN_2	We center the voices of those who are directly impacted by the outcomes of the design process.
	DJN_3	We prioritize design's impact on the community over the intentions of the designer.
	DJN_4	We view change as emergent from an accountable, accessible, and collaborative process, rather than as a point at the end of a process.
	DJN_5	We see the role of the designer as a facilitator rather than an expert.
	DJN_6	We believe that everyone is an expert based on their own lived experience, and that we all have unique and brilliant contributions to bring to a design process.
	DJN_7	We share design knowledge and tools with our communities.
	DJN_8	We work towards sustainable, community-led and -controlled outcomes.
	DJN_9	We work towards non-exploitative solutions that reconnect us to the earth and to each other.
	DJN_10	Before seeking new design solutions, we look for what is already working at the community level. We honor and uplift traditional, indigenous, and local knowledge and practices.
TADA Principles (AMS Insitute, 2023)	TADA_1	Legitimate and monitored: The residents of Amsterdam, visitors and users have control in the shaping of our digital city.
	TADA_2	Open and transparent: Transparency and openness are the basic criteria for the Amsterdam data values.
	TADA_3	From everyone for everyone: Data that local authorities, businesses and other organisations collect in and about the city is public property.
	TADA_4	Inclusive: Data must contribute towards an inclusive society. Take into account the differences between individuals and groups, without losing sight of equality.
	TADA_5	Control: Control over data increases the influence and freedom of the residents of Amsterdam and of visitors.
	TADA_6	Tailored to the people: Data contributes to human values and never has the last word.
Crowd Monitoring System Goals (AMS Institute, 2023)	CMS_1	Avoiding and controlling unsafe situations.
	CMS_2	Good pedestrian accessibility of public functions and good traffic flow in a larger area around the busy locations.
	CMS_3	A high-quality public space in which pedestrians feel welcome, safe and comfortable.

2_1_7
Qualitative Interviews on Perceived Safety
Part_1/3

Aim
Qualitative interviews were conducted to identify potential discrepencies and similiraties with the Value-Sensitive literature research on perceived safety, smart sensing technology and the public space, in that respective order. This part (1/3) discusses insights relevant to perceived safety.

Process
Due to the qualitative nature of these interviews, a relatively small sample size of n = 4 was selected with a focus on maximal demographic variety (refer to Tab. 4). Participants were informed beforehand about the aim, duration (30 minutes) and nature of the interview and how their anynymous data might be used within this design project. The participants were also reminded about their right to withdraw from the interview and the possibility to classify given data at any time. All interviews were audio-recorded and consent was given verbally. Participants were thanked after the interview and urged to get in contact about any questions or issues that might come up. All interviews were subsequently transcripted and key themes, or 'codes', were extracted with corresponding interview extracts.

Safety as a Subjective Experience
Qualitative interviews were specifically chosen as the perception of safety as a value is at least to some extent subjective. This was reflected by the participant's answers during the interview, with IP3 stating "I think safety is subjective. What one person sees as safe, another sees as completely unsafe."

Safety in Numbers
Safety in numbers was found to be a key theme, in line with literature research, with participants stating that they felt more safe with people around them and emphasising the need to belong. Familiarity with these people contributed even more to perceived safety, relating to values such as inclusiveness and personal contact.

Reputation
Reputation described the tendency of participants to use preconceptions and the opinions of others to aid in the perception of safety. These preperceptions primarily regarded people's ethnicity and cultural background, certain urban areas and neighbourhoods, and the overall appearance of people and the direct environment. This theme is relevant to values such as trust, attractiveness and personal contact.

Eyes on the Street

A key theme–again very much in line with literature research, was the concept of 'eyes on the street'. Further building on the theme of 'safety in numbers', participants emphasised the importance of being able to be noticed by others if something were to happen to them. Here, being noticed referred primarily to being seen, not just heard, revealing a strong reliance on the eyes as a sense when it comes to the perception of safety. Furthermore, although 'eyes' mainly refers to the physical presence of other people, this presence can in fact come in any shape related to vision, such as cameras, windows and doors. Here, the values of awareness, inclusiveness and personal contact were clearly reflected.

Excessive Awareness

Excessive awareness was another emergent theme. As previously described, participants stated the importance of visual awareness and the visual awareness of those around them, known as 'eyes on the street'. Although such a state of alertness was indicated to contirbute to perceived safety, excessive awareness about potential danger and safety measures being taken resulted in a steep decline of perceived safety. One participant remarked "It's funny because you see a uniform and you should think: 'safety', but because you see a uniform you also think: 'oh, something is happening'. That's also unsafe." In these cases, the possibility and risk of danger–however small, is emphasised out of proportion, and the fulfillment of values such as awareness and personal contact can thereby have a negative effect on perceived safety. Such situations can present a 'safety paradox' in which a citizen experiences high actual safety and low perceived safety at the same time.

Tab. 4: Interview Participant Demographics
A relatively small sample size of n = 4 was selected with a focus on maximal demographic variety

Demographic Factor	IP_1	IP_2	IP_3	IP_4
Age	59	23	50	27
Sex	F	F	M	M
Parent	Yes	No	No	No
Sex. orientation	Heterosexual	Heterosexual	Homosexual	Heterosexual
Work	Personal stylist	Student	KLM supervisor	Aerospace engineer
Work location	Amsterdam	Amsterdam	Amsterdam	Delft
Nationality	Dutch	Dutch	Dutch	Italian
Mother tongue	Dutch	Dutch	Dutch	English
Ethnicity	Dutch	Dutch / Indo	Dutch	Dutch / Italian
Home location	Amsterdam	The Hague	Amsterdam	Rotterdam

Social Control

The last theme relevant to perceived safety is that of social control, which can be formal and organised in the form of police presence or security guards, or informal in the form of ordinary passers by. Within this theme, participants also described a personal responsibility to personally contribute to informal social control, with IP_1 stating: “I feel like you shouldn’t look away, that you should report abuse, otherwise it keeps happening.” This theme relates to the values of trust, personal contact and autonomy.

Tab. 5: Perceived Safety Codes
All interviews were subsequently transcripted and key themes, or ‘codes’, were extracted with corresponding interview extracts.

Code	Code Description	Interview Excerpt
Safety in Numbers	Participants associated being alone with lower levels of perceived safety	IP_1: “In principle, you’re more vulnerable when you’re alone.” IP_2: “I would feel safer if I was calling someone at that moment.”
Reputation	Participants’ perception of safety are influenced by preconceptions and reputations regarding: 1. Ethnicity and cultural background 2. Certain places or neighbourhoods 3. Appearance	IP_2: “In The Hague I never keep an eye on my bag, but [in Amsterdam] there’s a pickpocket every few meters, I think.” IP_4: “Having social media and stories, you have a preconceived idea of these places, and that obviously plays a role in how you perceive things.”
Eyes on the Street	Participants stress the importance of the presence of people to witness or help, should they be in danger	IP_1: “You feel more vulnerable when you’re alone in an area where no one can see you. You don’t know if someone can help you.” IP_1: “The idea that there are people there that could potentially help you goes a long way in feeling safer.”
Excessive Awareness	Participants associate increased states of alertness with decreased feelings of safety	IP_2: “I think I’m very alert. I notice things easily, which can make me feel safer, or the exact opposite.” IP_3: “It’s very subjective. [A friend] went to Rio as well and didn’t feel unsafe for a moment. But because I was constantly aware and made aware of the risks, yeah that made a difference.”
Social Control	Participants emphasise the importance of both formal and informal social control regarding perceived safety, as well as its potential drawbacks	IP_1: “I feel like you shouldn’t look away, that you should report abuse, otherwise it keeps happening.” IP_2: “Having something to go to to report [an unsafe situation].”

Interview Excerpt from Interview Participant 1

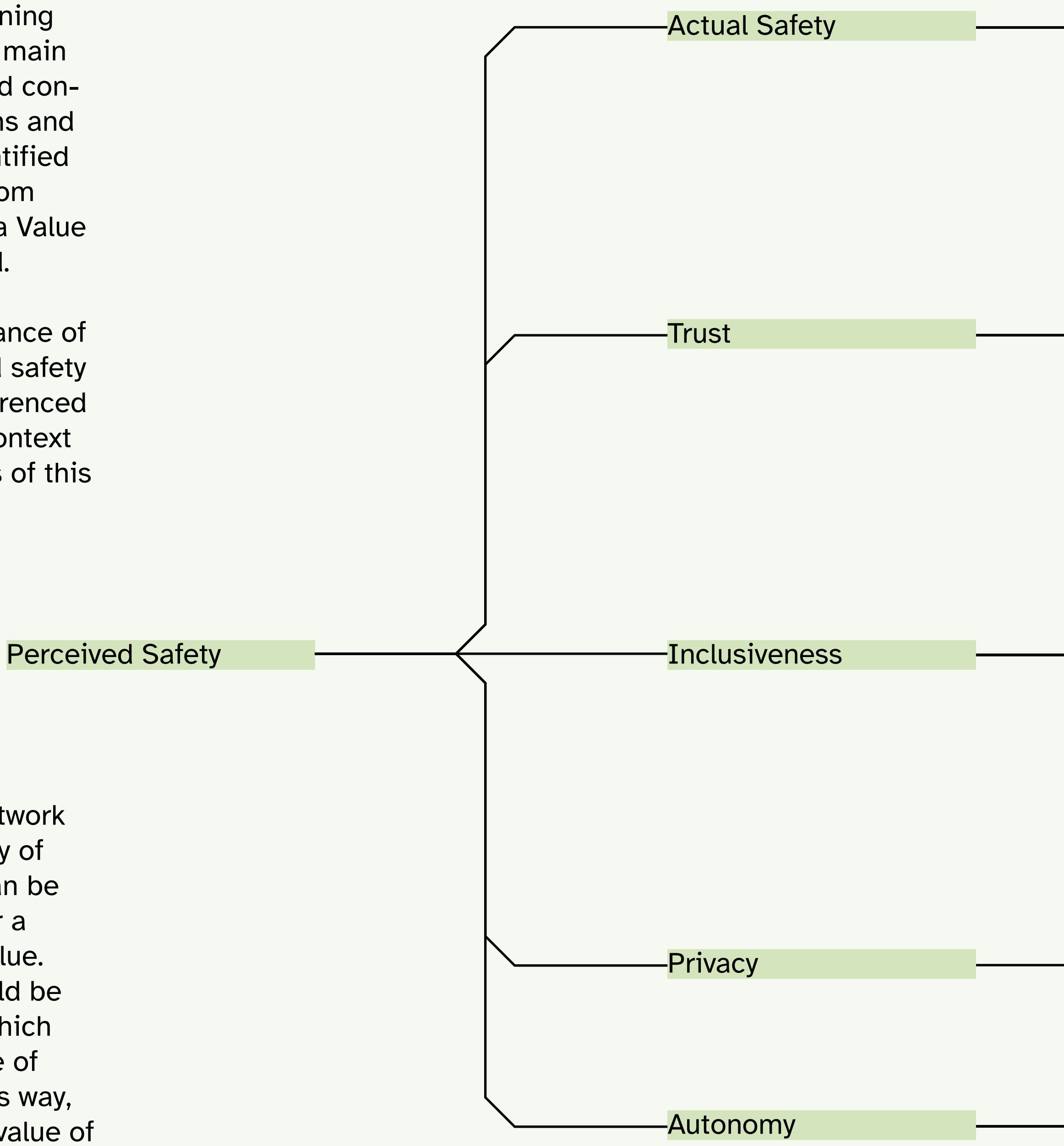
“The idea that there are **people there that could potentially help you** goes a long way in feeling safer.”

2_1_8

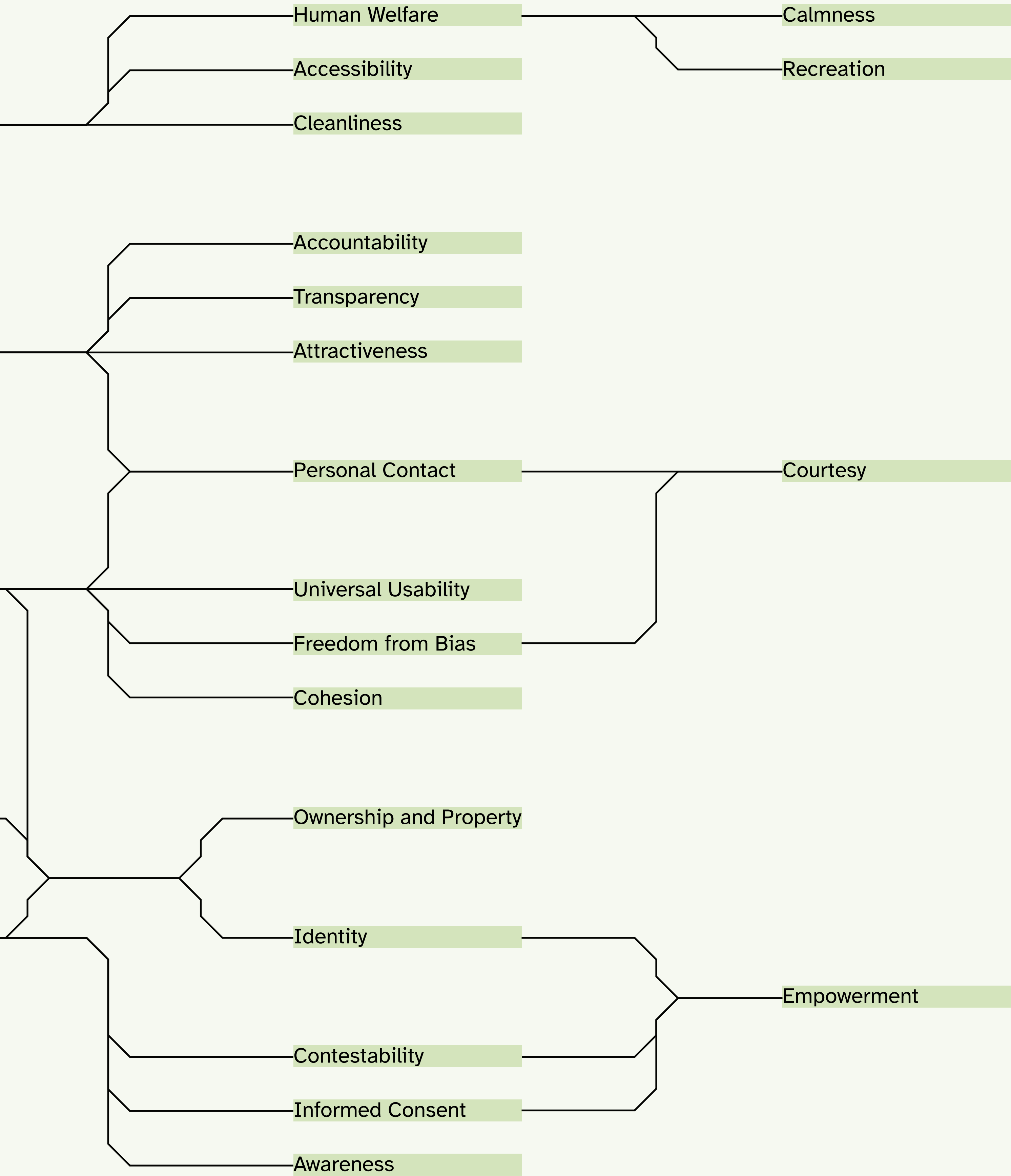
Value Network

So far, many values have been identified and analysed from different perspectives, both through primary and secondary research. By positioning perceived safety as the main value of this project, and considering the descriptions and specificity of other identified values as interpreted from different stakeholders, a Value Network can be created.

As a result, the significance of each value to perceived safety can more easily be referenced to other values in the context and subsequent phases of this project.



Moreover, the Value Network visualises the specificity of certain values, which can be considered to fall under a broader, overarching value. An example of this would be the value of courtesy, which is a sub-set of the value of personal contact. In this way, the crucial but general value of perceived safety can be broken down into more specific, detailed values, allowing for a more thorough analysis of how exactly perceived safety is influenced as a value.


Human Welfare
Calmness
Accessibility
Recreation
Cleanliness
Accountability
Transparency
Attractiveness
Personal Contact
Courtesy
Universal Usability
Freedom from Bias
Cohesion
Ownership and Property
Identity
Empowerment
Contestability
Informed Consent
Awareness

2_1_9
Value Conflicts and Ethical Implications

The pursuit of actual, pubic safety potentially leads to the oppression and limitation of other values, such as the perception of safety. This section views value conflicts between actual safety and other stakeholder values connected to perceived safety (as visualised in the Value Network diagram) from an ethical perspective.

Public vs. Private Space
According to Patton (2000), public space gives any member of the public to undergo a range of activities such as recreation, social interaction or political activism, with no one single group or citizen being able to claim exclusive ownership. Auerhahn et al. (2002) reinforces this, stating that public space is a “space of freedom”, of course within the confines of the law. These perspectives are closely linked to the values of inclusivity and ownership and property.

Auerhahn et al. further argue that–despite the open nature of public space, there is a certain and clear expectation of anonymity, only to be broken by casual scrutiny as a result of socially unacceptable behaviours as influenced by the other–easily observable, people in that public space. Private spaces, in contrast, have clear ownership and property, ultimately limited to certain individuals, and comes with the freedom of more control (autonomy) over personal behaviour and who has access to observation.

In the case of public space, Patton explains that this sense of public anynomity and clear socal expectations are blurred due to the ambiguity surrounding–and inability to analyse who is 'observing'. Essentially, a mysterious, outside authority-figure and observer has access to the autonomy and ownership asociated with private space, thereby restricting the freedom initially associated with public spaces.

The Unobservable Observer
The shift from having "casual and observable" observation (Auerhahn et al., 2002) to a an uneasy and socially opressive ambiguity regarding observation in the public space is known as the 'Unobservable Observer Problem'. The first option to deal with this problem is to address the observer, typically in the form of CCTV. However, it is safe to assume that due to both its prevalence and arguable effectiveness in achieving actual safety, CCTV is here to stay in the near future. The second option is then to address the 'unobservable' nature of the observer. Auerhahn et al proposes that CCTV and other forms of surveillance should not be covert and be fully observable.

Fig. 7: Unobservable Observer (Fauvet, 2019)
An installment of camera sensors, with no visual clues regarding its operation, objective or implications.

Privacy as a Safe Space
Patton goes on to refer to privacy as “the right to privacy protects people’s personal information and the ability to be left alone” (2000), outlining 3 aspects of privacy: 1) informational privacy; control (autonomy) over how personal information is made available, 2) accessibility privacy; protection from invasion by others regardless of whether or not personal information could actually be gained from these intrusions, and 3) expressive privacy; protection of a space for individual self-expression.

While the first 2 aspects relate to values like awareness and autonomy and are widely understood and associated with privacy–although not always practiced, the aspect of expressive privacy focuses on the maintenance of a socially safe space that in its goal to that of public space itself. This aspect presents a link between the invasion of privacy and its indirect yet significant chilling effect on this socially safe space, with Patton arguing that “with diminishing privacy, individuals become increasingly susceptible to the pressure of social norms, especially if their behaviors are not acceptable to the majority”. Invasion of privacy therefore not only has an influence on individuals, but society as a whole, negatively affecting other social values like freedom from bias, inclusivity, identity and empowerment, especially for both general and situational minority groups.

‘Nothing to Hide’
Identified numerous times throughout the qualitative interviews and further developed by Wu et al., (n.d.) an argument is often made that invasive data collection and sensing technology only poses a threat to those that engage in criminal activity and therefore have something to ‘hide’.

The ethical counter-agument is that data collection and its related position of authority is prone to abuse such as function creep and social engineering, especially if values like transparency, informed consent, accountability and contestability are ignored. Even in a legally and socially just system with clear goals that are representative of important societal values, corrupt individuals can exist and abuse their position of authority.

Fig. 8: Surveillance Society (CBS News, 2018)
Behaviour monitoring in China, with the result of instilling a sense of discipline and acceptable behaviour.

Discipline and Desirability
Although surveillance is usually associated with actual safety, its use and potential abuse can spread directly or indirectly to either disciplining or excluding a certain group of people, depending on what is deemed desirable by those in charge (Auerhahn et al., 2002). Lysol (2022) further builds on this idea, first of all identifying the surveillance society, which aims to use surveillance to instill a sense of discipline and condition citizens to a pattern of behaviour deemed acceptable. This effect of surveillance and subsequently diminished privacy very closely matches that described by Patton (2000).

Secondly and lastly, Lysol describes the security state, which emphasises the role of the authorities (typically the government) in preventing and 'fighting' crime and ensuring actual safety. Thus, criminals are considered 'enemies' and as such a group of people of people are labelled as 'undesirable' and deviant, serving as an excuse for invasive surveillance practices such as profiling.

2_2_0
Smart Sensing Technology
Technology

2_2_1
Defining Smart Sensors

Within the context of this project, smart sensors can be defined as any device that is part of a city-wide network of interconnected devices that collect data in order to aid in city operations and policy (AMS Institute, 2021).

Part of the name, 'smart' refers to the interconnected nature of these devices. For example, smart sensors can be connected to actuators such as street- or traffic lights. It is therefore useful to think of smart sensors as part of a system, or network, rather than an isolated device.

2_2_2
Registered Smart Sensors in Amsterdam

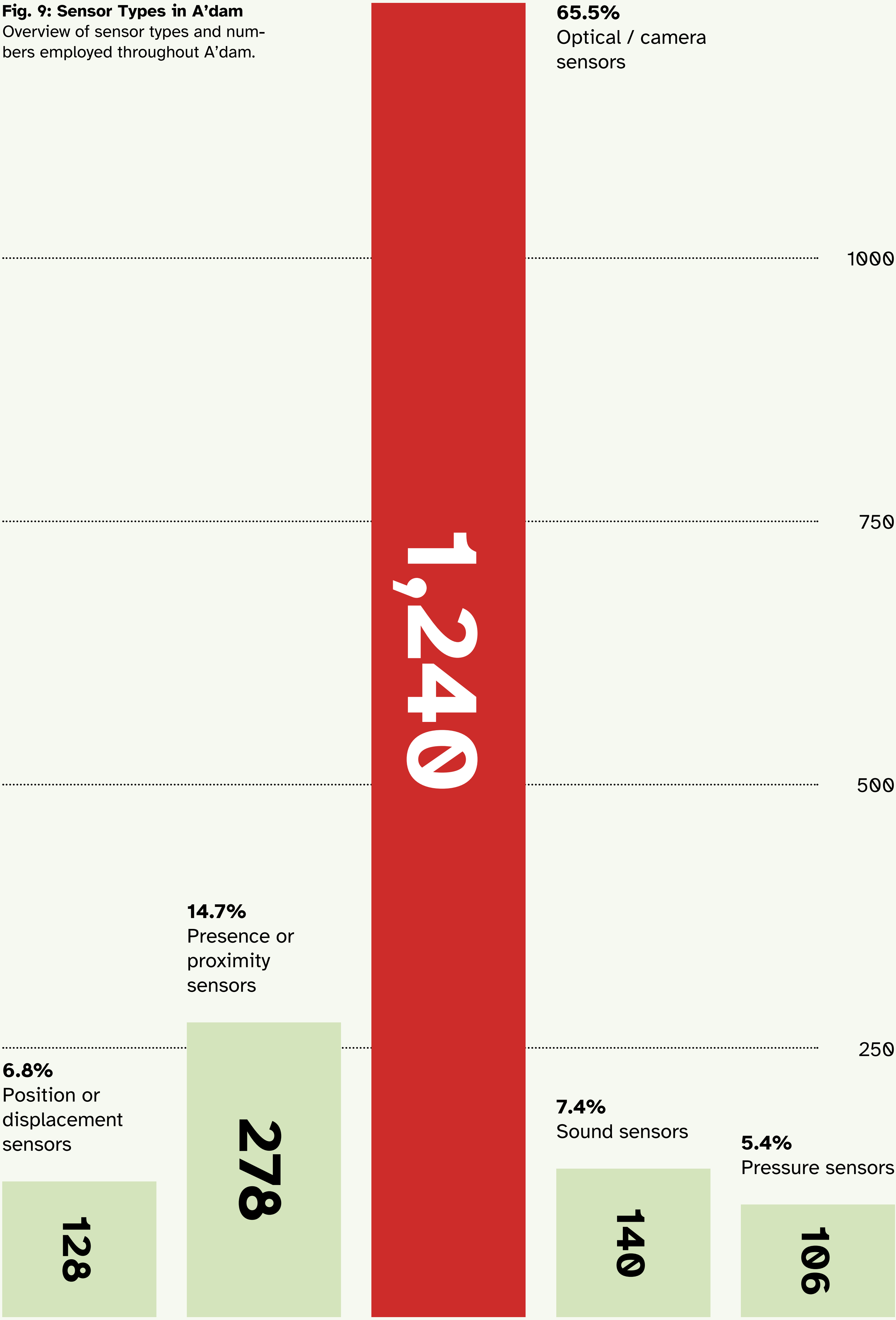
The sensory register or 'sensorenregister' (Fig. 10) of Amsterdam (Gemeente Amsterdam, 2023a) is an online map that provides information on every registered smart sensor within the city. Every sensor is labelled as either a position or displacement sensor, presence or proximity sensor, optical / camera sensor, sound sensor or a pressure sensor.

Additionally, information such as mobile or stationary status, reference codes, the data collection goal and operational duration can be found in the sensor legend. Such information is required to be available to the public according to the DDPA and is therefore already readily available.

Insights
Three main insights come up when analysing the sensory register map. Firstly, although the map is clear and intuitive in its message and user interface, it requires citizen awareness and effort on their part to be able to access this information. Although arguably relatively small, such a boundary has proven sufficient to prevent most citizens from accessing this data or even being aware of its existence.

Secondly, as seen on the map, optical / camera sensors account for 65.5% of all registered smart sensors (Fig. 9), thereby vastly outnumbering all other sensor types combined. This reflects a strong reliance of the municipality

Fig. 9: Sensor Types in A’dam
Overview of sensor types and numbers employed throughout A’dam.



of Amsterdam on the collection and processing of visual data, which is typically regarded as the richest form of data and therefore has the highest potential to be invasive. Since these numbers only account for registered smart sensors, CCTV used by third parties alongside publically unregistered surveillance cameras used by the police or not included. It can therefore be expected that the proportion of optical and camera sensors to other sensor types is in fact even higher than 65.5%. As a result, this type of sensor can be considered to have the highest impact on the experience of citizens.

Lastly, it should be noted that all other sensor types–with the exception of pressure sensors, measure human activity to some degree. Traffic, crowd control and monitoring, selective access for vehicles, noise pollution measurement and number plate recognition are all applications that involve human activity, where pressure sensors are used to measure weather phenomena. Although expected, the register reflects that smart sensor usage and the colleciton of data in the public space primarily concerns humans themselves and related ethical considerations.

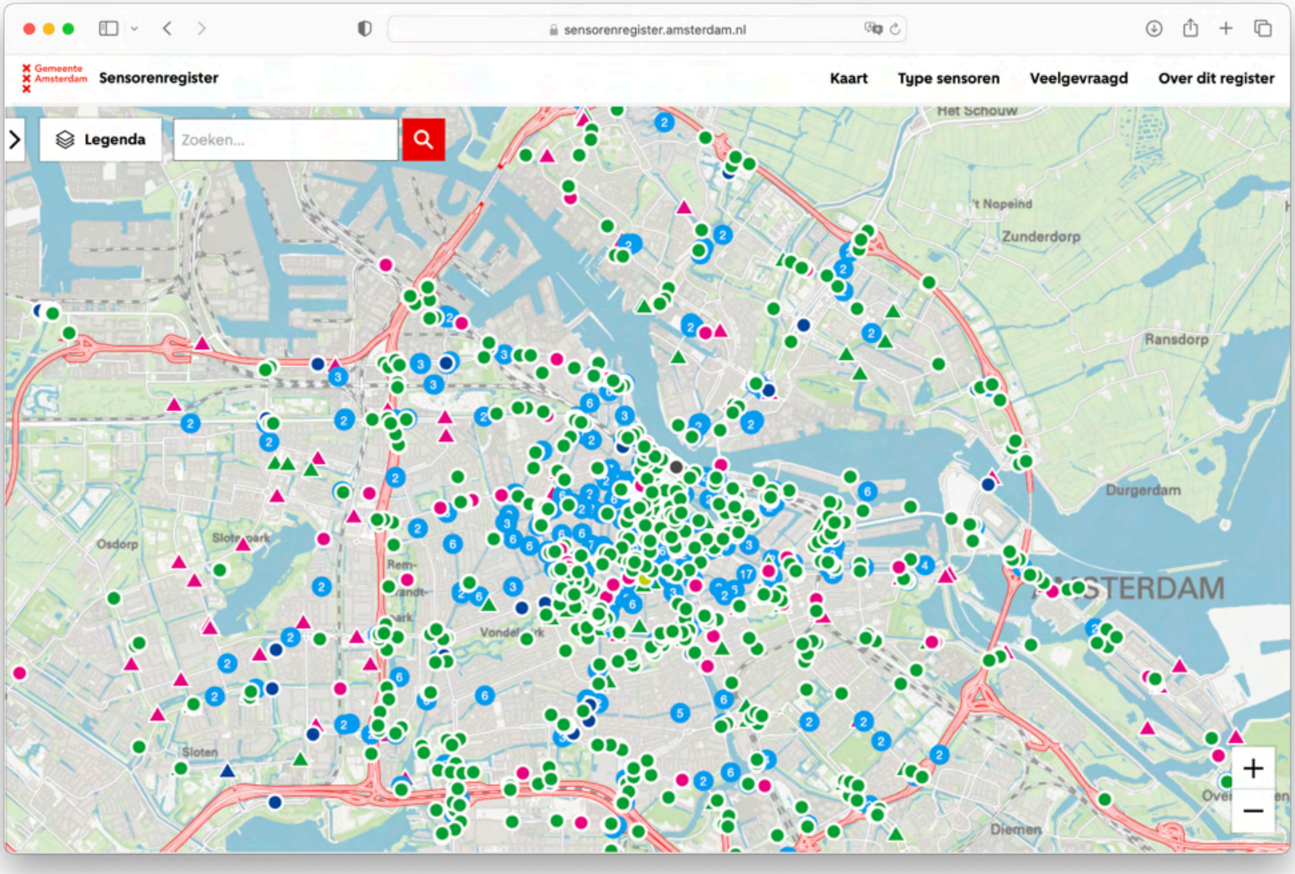


Fig. 10: Sensory Register
An online map that provides information on every registered smart sensor type within A'dam:

Legend
- Position or displacement
- Presence or proximity
- Optical / camera
- Sound
- Pressure

2_2_3
On-Site Visit to Camera Surveillance Control Room at Kleinpolderplein

Kleinploderplein
Fred Maliepaard, an 'operational specialist B' at the camera surveillance center at Kleinpolderplein, allowed me to visit the facility in person, explaining his role within a supervisory team concerning the operation and management of smart sensors such as cameras, drones Automatic Number Place Recognition (ANPR) cameras and police body cameras. This supervision by the police of Rotterdam was done in close communication with the municipality of Rotterdam, employing the bulk of the employees within the facility, with the overarching goal of contributing to public– or actual safety.

Triangle of Authority
To ensure 'responsible' usage of smart sensors and public data collection, a 'triangle of authority' exists in every major Dutch city between 1) the mayor–representing the voice and values of the citizens, 2) the police, who plays an advisory and operational role in achieving the goal of public safety, and 3) the Dutch Public Prosection Service or 'Openbaar Ministerie' who is there to hold the police accountable. Here, sensors are required to be registered, regularly evaluated and strictly temporary, usually between 2-3 years.

Data Ethics
Regarding the prevention of surveillance state-related function creep, chilling effects or unnecesary invasion of privacy, the Dutch Data Protection Authority (DDPA) has specific rules and guidelines in place when personal data is involved. Camera surveillance is done according to article 151C of the municipal law, with describes in detail its use in the public space to prevent disturbance of public order and safety.

Data Processing
Aside from the live monitoring of roughly 600 cameras throughout Rotterdam by a crew of around 8-9 employees at any given time, collected data is also stored for a period of 2 weeks, after which it is deleted according to the DDPA and because of the simple fact that data storage is limited. Since the police has limited prior knowledge on what collected data come of use and be requested in the future, it does not have the privilige of anynomising and simplifying collected data within this 2 week period. Instead, the principle of data minimalisation is achieved through strict and limited access to the collected data for relevant parties.

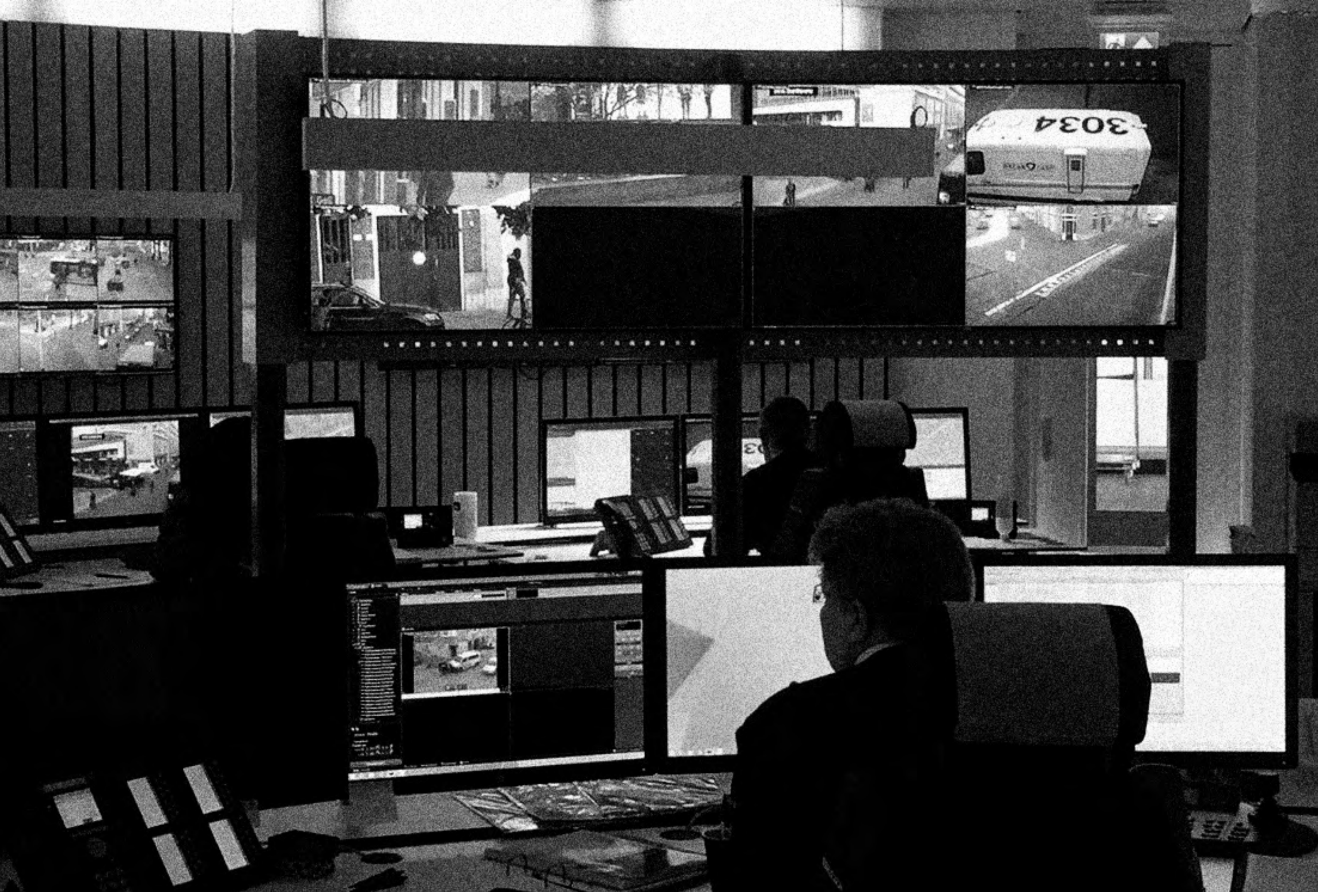


Fig. 11: Control Room (Rijnmond, 2016)
Control room at Kleinpolderplein, in which cameras throughout Rotterdam are live-monitored.

In this case, rich data–almost exclusivelly visual data collected through optical and camera sensors, is most useful to the police. Despite being considered the 'heaviest' and most invasive of sensing technologies, this is mirrored in the high number of camera sensors employed in Amsterdam when compared to other sensor types, and even the interesting fact that the police regards witnesses and citizens on-the-scene to be a form of sensor as well.

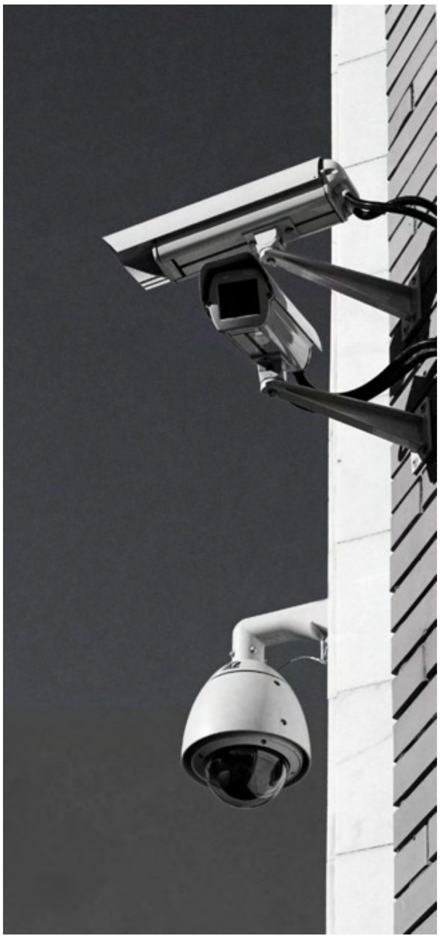
Symbolic Presence

Lastly, Fred Maliepaard mentioned the objective and responsibility of the police to use cameras and other sensors to symbolise 'police presence' in certain areas to increase perceived safety. Typically, Mobile Camera Units (MCU's) are used as a temporary tool not only to monitor areas prone to crime or other unsafe situations, but also as a gesture to take citizen complaints and inquiries seriously. Interestingly, Fred also mentioned that these MCU's are specifically designed to be noticed and deter crime, although this effect tends to diminish as they are accepted into the urban environment more over time.

2_2_4
Qualitative Interviews on Smart Sensing Technology
Part_2/3

Aim
Qualitative interviews were conducted to identify potential discrepencies and similiraties with the Value-Sensitive literature research on perceived safety, smart sensing technology and the public space. This part (1/3) discusses insights relevant to smart sensing.

Sensors as Camera-Centric
When asked about smart sensors, participants almost exlusively mentioned associations with camera sensors with advanced features that could very accurately recognise and analyse human behaviour. Just 1 participant mentioned a 'smart thermostat', a sensor that was not directly linked to monitoring human behaviour and focused on visual data.



Misunderstanding
Citizen awareness of- and interest in the use, application and prevalence of smart sensors throughout cities was found to be alarmingly low. Because of this, many preconceptions presented themselves regarding the usage, goal and functionality of smart sensors within the public space. Here, 'sensor' was interpreted as a camera and 'smart' to its enhanced capabilities to monitor human activity, highlighting that visual data and human behaviour is of key concern to citizens regarding smart sensing.

Privacy
As expected, participants were found to have strong opinions and concerns regarding privacy. Despite the existance of the DDPA and strict privacy regulations regarding smart sensing of personal data, participants conveyed either a lack of awareness about such regulations or skepticism and a lowered perception of safety despite these regulations. The notion of 'having nothing to hide'–as mentioned by IP_1, seems to also either be used as an argument for the use of camera surveillance or a reason for added uneasiness and suspicion towards CCTV and camera sensors.

Fig. 12: Bullet and Dome Camera (Engineering Discoveries, n.d.)
Bullet camera (top), usually static and for long-range surveillance, and dome camera (bottom) for 360° view and short-range surveillance.

Tab. 6: Smart Sensing Technology Codes
All interviews were subsequently transcripted and key themes, or 'codes', were extracted with corresponding interview extracts.

Code	Code description	Interview excerpt
Sensors as Camera-Centric	Participants strongly interpret sensing as a means of filming and monitoring people using CCTV and security cameras	IP_2: "Something like a camera that can detect a lot of things. Things like body language, temperature, suspicious activity." IP_4: "There's a lot of cameras nowadays that track and identify people."
Misunderstanding	Participants generally associate 'smart' with enhanced sensing capabilities, specifically regarding CCTV and crowd monitoring	IP_2: "A security camera just records you, I think. ButI think a smart sensor goes into more detail about what you look like or something like that." IP_3: "I can imagine it's something that can measure a lot of things, and can send this to a computer that collects all the data and draws conclusions from it."
Privacy	Participants express concerns about excessive use of CCTV and crowd monitoring	IP_1: "Even though they say it can't look [into our house], you get this 'big brother is watching you' feeling, even if you have nothing to hide." IP_3: "There are rules for what footage you can and can't save, but exactly what and how? No, I haven't really read into that."
Design Aesthetics	Participants comment about how the design aesthetics of security cameras and the police conflict with the surrounding public space	IP_1: "[cameras] should fit into the cityscape more aesthetically, because now we have these ugly, industrial-looking things that stick out like a sore thumb." IP_2: "You have these round cameras, you know, but you also have these long cameras. Those I really don't like, because they're so big. Maybe they see more, that's how I think. If it was very subtle, it would be better."
Blind Trust	Even when skeptical about the government, participants tend to trust the government and government-related institutions over profit-driven and private institutions	IP_1: "The government [collects data] for your own wellbeing and safety, not out of financial interest." IP_4: "Even though maybe it shouldn't, it does feel more comfortable knowing that the government has this information. Although history shows that governments aren't necessarily always to be trusted. It does give a false sense of security."

Design Aesthetics
Participants harshly criticised the aesthetic quality of smart sensors and their visual role in the public space, again referring to cameras mostly. and utilitarian-looking, sensor functionality was visually unclear to the participants, leading to misconceptions about technological capabilities and respective invasiveness of privacy. IP_2 stated that she preferred 'dome' cameras over 'bullet' cameras (see Fig. 11), as she associated the focused, pointed nature of bullet cameras with the ability to see more, despite actually being less invasive. This is of concern because a lack of proper understanding, awareness prevents citizen involvement, inclusiveness and autonomy regarding the use and application of smart sensors. Furthermore, this lack of understanding lead participant to make negative assumptions which negatively affected perceived safety.

Blind Trust
Even despite high levels of skepticism, participants generally associated smart sensing and data collection by the government–primarily in the form of camera surveillance with the goal of public safety, with good intentions and high levels of trust. This was strongly contrasted by similar data collection conducted by private institutions, as these were considered profit-driven and inconsiderate or indiffirent to citizen privacy and online safety. This trust might be linked to values such as accountability and contestability, where citizens felt more empowered and able to criticise and hold the government accountable compared to private institutions.

Interview Excerpt from Interview Participant 1

"The government [collects data] **for your own wellbeing and safety**, not out of financial interest."

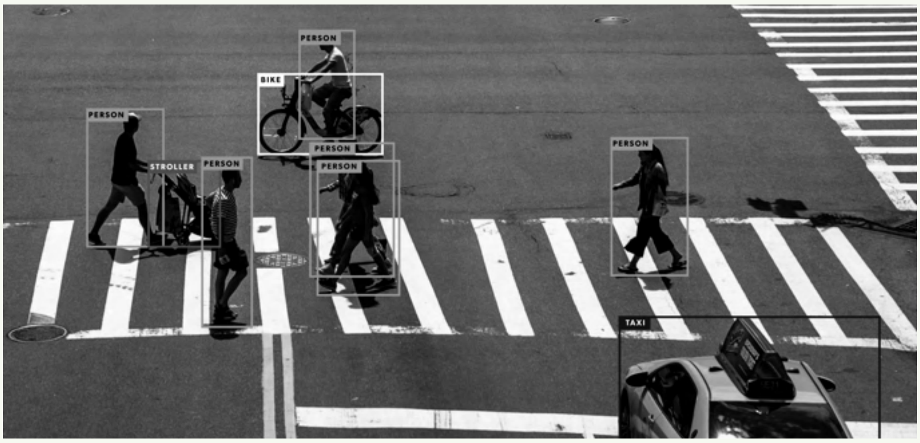
Fig. 13: Camera Sensor Bias (Senoner, 2020)
Participants strongly interpret sensing as a means of filming and monitoring people using CCTV and security cameras.

2_2_5
Smart Sensor Technology Invasiveness Matrix

An overview of modern smart sensing technologies identified from the RST, including examples, applications, collected data types and degree of invasiveness (AMS Institute, 2023).

Computer Vision (CV): Facial or object recognition

(Couto, 2019)



Computer Vision (CV): Edge / anonymised algorithms

		Computer Vision (CV): Facial or object recognition	Computer Vision (CV): Edge / anonymised algorithms
Description		Can classify images and localise objects in photos when trained with enough samples. However, it is difficult achieve a high level of accuracy. CV applications include facial and object recognition and biometrics.	Version of CV used to detect boundaries between objects or to automatically anonymise collected data, thereby limiting invasiveness
Meta data	Date	✓	✓
	Time	✓	✓
	Location	✓	✓
Contextual data	Photo	✓	
	Video	✓	
	Sound		
Biometric data	Behaviour	✓	
	Age	✓	
	Sex	✓	
	Race	✓	
Object data	Accessories	✓	
	Other objects	✓	
Degree of invasiveness		High	Low

Closed Circuit Television (CCTV)	**Sound sensors / microphones**	**Thermal**
(Jakubowski, 2020)	**(Koenen, 2021)**	**(Teledyne FLIR, 2015)**
		
CCTV is traditionally used for security purposes. Collected video footage can be processed by CV software, which makes it the most invasive of sensing technologies.	Can be highly accurate to measure volume (dbl), tone, pitch, and/or frequency or simply detect sounds above a certain threshold. Often used to toggle camera sensors.	Typically used for crowd monitoring. Measures object radiation through infrared technology. Can vary greatly in range and accuracy.
✓	✓	✓
✓	✓	✓
✓	✓	✓
✓		✓
✓		✓
✓	✓	✓
	✓	
Intermediate / high when combined with CV	Intermediate / high when combined with CCTV	Intermediate

Mobile app / geofencing	WiFi Sniffer	Bluetooth (BLE)
(Wu, 2019)	(TurboFuture, 2023)	(Open Circuit, n.d.)
		
Virtual geographic boundaries and perimeters created that interact with devices that have access to internet or GPS.	A.K.A packet sniffer. Detects smart phones on Wifi mode searching for networks by sniffer intercepting probe requests and the MAC address of the device, which can be used for tracking.	Functions in the same way as a WiFi sniffer, but through connection by Bluetooth.
✓ ✓ ✓	✓ ✓ ✓	✓ ✓ ✓
✓ ✓ ✓ ✓		
High	Low	Low

Motion sensing	Radar / mmWave
(AEC Illuminazione, n.d.)	**(AMS Institute, n.d.-b)**
	
Technologies include Passive Infrared (PIR), Microwave, Sonar, and Ultrasonic. Although useful to detect single object presence, it is not effective for multiple objects or crowds in large spaces.	High resolution radar uses an ultra high frequency radio wave to detect, locate, and track moving targets with a very high level of accuracy but with a limited distance.
✓ ✓ ✓	✓ ✓ ✓
✓	✓
Low	Low

Fig. 14: AMS Institute (AMS Institute, n.d.-a)
The Amsterdam Institute for Advanced Metropolitan Solutions at the Marineterrein, Amsterdam.

2_2_6
On-site Visit to the Responsible Sensing Lab

As an introduction to the collaborative nature of this project, Anouk Wieleman invited me to visit the Amsterdam Institute for Advanced Metropolitan Solutions at the Marineterrein in Amsterdam. Alongside other organisations like the Living Lab and NEMO Kennislink, Marineterrein serves as a creative hub for discussions, collaborations and pilot studies related to urban challenges that modern cities like Amsterdam face today.

Here, I had the chance to meet with each member of the RSL team, gain their respective throughts and feedforward on this project and get a chance to see how the team operates on a daily basis.

Insights
Besides the value of getting familiar to the faces behind the RSL team and the projects they've worked on, there was also the value of the team's existing experience relevent to smart sensing. As stated by Anouk, one of the main challenges of the RSL is for citizens to be awareness of- and gain the interest in being involved with how smart sensors work and are used, mostly for civic benefit. To this day, there remains a gap between citizen awareness and the application of smart sensing technology, which makes the responsible integration of public and social values into this technology all the more challening.

2_2_7
Expert Insight from Sam Smits on Implementation & Policy

Sam Smits, being both a Lab Lead & Projectmanager for the RSL and a D&I - Urban Innovation and R&D for the Municipality of Amsterdam, was able to provide some crucial insights into the policy and protocol surrounding smart sensor implementation in Amsterdam.

Insights
As of yet, there is no concrete process concerning the implementation of smart sensors, which makes it difficult to get a precise overview of all the different ways in which the municipality arrive at the solution of using a specific sensor type at a specific location.

Additionally, the municipality of Amsterdam consists of different departments that each communicate with various third parties. For example, the department of air quality might aim to measure the presence of certain particles at a specific location. This might be outsourced to a company that supplies the necessary sensors (VCS being the main company for camera sensors, for instance), and be communicated with representatives of the related urban area.

A recurring step is the involvement of legislation like the Algemene Verordening Gegevensbescherming (AVG) when data is collected that can be linked to citizens. Here, the completion of a Data Protection Impact Assesment (DPIA) is a necessary step as well.

Steps are also being taken in the development of more general, structured and intuitive framework for this implementation process, expected to be complete at the end of 2023. RSL projects like the Responsible Sensing Toolkit and 'RAAK-PRO: deploying ethical technology' serve as preliminary guides towards this goal.

2_2_8
Relevant Projects by the Responsible Sensing Lab

A number of projects from the RSL relevant to the identified values and the public space as a context of use, were analysed as to build on previous experience from the RSL and to serve as inspiration for the eventual ideation & development phase.

	Relaunch mmWave sensor	**Contestable AI: designing responsible decision-making systems**
	(AMS Institute, n.d.)	**(AMS Institute, n.d.)**
		
Description	“As a continuation of the mmWave project we have installed three sensors on the Marineterrein to improve the mmWave sensor as a fully-fledged, privacy-friendly alternative for monitoring crowd movements” (AMS Institute, 2023).	“‘Contestable AI’ explores algorithmic decision-making systems that are open and responsive to dispute” (AMS Institute, 2023).
Relevant values	• Privacy through data minimalism	• Trust through accountability and transparency • Inclusiveness through universal usability • Cohesion, autonomy through informed consent and awareness • Contestability
Type of design	General design	Campaign
Technology-intensive	High	High
Involves personal data	No	Yes
Technology Readiness Level	7	3

Citizen communication and participation regarding sensors	**RAAK-PRO: deploying ethical technology**	**Shutterring**
(AMS Institute, n.d.)		**(AMS Institute, n.d.)**
		
"Smart city systems are on the rise. Together with national partners we are working towards a standard communication approach to enhance awareness on the use of sensors and, with that, the involvement of citizens" (AMS Institute, 2023).	"With this project we aim to help professionals from different sectors develop an integrated, value-based design approach for smart city technologies' ethical implementation. We do so by focusing on the concrete and urgent case of machine-vision in public space" (AMS Institute, 2023).	"The Shutterring project aims to make smart doorbells more responsible by ensuring the privacy of bypassers and owners while keeping the main functionality of the device intact" (AMS Institute, 2023).
• Inclusiveness through universal usability • Cohesion, autonomy through empowerment, informed consent and awareness	• Inclusiveness through universal usability • Cohesion and privacy through ownership and property	• Trust through transparency • Privacy through identity, autonomy through empowerment
General design	Campaign	Speculative design
Low	Intermediate	Low
Yes	Yes	Yes
3	3	6

Shuttercam	**Simple Sensors**	**The Transparant Crowd Monitoring Camera**
(AMS Institute, n.d.)	**(AMS Institute, n.d.)**	**(AMS Institute, n.d.)**
		
“The Shuttercam project originated based on the notion that people do not know if and when cameras in public space are recording or not” (AMS Institute, 2023).	“The Simple Sensors project investigates these questions: What if sensors are designed to be seen? What if they communicate clearly what data they collect and how? And what if sensors invite you to interact with them?” (AMS Institute, 2023).	“The number of crowd monitoring cameras in public places is increasing. What could be done to inform and ensure people that counting cameras are just there for the counting?” (AMS Institute, 2023).
• Trust through transparency • Privacy through autonomy, autonomy through empowerment and awareness	• Trust through transparency and interaction • Inclusiveness through universal usability • Autonomy through informed consent and awareness	• Privacy through awareness • Trust through transparency
Campaign	Speculative design	Campaign
Low	Intermediate	Intermediate
Yes	No	No
7	4	7

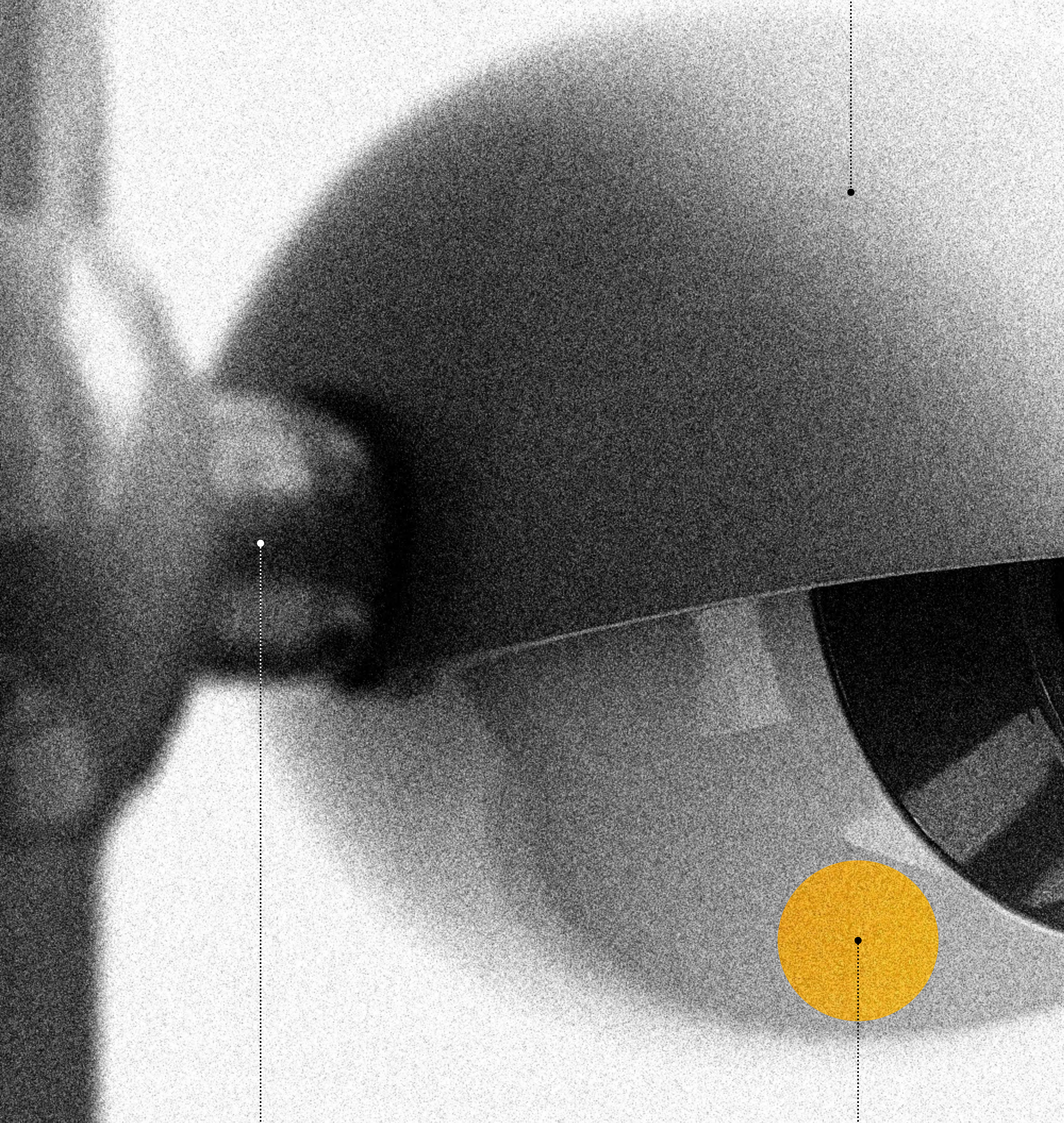
2_2_9
Het Oogje

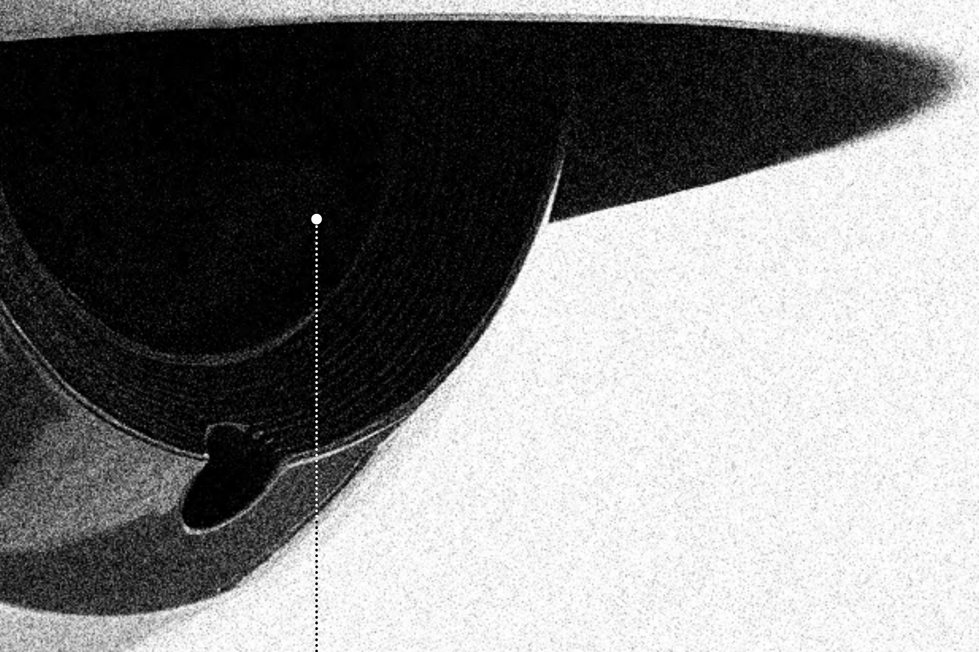
In response to the Dutch National Railway's (NS) search for solutions to improve the overall feeling of safety at train stations throughout the Netherlands, design studio Fabrique designed and developed Het Oogje, also known as the 'Cute, Yellow Eye' in English. Instead of being either too aggressive or mysterious in appearance, this renewed physical design for NS's surveillance cameras aimed to be be seen and noticed as friendly, caring and assuring (Smeets, 2013).

Current Camera Design
Having started with a clearly defined brief, problem and a dedicated testing station at Duivendrecht, an analysis of current CCTV and surveillance cameras. According to Fabrique, most of these cameras are currently perceived with suspicion and an association with 'Big Brotherism'. These perceptions tend to evoke negative emotions, rather than the desired feeling of safety as a consequence to an assured level of actual safety.

Fig. 15: Extruded Bullet Cameras (Jakubowski, 2020)
Camera housings manufactured using extrusion, accentuating the directionality of the camera and reminiscent of the barrel of a gun.

Fig. 16: Cute, Yellow Eye (Farhoudi, n.d.)
Het Oogje, round, colourful, expressive, friendly and noticeable, reducing a sense of ‘Big Brotherism’.





Additionally, current camera design is based on the manufacturing technique of extrusion, creating visible lines, making the camera look mechanical and utilitarian as well as emphasising a clear sense of direction. When this directionality is compared with the pointed barrel of a gun, the term 'bullet camera' becomes self-explanatory. When different cameras, each with different directions are combined (Fig. 16), the result is visual confusion and an ambiguity regarding the camera's field of vision (Smeets, 2013).

Insights

A major important insight from the case study of Het Oogje concerns the 'two-way street' of information; cameras do not only collect data within the public space, but also– either intentionally or inadvertently send out a signal to anyone within that public space. This signal is primarily influenced by the design aesthetics of the camera sensor itself. In the case of Het Oogje, the camera housing is akin to an expressive eye, with the adjustable cap loosely resembling an eyebrow allowing for a range of different expressions depending on how the camera is installed. Through this design, the sense of 'Big Brotherism' declined from 34% to 12% and the aesthetic experience rose from 9% to up to 80% (Smeets, 2013).

2_3_0
The Public Space
Context of Use

2_3_1
Demographics

Demographic factors can play a crucial part in linking the experience and perception of the public space with that of perceived safety. This part (3/3) aims to explore this link in detail and with a critical view.

Age
According to Syropoulos (2018), age tends to be a predictor of perceived safety with the elderly being a particularly vulnerable group. This contrasts strongly with research from Akkermans et al. (2021) who found that Amsterdam citizens aged 65+ tend to feel most safe. According to their research–which is more directly relevant due to its focus on the city of Amsterdam, 15-25 year olds suffered most from low perceived safety, with an increasingly higher perception of safety as aged progressed. A potential explanation for this discrepancy might be that respect towards elderly people is culturally influenced and relatively higher in Amsterdam. However, Du et al. (2021) argue that along with women, elderly tend to be "more attentive to place quality attributes", urging their involvement and consideration in the design of public spaces.

Gender
Most research referred to sex instead of gender, thereby only including male and female as distinct categories. However, from the qualitative interviews, the perceived safety of non-binary people was discovered to be very similar to that of LGBTQ+ people and heterosexual women due to shared experiences. This is in line with research indicating that women generally feel most unsafe in the public space (Du et al., 2021) (Sund et al., 2017) (Akkermans et al., 2021), as well as LGBTQ+ (Akkermans et al., 2021), especially when compared to men. Because of this, it is arguable that 'gender' instead of sex and the inclusion of 'non-binary' as a demographic category is more valuable in the context of perceived safety.

Tab. 7: Demographic Factors of Perceived Safety
Overview of demographic factors and respective influence on the perception of safety

Demographic Factor	Sub-Groups	Proneness to Low Perceived Safety
Age	15-25	High
	15-45	Intermediate
	45-65	Intermediate
	65+	Low
Gender	Man	Low
	Woman	High
	Non-binary	High
Background	Native	Low
	Non-native	High
Sexuality	Heterosexual	Intermediate
	LGBTQ+	High
Income Level	Unemployed	High
	Low	High
	Intermediate	Intermediate
	High	Low
Education Level	No formal education	High
	Secondary education	Intermediate
	Tertiary education	Low

Background
Closely related to the value of inclusiveness, being native was found to significantly contribute to perceived safety in the public space (Sund et al., 2017). In contrast, being non-native had a significant, negative effect. An explanation of this might be that non-native people, as the name defines, is to not be included in the native population. This relates to a key theme coded from the qualitative interviews on perceived safety in which 'safety in numbers' was stated to have a high, positive effect on perceived safety. Additionally, related factors like culture-shock and an inability to speak the native language or English can further lower perceived safety through related values like autonomy and awareness.

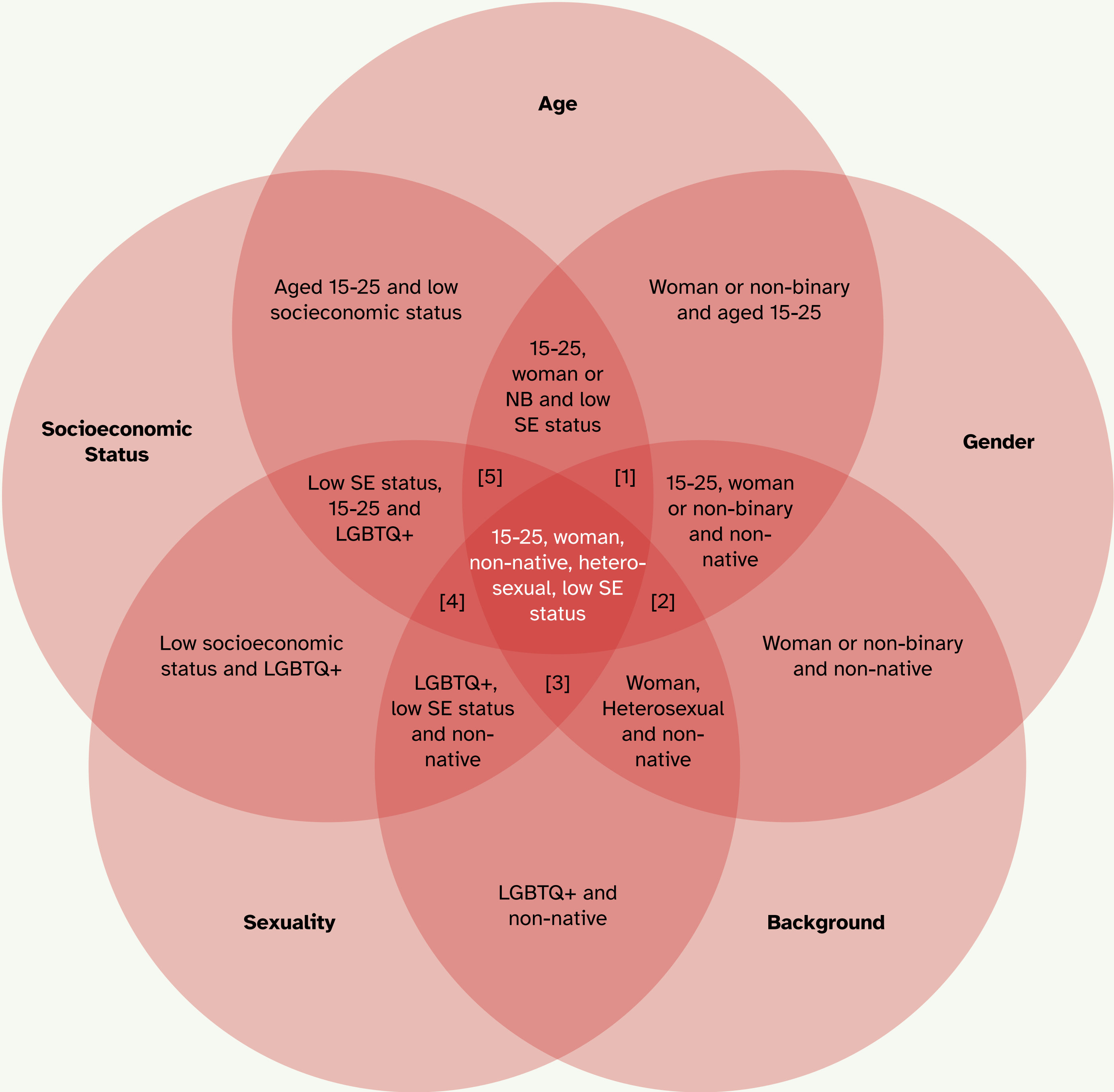
Sexuality
Sexuality closely correlates with gender in the context of perceived safety. Compared to being LGBTQ+, being heterosexual generally leads to higher perceptions of safety (Akkermans et al., 2021). However, when looked at from a perspective of intersectionality, it becomes clear that heterosexual women have significantly lower perceived safety in the public space, even compared to LGBTQ+ and especially compared to heterosexual men.

Socioeconomic Status
Socioeconomic status entails the sub-categories of income and education level. In general, a direct correlation can be found between the level of education and income and the perception of safety, with higher socioeconomic status corresponding to higher perceptions of safety (Syropoulos, 2018) (Sund et al., 2017). Sund et al. argues that high education may increase a person's sense of control and thereby autonomy, which increases confidence and therefore perceived safety.

A point should also be made for the relationship between education and income level, as higher levels of education are often associated with higher paying jobs. In the same way, education level and income level can also be indicative of in which area of a city a person lives, thereby linking urban area and its public space to these demographic factors and ultimately perceived safety.

Intersectionality
As can be seen in Fig. 17, when all identified demographic factors relevant to the perception of safety are viewed from the perspective of intersectionality, heterosexual women aged 15-25 are specifically vulnerable to low perceptions of safety in the public space. Interestingly, when gender is taken out of the equation, LGBTQ+ people are seen as more vulnerable. Socioeconomic status and background have a general influence and are minimally influenced by intersectionality.

Fig. 17: Intersectionality Venn Diagram
Intersectionality venn diagram mapping out 5 key demographic factors of perceived safety.



[1]: Low socioeconomic status, 15-25, woman or non-binary and non-native
[2]: 15-25, woman, non-native and heterosexual
[3]: Woman, non-native, heterosexual and low socioeconomic status
[4]: 15-25, non-native, LGBTQ+ and low socioeconomic status
[5]: 15-25, woman, heterosexual and low socioeconomic status

2_3_2
Perceived Safety Aspects

In his research, Jansson (2019) paints a clear picture of 9 aspects of perceived safety along with corresponding features. For each aspect, a visual example is given from Amsterdam, alsongside a number of relevant values. Most impactful on perceived safety are 1) mix of people, 2) informal social control and 3) urban form.

Insights
Interestingly, besides the clear link to identified values, social control and information were found to sometimes lower perceived safety rather than contributing to it. This is in line with the code of 'excessive awareness' from the qualitative interviews on perceived safety.

Urban Form
- Comfortable places to stand in and sit on
- An exciting and inviting atmosphere

(Context Travel, n.d.)

- Accessibility
- Attractiveness

Mix of Functions
- Shops and services have late closing times
- The ground floor windows are unblocked
- Shops are very accessible

(Cosette, 2022)

- Recreation
- Attractiveness

Mix of People
- People who sit outside enjoying recreational activities

(Lucker, 2023)

- Inclusiveness
- Recreation
- Personal contact
- Courtesy
- Identity
- Trust

Clearness
- To be aware what institution is in charge (e.g. cleaning, maintenance)
- Clear wayfinding

(Transport Online, 2018)

- Accessibility
- Universal usability
- Awareness
- Cleanliness

Social Control

- Visible security, safety staff or police presence (formal)
- Ordinary people who can be witness, should something happen (informal)

(Metro Nieuws, 2020)

- Actual safety
- Accountability
- Personal contact
- Trust

Lighting

- Streetlighting providing a good overview
- Lit shop windows at night

(Schlijper, 2020)

- Awareness
- Attractiveness

Perimeter Protection

- Easy to see where the entrances to the buildings are
- Non-noticeable burglary protection like locks and alarms

(Gemeente Amsterdam, n.d.)

- Actual safety
- Awareness
- Ownership and property
- Privacy

Management

- Everything along the street is fully functional and clean
- Bikes, electric scooters and cars are parked in assigned places

(NOS, 2023)

- Accountability
- Accessibility
- Cleanliness

Information

- Information on who you may contact in case of danger

(Gemeente Amsterdam, n.d.)

- Informed consent
- Awareness
- Trust

2_3_3
Eyes on the Street

Fig. 18: Eyes on the Street (Hafeisi, 2017)
Although at night with limited lighting features, this busy street provides a high mix of people and informal social control, increasing perceived safety

Introduced by Row and Jacobs (1962), the concept of 'eyes on the street' is first mentioned in The Death and Life of Great American Cities and describes the ability to be seen and heard by other people in the public space, subsequently having a positive effect on the actual experience and perception of safety.

According to Row and Jacobs (1962), American cities insufficiently cater to this concept in their urban design. Key factors of 'eyes on the street' theory include mixed-use public space, encouraged walking and movement of people which stimulates citizens to look outside through their windows and doors.

CPTED
Building off the concept of 'eyes on the street' and similar to Jansson's (2019) aspects of perceived safety, Crime Prevention Through Environmental Design (CPTED) further develops on the relationship between "environmental features and crime occurrence through the principles of surveillance, territoriality, access control, target hardening, activity support, and image/maintenance" (Iqbal, 2021).

Also challenging the theory, CPTED argues that a higher presence of people and eyes on the street can also lower perceived safety through providing potential targets for crimes such as pickpocketing (Cozens et al., 2005).

2_3_4
Active Frontage

Another way to look at the public space through the lens of perceived safety is to look at the urban environment that encompasses this public space. Buildings have 'frontages' (Jansson, 2019), which can be described as the "facade of a building facing a street or other public space, that includes different elements that can be judged as active or passive from an urban design perspective". 'Active' frontage is argued to contribute to positive perceptions of safety and can be characterised through the quality of 6 different factors: 1) the number of premises, 2) the mix of functions, 3) the number of blind or passive facades, 4) the number of windows and doors, 5) the presence of depth and 6) relief and the quality of materials and details, as seen in Tab. 8. Of these factors, the first four of these were found to have the most significant effect.

Premises
The number of premises– which is be defined as the number of house properties and measured over a distance of 100m, contributes to perceived safety in that a denser number of premises increases the number of people that can act as 'eyes on the street'. Additionally, a denser number of functions also increases the opportunity for a greater range of functions and social meeting spots known as 'third places', thereby also increasing the number and mix of people, increasing eyes on the street and perceived safety as a result.

Tab. 8: Active Frontage Assesment Scale
Scale used for assessing the level of active frontage into a grade of A, B C, D or E (Jansson, 2019).

Grade	Active Frontage	Additional Features
A	• 15+ premises every 100m • 25+ doors and windows every 100m • Large range of functions	• No blind, few passive facades • Much depth and relief in building surfaces • High quality materials and details
B	• 10-15 premises every 100m • 15+ doors and windows every 100m • Moderate range of functions	• Few blind or passive facades • Some depth and relief in building surfaces • Good quality materials and details
C	• 6-10 premises every 100m • Some range of functions • <50% blind or passive facades	• Almost no blind or passive facades • Standard materials and details
D	• 3-5 premises every 100m • Little to no range of functions • >50% blind or passive facades	• Flat building surfaces • Few to no details
E	• 1-2 premises every 100m • No range of functions • <50% blind or passive facades	• Flat building surfaces • No details or featues

Functions
The number and mix of functions refers to the presence and range of 1) commercial functions or shops, 2) transport functions like bus or tram stops and 3) social functions such as cafés, bars or restaurants. Here the concept of 'third places' and a good mix of people–which was found to be the most crucial aspect to perceived safety, come into play again. Functions also increase the presence of social control, both informal and formal. Especially for women, social functions were found to have a significant, positive impact on perceived safety.

Blind and Passive Facades
Urban form is another crucial aspect of perceived safety and concerns the presence of blind or passive facades, which can be referred to simply as the absence of active frontage features. Streets lacking in functions, premises and windows and doors have lower opportunity for 'eyes on the street' and therefore significantly lower perceived safety. Active frontage graded as A or B should have no blind or passive facades.

Fig. 19: Active Frontage in A'dam (ANP, 2021)
Although having a high number of premises, functions, windows and doors, active frontage is decreased due to the lack of mix of people and social control at night.

Windows and Doors
The number of windows and doors is self-explanatory, and its increased presence has a positive effect on perceived safety due to the related opportunity for 'eyes on the street' and mix of people and informal social control. However, this positive effect is less significant than the beforementioned active frontage factors.

Other Factors
In theory, the depth and relief of the frontage of buildings should contribute to perceived safety in that more depth and relief are associated with a more dynamic and varied urban form, which can bring about an increased mix of people, functions and premises. Jansson (2019), however, found that depth and relief did not necessarily have such an effect and that it could even provide suspicious hiding spaces which significantly lowered the perception of safety, as per prospect-refuge theory (Eller & Frey, 2019).

The final factor comes in the form of materials and details, good quality of which is typically associated with grade A and B active frontage. According to Jansson (2019), more interesting and detailed facade tends to attract more activity, bringing social control and a mix of people as well as reflecting a high level of clearness and management.

2_3_5
Qualitative Interviews on the Public Space
Part_3/3

Aim
Qualitative interviews were conducted to identify potential discrepencies and similiraties with the Value-Sensitive literature research on perceived safety, smart sensing technology and the public space. This section discusses insights relevant to the public space.

Familiarity
As was to be expected, participants perceived the public space to be safer in areas that were familiar to them. IP_2 referred to the value of being included and relating with the people in her direct environment (a university campes) more. IP_4 mentioned a heightened state of alertness to compensate for lowered awareness and understanding in unfamiliar environments, something that he did not experience in areas that were familiar to him.

Management
The quality of maintenance and management of the public space in a certain area or neighbourhood was also found to be important to citizens. In line with the perceived safety aspect of management (Jansson, 2019), participants had lowered perceptions of safety when an area looked run down and therefore abandoned by the authorities. Although this may factually not be the case, the perception of homelessness, trash and lack of maintenance is strongly associated with a lack of authority and therefore a lack of safety.

Time of Day
Although obvious, the qualitative interviews also reinforced the relationship between perceived safety and time of day. Here, participants stated to feel more vulnerable, with IP_2 pretending to call someone in order to display a false sense of informal social control to potential criminals.

Prospect-Refuge
The theory of prospect-refuge was reflected by participants through a desire for maximum awareness of the direct environment when experiencing a sense of danger, while simultaneously attempting to be minimally noticed by potential criminals themselves. IP_1 referred to shrubbery and greenery–features that are normally associated with good urban design, as having negative effect on perceived safety.

Escape
Finally, being consciously or sub-consciously aware of potential escape routes in case of danger was another code emerging from participant answers. Especially in narrow and claustrophobic environments, like an alley, a very busy street or in the case of IP_2 and 3 a train and a night club, respectively, a conscious awareness of– and a sense of autonomy to be able to escape, greatly improved the perception of safety.

Tab. 9: Public Space Codes
All interviews were subsequently transcripted and key themes, or 'codes', were extracted with corresponding interview extracts.

Code	Code description	Interview excerpt
Familiarity	Participants felt safer in environments and around people that were familiar to them	IP_2: "I feel safe [on campus]. I see myself walking there x100, people of my age with the same purpose." IP_4: "When I'm walking on my street I'd never look behind me but when you're in those kinds of [neighbourhoods] you'd start looking around you more."
Management	Participants relate perceived safety to the perception of management and maintenance of the public space	IP_3: "It would help if they showed that they did everything to make it as safe as possible." IP_4: "Certain stores and houses were cracked and had people camping inside. People camping at the gas stations so there was obviously a lot of homelessness around."
Time of Day	Participants felt less safe at night	IP_1: "When it's late at night you feel more vulnerable than during the day." IP_2: "When I'm walking somewhere alone at night, I pretend to call someone."
Prospect-Refuge	Participants value awareness and perception of the surrounding public space, while being minimally noticed themselves	IP_1: "If they couldn't see me, I wouldn't feel vulnerable but I could still do something." IP_1: "You have the feeling that at any moment someone can jump at you from behind the bushes."
Escape	Participants expressed lower levels of perceived safety when possible means of escape were unclear	IP_2: "It's even worse because I can't get out. I'm stuck. The train is driving so I can't just jump out." IP_3: "It would help if you clearly know where the emergency exits are."

Fig. 20: Blind Facades (Patrick, 2014)
A street with little to no active frontage and an urban form consisting mostly of passive facades. Perceived safety would be especially low here.

"It would help if [authorities] **showed that they did everything to make it as safe as possible.**"

Interview Excerpt from Interview Participant 3

(Onlyyoujq, n.d.)

3_0_0
Key Takeaways

In this chapter, the preceding contextual Research & Analysis is summarised into 12 Key Takeaways (TAs) in preparation for the upcoming Design Vision, Concept Development and Product Design phases.

TA_1
Statistically high actual safety does not indicate a high perception of safety.

Research into perceived safety as a value and public space as a context of use reveals a wide range of personal, situational and environmental factors that have the potential to significantly influence an individual's perception of safety in a given public space.

In contrast to the subjective nature of perceived safety, actual safety is often indicated through an objective and reductionist statistic (typically based on crime rates) which fails to fully take into account the experience of the citizen.

TA_2
Perceived safety is a value interconnected to other values, such as trust, privacy and inlusiveness.

When looking at perceived safety in the specific context of this project and in relation to the values of the stakeholders involved, it is evident that the value of perceived safety should not be considered in isolation to other values.

Actual safety, trust, inclusiveness, privacy and autonomy, along with the sub-values that these are composed of, were each interpreted to influence the perception of safety, and will therefore be considered in the following steps of the project.

TA_3
Perceived safety is highest around the visual presence of others, or 'eyes on the street'.

According to Jansson's aspects of perceived safety, the factors of a mix of people and informal social control contribute most to the feeling of 'eyes on the street', and in so doing have the highest impact on perceived safety in public spaces.

TA_4
Excessive awareness of potential dangers drives the value conflict between actual and perceived safety.

As previously discussed, actual safety is not always representative of perceived safety, and vice versa. This is especially problematic when a public space with high actual safety (in the form of low crime rates, for example) evokes a low perception of safety.

From the contextual research, the main driver for this discrepancy is driven by an excessive awareness of potential dangers and threats to safety, as a result of negative media coverage and negative associations with safety measures such as police presence or CCTV.

TA_5
Without feedback, smart sensing blurs the social context of public space and harms expressive privacy.

Smart sensors–and specifically camera sensors, blur the social context of public spaces through the vagueness and ambigiuity surrounding their functionality and necessity.

As a result, citizens become skeptical about their privacy and careful to express themselves as freely as they otherwise would have in the public space.

TA_6
Current smart sensor designs follow a form-follows-function approach.

Currently, both the physical embodiment and the use and implementation of smart sensors in the public space is result-oriented and excessively utilitarian.

Analysis of an installation of bullet cameras using the aesthetic design principles further reinforces the notion that functionality, cost and manufacturability are the current priority.

TA_7

Camera sensors make up 65.5% of Amsterdam's total number of smart sensors.

Looking at Amsterdam's sensory register, a total of 1,998 registered sensors can be identified. Of these, 1,266 are camera or optical sensors, making up the lion's share of all registered smart sensors at 65.5%.

The use of camera sensors can also be highly invasive, which can lead to controversy– as indicated by the Technology Invasiveness Matrix and qualitative interviews, respectively. Thus, a significant impact can be made by focusing on this specific sensor type.

TA_8

Smart sensors are almost exclusively associated with surveillance cameras by the public.

From qualitative interviews, it became evident that users of the public space either 1) have insufficient awareness and understanding of smart sensors, therefore focusing on the more universally understood concept of camera sensors, or 2) were sufficiently aware about other sensor types, but still were most opinionated on camera sensors.

A conclusion that can be drawn from these interviews is that the use of camera sensors has a much more direct and personal impact on citizens, compared to pressure sensors, for example. Applications and technologies like computer vision and thermal imagery further support this conclusion.

TA_9

Smart sensing has high Technology Readiness, yet low Human Readiness.

As can be seen in the Smart Sensor Technology Invasiveness Matrix, there are many different sensor types and ways of collecting data in public spaces. To certain degree, the advancement of smart sensing technology correlates to an increase in the invasiveness of its use. Gradually, more and more information is collected in public spaces.

This rapid progress upwards on the TRL scale has not been replicated on the HRL scale. In fact, 'Human Readiness' has only been introduced as a response to a lack of social, societal and legislative considerations. Hence, 'responsible sensing' means to consider Human Readiness in sensor design and implementation.

TA_10

Perceived safety in public spaces is influenced by urban form, and therefore camera sensor design.

The second subject in the 'eyes on the street' principle is the 'street' itself, or the public space and its urban form. According to Jannsson (2019), urban form had the 3rd highest impact on perceived safety, behind a mix of people and informal social control.

The camera sensors that are increasingly present in public spaces, consequently become a part of the public space itself, thereby contributing to the urban form perceived by users of the public space. The design aesthetics of these cameras therefore indubitably have an influence on perceived safety, as well.

TA_11

Young women aged 15-25 are most prone to feeling unsafe in the public space.

When looking at the demographic factors of perceived safety from the perspective of intersectionality, it was found that heterosexual, non-native, women aged 15-25 and with low socioeconomic status are most prone to feeling unsafe in public spaces.

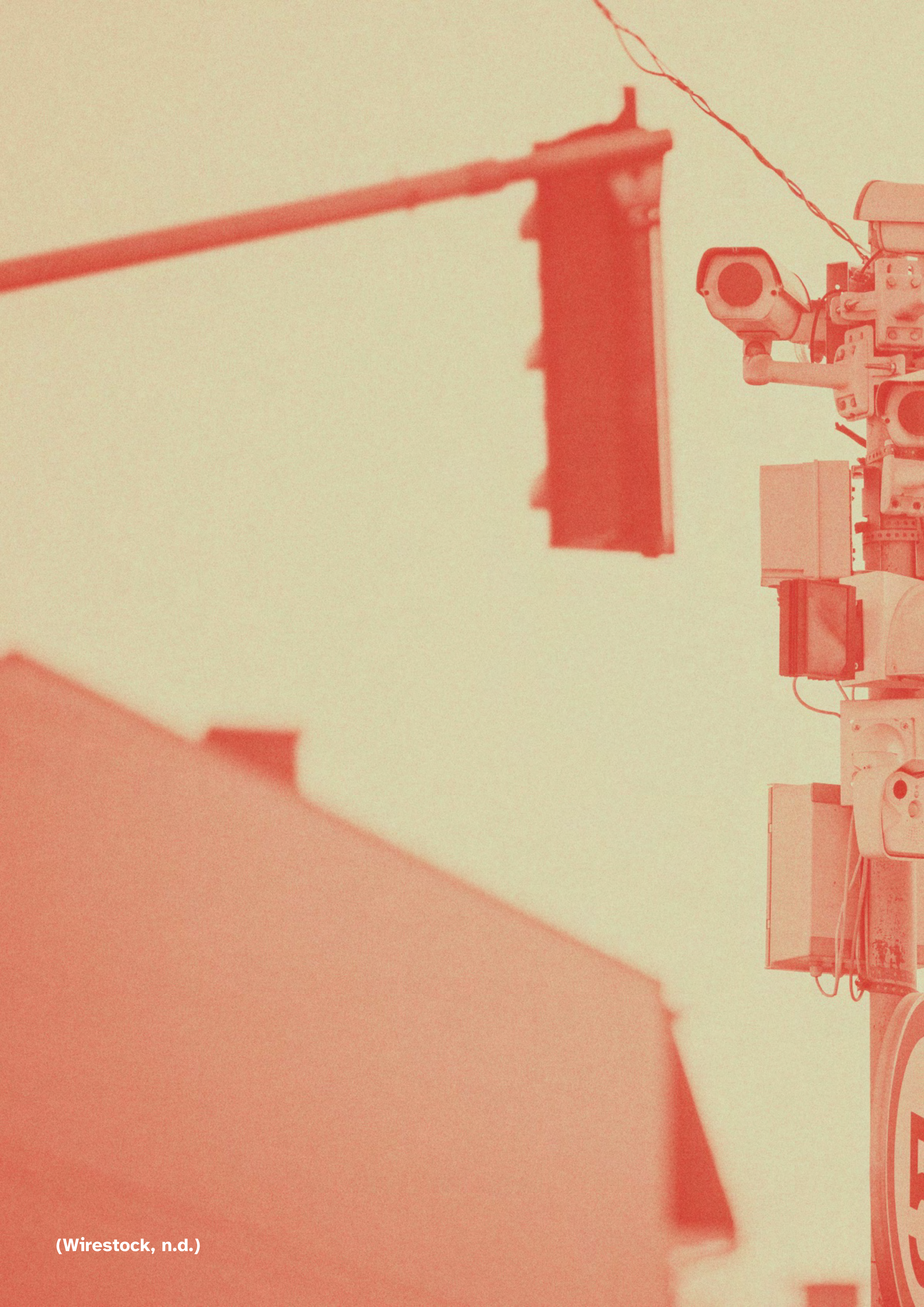
Socioeconomic status and nativeness were considered general factors, applying to all potential user groups. Thus, heterosexual women aged 15-25 were defined as the target user group, with LGBTQ+ included as a secondary user group due to the similarities in their perception of safety.

TA_12

Current camera sensor design does not contribute to perceived safety in public spaces as much as it could.

Considering the current context surrounding the design and use of smart sensors in public spaces, as well as the factors and values related to perceived safety in said public spaces, a number of opportunities for improvement could be identified.

Moving forward, this project will focus on the design aesthetics of camera sensors with the aim of improving perceived safety in public spaces, specifically considering and involving the target user group of women aged 15-25.



(Wirestock, n.d.)

4_0_0
Design Vision

Following the completion of the contextual research, a Design Vision was developed through the integration of Design Drivers, projecting a Product Timeline and following the ViP method, with the goal of taking the first steps towards a final design.

4_1_0
Design Direction

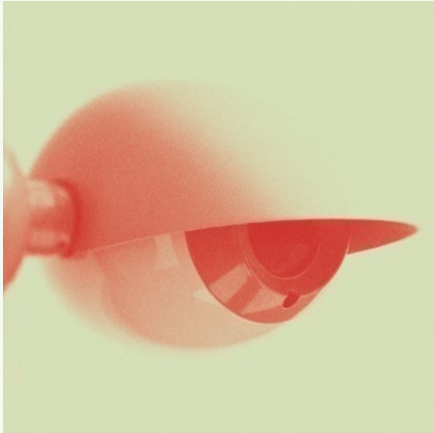
4_1_1
Reformulated Focus

From the contextual research and Main Takeaways, the focus of this project has been refined in the following areas:

1. Very early on, safety was categorised into 'actual-' and 'perceived safety' the latter of which was selected as the starting value of this project
2. Citizens or users of the public space will now primarily refer to the target user group of women, aged 15-25
3. The broad, overarching technology of smart sensing has been recuded to the sensor type of camera sensors
4. Design aesthetics were chosen as the area of improvement to connect the value of perceived safety, the target user group and camera sensor design in public spaces.

To further enrichen and specify this already sharpened design direction, a list of design drivers–depicted on the right, was developed. These design drivers represent a slightly more subjective and personal motivations for the design direction by myself as the designer.

4_1_2
Design Drivers



(Farhoudi, n.d.)

Seeing is Believing

The perception of safety is strongly visually influenced, both through what the citizen is able to see of their surroundings and through what the surroundings are able to see of the citizen. This design project will therefore pay special attention to this visual significance.

(Clerk, 2022)

Perceived Safety Through Other Values

Perceived safety is subjective, complex and interconnected to other values such as trust, privacy and autonomy. By zooming in on these value-aspects, a more meaningful and multifaceted impact can be made on the perception of safety.

(Wirestock, n.d.)

Big Brother is ~~Watching You~~ Looking Out For You

Current perceptions of smart sensing revolve around camera surveillance and can evoke a sense of ‘Big Brotherism’. This project will focus on shifting public perception and awareness to smart sensing that is done for– understood by– and overseen by citizens.

(Home Office, 2023)

No One Gets Left Behind

Intersectionality research reveals that certain groups of citizens are disproportionately affected by low perceptions of safety in the public space. The design will center these voices within the design process with the aim of maximising the potential benefit of smart sensing for this user group.

(AMS Institute, n.d.-b)

An Eye to the Future

With the development of camera sensor alternatives in the near and far future, this project aims to serve as a general vision for the aesthetic design of smart sensors in the public space, with an openness to– and consideration of the technological developments of smart sensing in the future.

Fig. 21: Third Place (I amsterdam, 2023)
A public space that serves as a 'third place' outside of the home of work, with high expressive privacy.

4_2_0
Product Timeline

4_2_1
General Design

For the succeeding concept development and product design phases, a choice had to be made between using a general design, campaign or speculative design approach. As this project aims to achieve a high level of creativity and novelty while maintaing a reasonable level of feasibility and viability, the choice was made for a general design.

4_2_2
Human Readiness

As mentioned in Takeaway 9, a discrepancy exists between the Technology Readiness and Human Readiness of smart sensing technology, and consequently the design and use of camera sensors. In accordance with the Design Driver of 'An Eye to the Future', this project and the eventual design will aim to take the intial steps towards closing this discrepancy, by considering the two-way influence of technology and social values on one another (in this case the perception of safety and design aesthetics of camera sensors), and hopefully serving as useful inspiration for the design and implementation of future generations of smart sensors.

4_2_3
Product Readiness Timeline

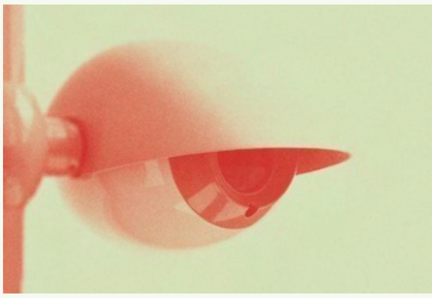
Visualised below is an envisioned timeline of the potential implementation of the final design, in relation to the current state of camera sensor design and relevant future technological developments.

Smart Sensor Design

(Engineering Discoveries, n.d.)

Current Camera Sensors

(Farhoudi, n.d.)



Final Design

Position(s) on Timeline

Perceived Safety

- Value Conflict with Actual Safety

+ Transparency and Attractiveness

Technology Readiness Level
(Of Project)

Concept Design

Embodiment Design

Human Readiness Level

HSI Demo & User Evaluation

HSI Fully Matured

Timeline

2023

2025

4_2_4
Compatibility with Future Sensing Technologies

The RSL alone has already collaborated on countless projects that focus on data minimilasation through the development of innovative and non-invasive sensing technologies, as approach to responsible smart sensing.

The functionality of such technologies can and should be combined with the aesthetic principles of responsible sensor design in the near and far future.

(AMS Institute, n.d.-b)

Developing Sensing Technologies

(Context Travel, n.d.)

Fully Accepted into Public Space

+ Awareness and Inclusiveness

+ Autonomy and Contestability

+ Trust and Expressive Privacy

Detail Design & Engineering

Evaluate & Update

Human Performance Tested

HSI Requirements Test-Verified

Postdevelopment & Sustainment

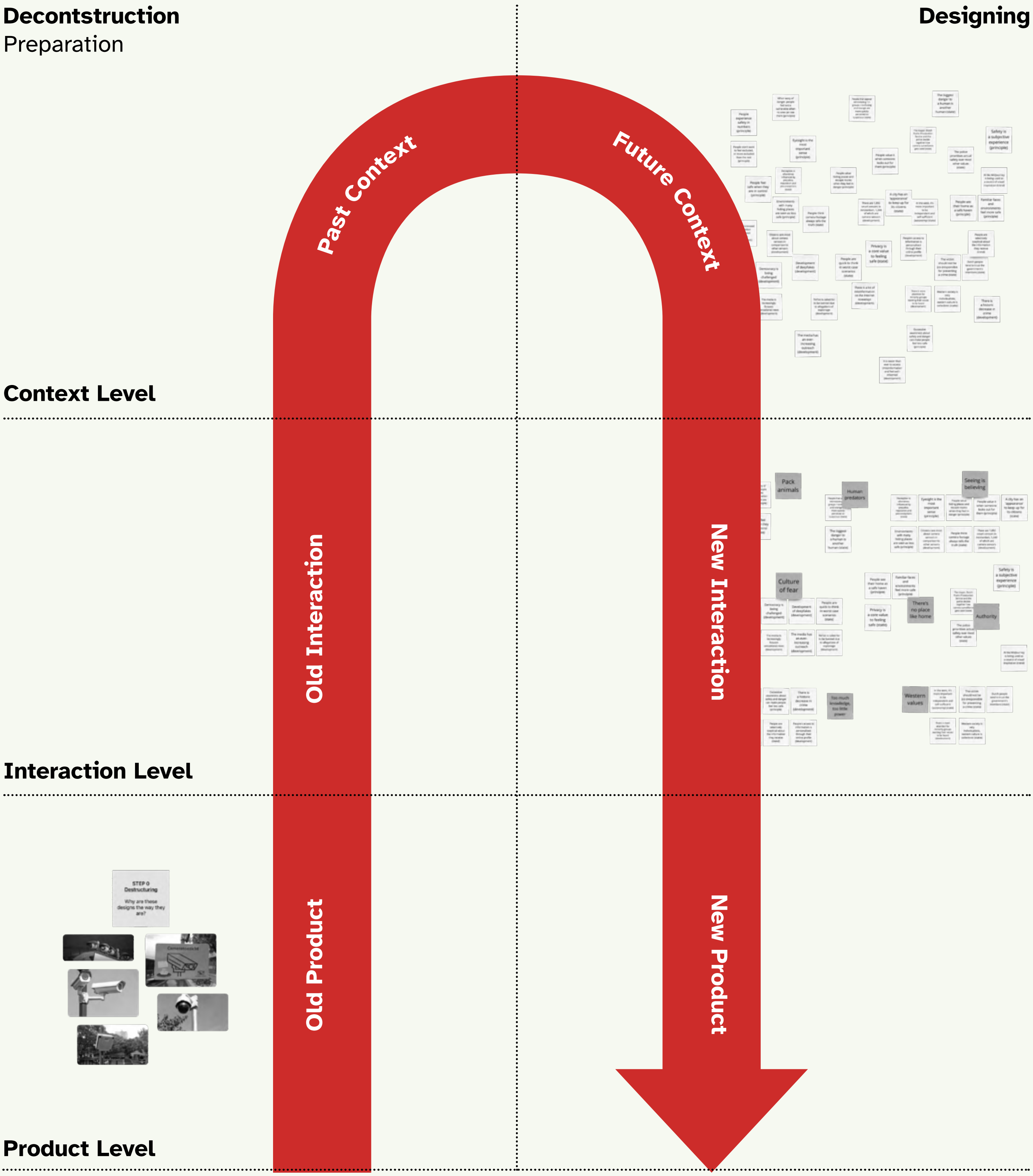
2027

2029

2031

4_3_0

Vision in Product Design



4_3_1
Process

The Vision in Product design method was developed by Hekkert & Van Dijk (2016) and is applied in the synthesis phase of this project to examine the current 'product' of smart camera sensors on three distinct levels: 1) the Product Level, 2) the Interaction Level and 3) the Context Level.

Following this 'deconstruction' of the status quo, a future-oriented phase of a future context, human-product interaction and product qualities is envisioned. The ViP method therefore serves as a contextual synthesis of the research completed and preliminary vision of what the final design will look like.

4_3_2
Deconstruction & Domain

Current camera sensors appear utilitarian, curious, either shy and mysterious or tall and omnipotent on the Product Level. Interactions can be described as evasive, reserved, intimidating, alert, provocative, structured and symbolic. Contextually, they are considered a 'last resort', 'necessary evil', 'one-size-fits-all'.

Domain
For the analysis of the status quo as well as the construction of a vision, a Domain was established:

Design a camera sensor that makes users of the public space feel safe.

4_3_3
Vision in Product

Worldview
Using the deconstructed past as a basis for looking at the future and analysing the solution space from a fresh perspective, numerous context factors were generated and clustered. These trends, developments, states and principles were encaptured in the following worldview:

To not feel safe is to not be in control. To not be in control is to not be connected to your environment. Building this connection through awareness, communication and understanding affords a feeling of safety that enables humans to bring out the best in themselves and those around them.

Statement
From this worldview, a ViP statement was formulated, in which expressive privacy and awareness of the citizen were prioritised:

I want Amsterdammers to have access to the best version of themselves and those around them by being fully in touch with the public space around them.

Interaction Analogy
Like slowly but surely learning a language in a foreign country.

Product Qualities
- Communicative
- Curious
- Open

Through its design aesthetics, camera sensors can and should contribute to the perception of safety in public spaces.

4_4_0
List of Requirements

4_4_1
Value-Based LoR

Based on the previous Research & Anlysis, Value Network and resultant Main Takeaways, a List of Requirements can be set up for the subsequent ideation, design and prototyping phases. Requirements are categorised by values that were identified through research to play a essential role in the perception of safety.

As the project is conceptual in nature and expected not to go beyond TRL_6 in terms of Technology Readiness, requirements have not been quantified, instead serving as key guidelines for the final design, as well as for the application of smart sensing technologies in the future.

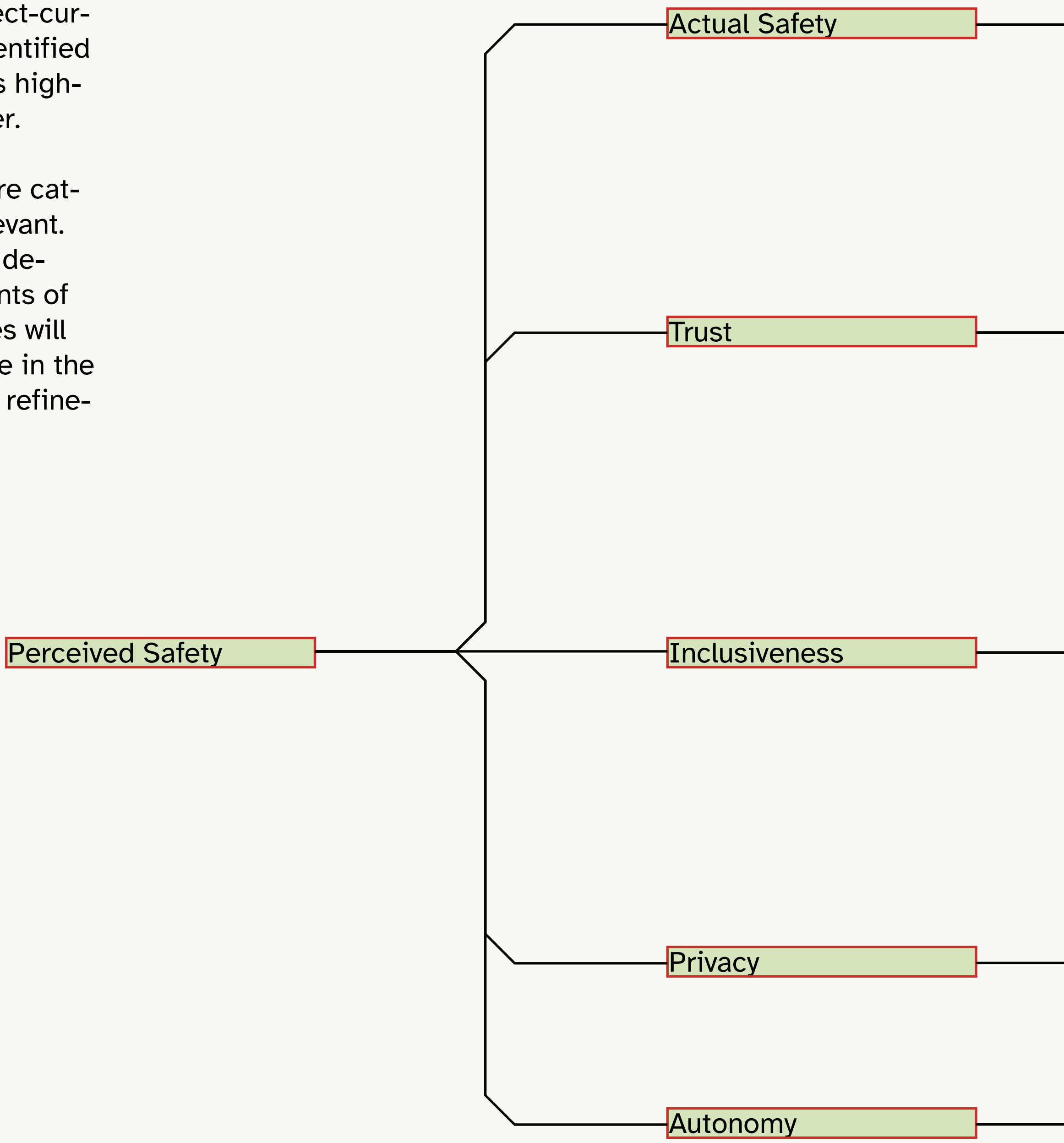
Tab. 10: LoR
List of Requierments based on key values connected to erceived safety from the Value Network (2_1_8).

Value	ID	Requirement
Actual Safety	AS_1	Camera sensor field of view is not limited (when active)
	AS_2	Quality of video footage is maintained (when active)
	AS_3	Compatible with standard bullet camera design
Trust	T_1	Transparency about sensor type, owner, goal, whether or not personal data is collected, whether stationary/mobile and duration of activity
	T_2	Aesthetically pleasing design that contributes visually to the aspects of urban form, clearness and management
Inclusiveness	I_1	Universally perceptible and understandable design
	I_2	No exclusion of user groups prone to low perceived safety
	I_3	Designed in accordance with Amsterdam's policy regarding the public space and smart sensing
Privacy	P_1	No added infringement upon accessibility privacy
	P_2	Respectful and considerate of expressive privacy
Autonomy	A_1	Encourages public feedback, criticism and contestibility
	A_2	Allows for further inquiry and generates public awareness

4_4_2
Prioritised Value Network

As the Research & Analysis phase of this project was conducted following a Value Sensitive Design approach, the LoR is based on 5 project-curcial values that were identified in the Value Network, as highlighted with a red border.

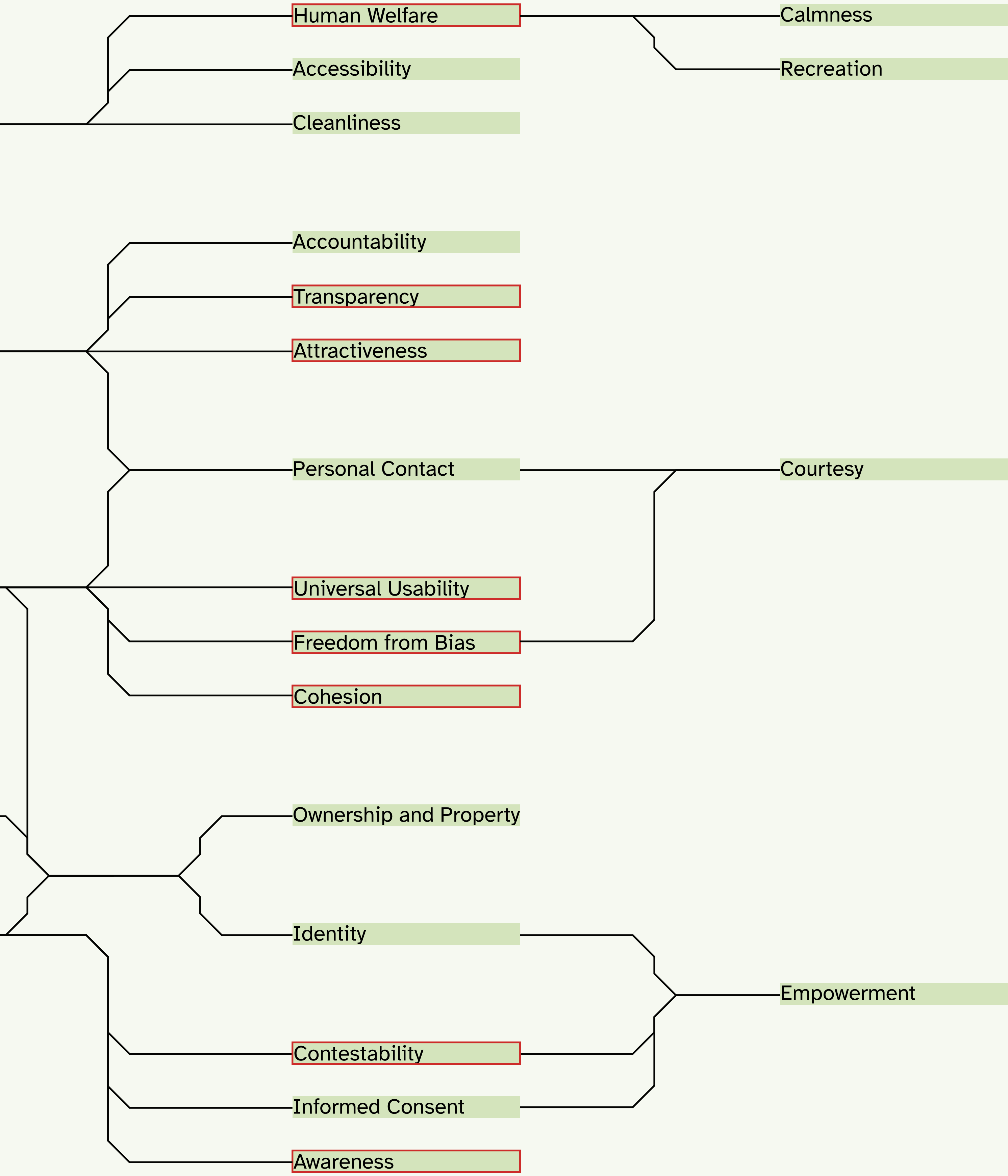
The remaining values are categorised as project-relevant. Considering the scope, design- and time constraints of this project, these values will only play an indirect role in the subsequent design and refinement phases.

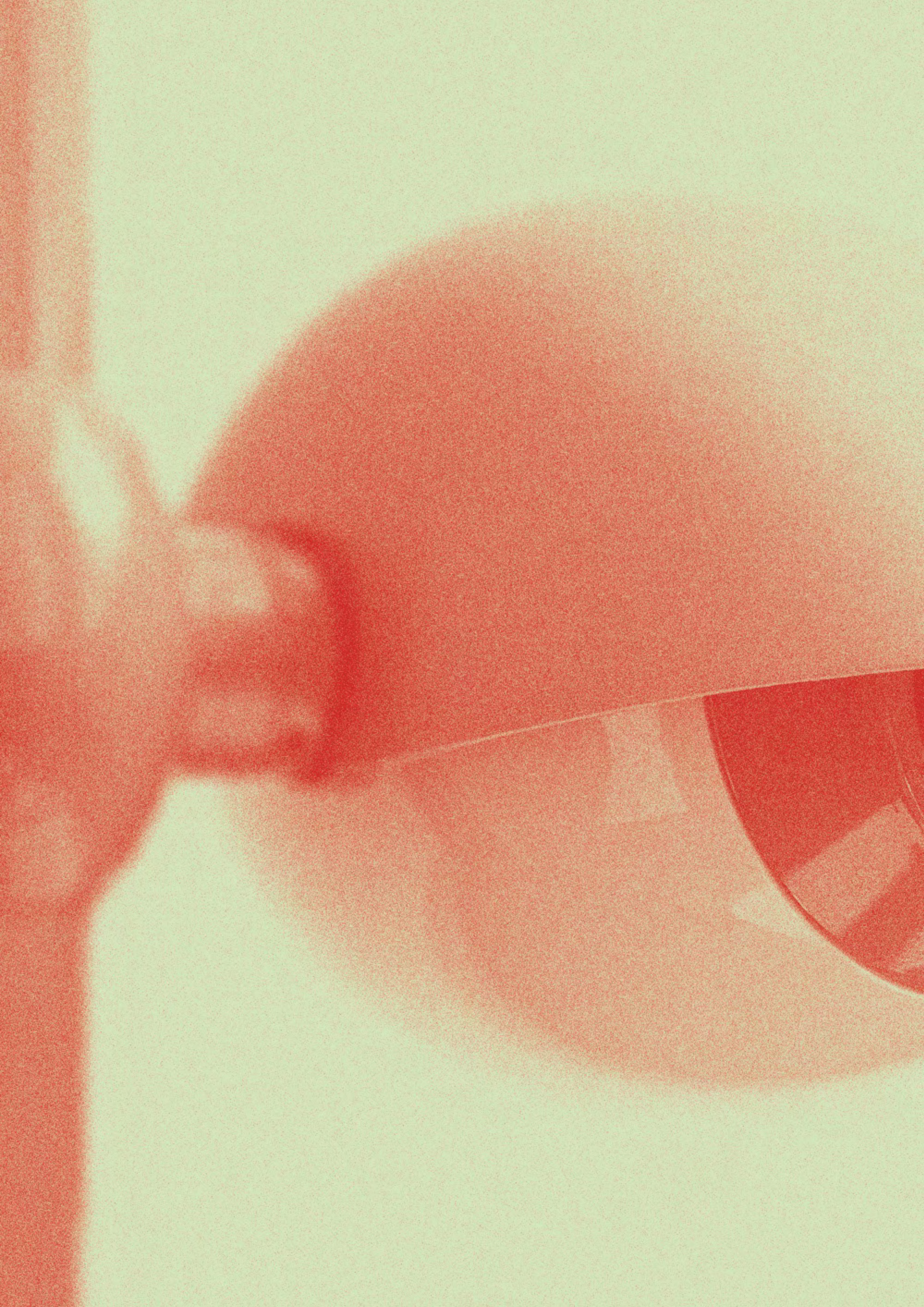


Legend

Project-Crucial Values

Project-Relevant Values


Human Welfare
Calmness
Accessibility
Recreation
Cleanliness
Accountability
Transparency
Attractiveness
Personal Contact
Courtesy
Universal Usability
Freedom from Bias
Cohesion
Ownership and Property
Identity
Empowerment
Contestability
Informed Consent
Awareness



(Farhoudi, n.d.)

5_0_0 Concept Development

From the definition of a final design direction and Design Vision, ideas were generated, developed into concepts and evaluated using the target user group. Throughout this phase of the project, a combination of the Technology Readiness Level (TRL) and Human Readiness Level (HRL) scales was used to provide structure and measure progress.

5_1_0
Ideation
CRL_1

5_1_1
Combined Readiness Level

Combining TRL and HRL
As stated in 1_3_5, both the Technology– and Human Readiness Level scales were chosen to provide a structure and a measure of progress during the the Concept Development and Product Design phases of this project. Considering both the technological– and human aspects of product maturity in a 'Combined' Readiness Level scale, additional inspiration was also taken from the low– and high fidelity prototyping methods often used in UX/UI design, in which different aspects of a design are evaluated in increasingly higher levels of detail.

Step by Step
A visualisation of this framework of steps with increasing fidelity is seen in Fig. 22. With the aim of achieving at least a Combined Readiness Level of 5, the Concept Development and Product Design phases could be broken into concrete steps with intermediate design goals. In this way, CRL_1-3 involves the ideation, conceptualisation and proof of concept design stages, with CRL_4-6 focusing on validation on a component-level, simulation-level and the refinement of the final design.

Fig. 22: CRL scale
The CRL breaks the Concept Development and Product Design phases into concrete steps with intermediate design goals.

<table>
<tr><th>Design Phase</th><th>Readiness Level</th><th>Technology Focus</th><th>Human Focus</th><th>Stage</th><th>Environment</th></tr>
<tr><td rowspan="3">Production & Deployment</td><td>9</td><td>Production</td><td>Deployment</td><td>Completion</td><td>Real</td></tr>
<tr><td>8</td><td rowspan="2">Tech.-System</td><td rowspan="2">Human-System</td><td>Qualification</td><td rowspan="2">Operational</td></tr>
<tr><td>7</td><td rowspan="2">Demo</td></tr>
<tr><td rowspan="3">Technology Demo</td><td>6</td><td>Technology</td><td>Interaction</td><td rowspan="2">Relevant</td></tr>
<tr><td>5</td><td>Component</td><td>User</td><td rowspan="2">Validation</td></tr>
<tr><td>4</td><td rowspan="2">Functionality</td><td rowspan="2">Interaction</td><td>Laboratory</td></tr>
<tr><td rowspan="3">Research & Development</td><td>3</td><td>Proof of Concept</td><td rowspan="3">Theoretical</td></tr>
<tr><td>2</td><td>Technology</td><td>Value</td><td>Application</td></tr>
<tr><td>1</td><td>Context of Use</td><td>Context of Use</td><td>Ideation</td></tr>
</table>

5_1_2 Aesthetic Design Factors

Aesthetic Framework
To apply structure to the concept of design aesthetics within this project, 8 factors are identified and elaborated according to 'The Principles of Aesthetics' (Parker, 2022). These aesthetic design factors are grouped into 3 main categories, each with increased specificity: 1) forms; the overall 3-dimensional shape and embodiment of the design, 2) details; the use of patterns and textures with these forms, and 3) finishes; the application of colour and visual weight to accentuate use clues or specific design features.

Aesthetic-Usability
Besides being a framework for aesthetic design ideation, the identified aesthetic factors can also be used as criteria to evaluate future concepts and design alongside the LoR in section 4_4_0.

An example of such an evaluation can be found in Fig. 23. Here, it becomes evident that current sensor design–including those of camera sensors, is primarily determined by functionality with little to no consideration of aesthetic quality. This severely restricts the benefit of the aesthetic-usability effect, in which users perceive an attractive design to be more usable, reliable and trustworthy (Nikolov, 2017)

Tab. 11: Aesthetic Design Factors
Factors of aesthetic design categorised and subdividided into specific design elements.

Category	Aesthetic Factor	Design Elements
Forms	Balance	• Symmetry • Contrast • Unity in variety
	Movement	• Displacement • Directionality
	Scale	• Absolute size • Relative size
	Form	• 3-dimensional shape • Structure • Functionality
Details	Pattern	• Repetition • Consistency
	Texture	• Surface quality • Material choice
Finishes	Colour	• Hue • Saturation • Brightness
	Visual Weight	• Attention • Focal point

Fig. 23: Aesthetic Evaluation of Example Sensor Installation (Wirestock, n.d.)
Currently, sensor design is almost exclusively based on functionality.

5_1_3 Co-Creation Workshop 1 on Camera Aesthetics

After the identification of a target user group in TA_11, the next step was to involve this user group in the ideation stage of Readiness Level 1 in the form of a co-creation workshop. Co-creation was chosen specifically in accordance with Value Principles DJN_2, 5, 6, and 8 and TADA_1 and 4, which emphasise the significance of the voices, inclusion and expertise of the identified user group. Therefore, in this preliminary step of the design process, it was important to position myself as a facilitator to this user group rather than an authority figure.

Target User Group Diversity
Even within the specific target user group of heterosexual women aged 15-25, it was considered beneficial to the project to diversify the demographic factors of the participants as much as possible. An effort was made to not only sample participants from Dutch cities other than Amsterdam such as The Hague and Rotterdam, but also include those with a different nationality, in this case British.

At the same time, diversity in age was considered important as well. With the age range spanning from 15-25 years old, CCP_3 represents the lower end of this range at 16 years old, while CCP_2, 4 and 5 represent the upper end of the range at 24 years old.

Tab. 12: Co-Creation Participant Demographics
Convenienve sampling of the target user group resulted in a sample size of n = 8 with the following demographic factors.

Workshop	Participant	Age	Nationality	City of Residence
1	CCP_1	23	Dutch	The Hague
	CCP_2	24	Dutch	The Hague
	CCP_3	16	Dutch	The Hague
2	CCP_4	24	Dutch	Rotterdam
	CCP_5	24	Dutch	Amsterdam
	CCP_6	22	British	Loughborough
	CCP_7	22	British	Loughborough
	CCP_8	21	British	Loughborough

Process
Partially serving as a preliminary co-creation workshop, the end goal was the co-creation of a mood board containing desired aesthetic factors for the design of a camera sensor in the public space. A sample size of n = 3 was used. To aid in participant availability and creative facilitation, the workshop took place online using Google Meet for communication and Miro for co-creation.

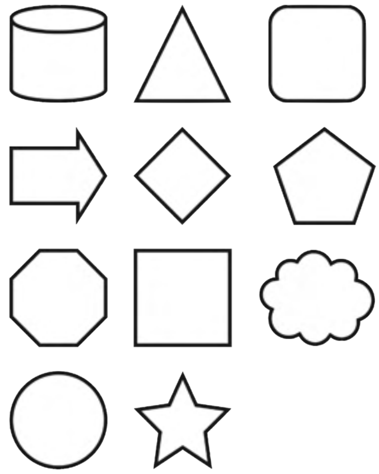
Limited by Google Meet to a meeting time of 1 hour, the workshop was divided into 3 stages of roughly 20 minutes each, which were subdivided into a total of 12 steps. The first stage of steps 1-5, starting off with a brief introduction of the subject, goal, participants and the researcher. This was followed up by brainwriting about camera surveillance in the public space and the subjective feeling of safety. Lastly, aesthetic factors such as shape (representing form) and colour were placed on a spectrum ranging from 'unsafe' to 'safe'.

In the second phase of steps 6-10, images of surveillance-related signage, camera sensor installations and camera sensor types were shown to the participants, to be evaluated using the PrEmo emotional response tool, consisting of 7 positive and 7 negative emotion 'stickers'. Participants were also asked to find their own images of camera sensors and subsequently position these on a matrix according to aesthetic design and perceived safety.

In the final stage of steps 11 and 12, using the conceptual framing and momentum of the previous 10 steps, participants were asked to create a mood board of desired aesthetic factors in the context of smart camera sensing in the public space. To aid in this process, participants were encouraged to ask questions and communicate to each other. Additionally, a mood board template and several examples were provided.

Fig. 24: Miro Post-Its
Virtual post-it notes used on the online miro boards for brainwriting and mindmapping.

Fig. 25: Forms through Shapes
Form was represented through the range of shapes given below.



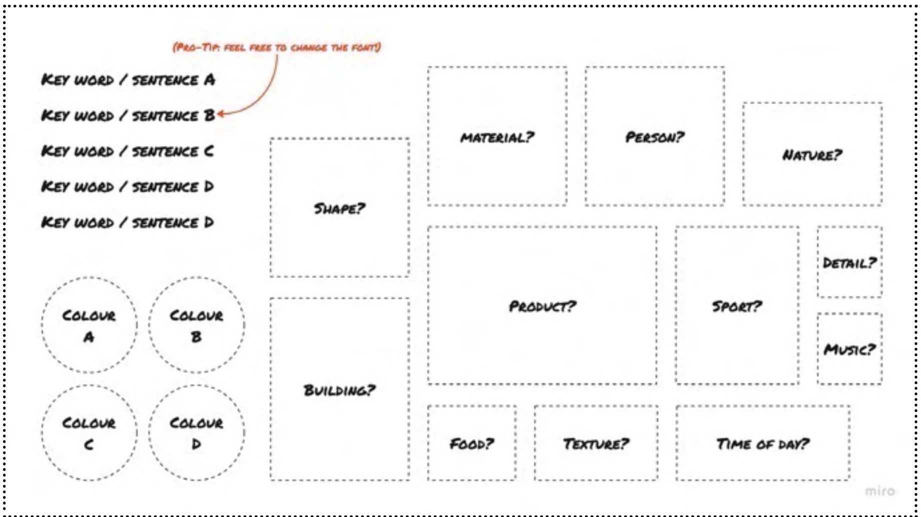


Fig. 26: Mood Board Template
Template provided to participants in need of a starting point during the mood board co-creation.

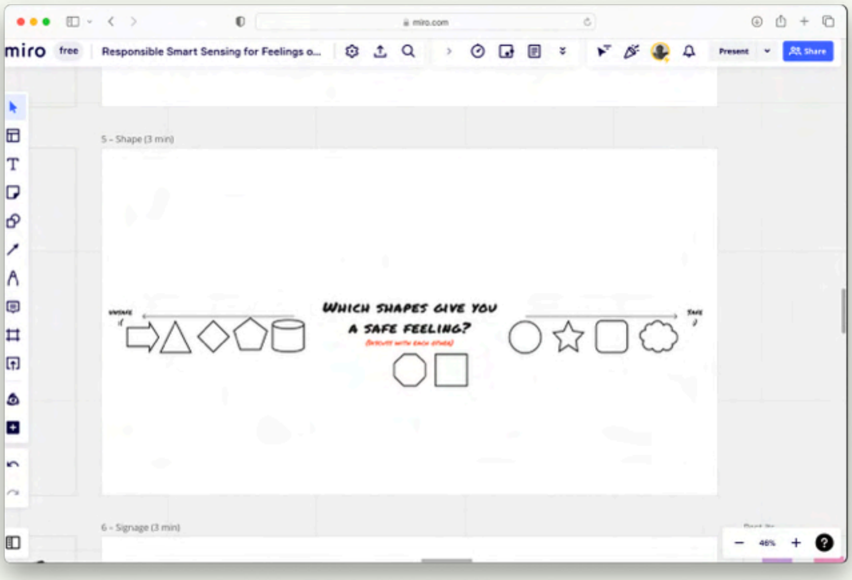


Fig. 27: Steps 1-5 (~20 min.)
The workshop started with brief introduction, 2 steps of brainwriting and 2 steps of evaluating shapes and colours as aesthetic factors.

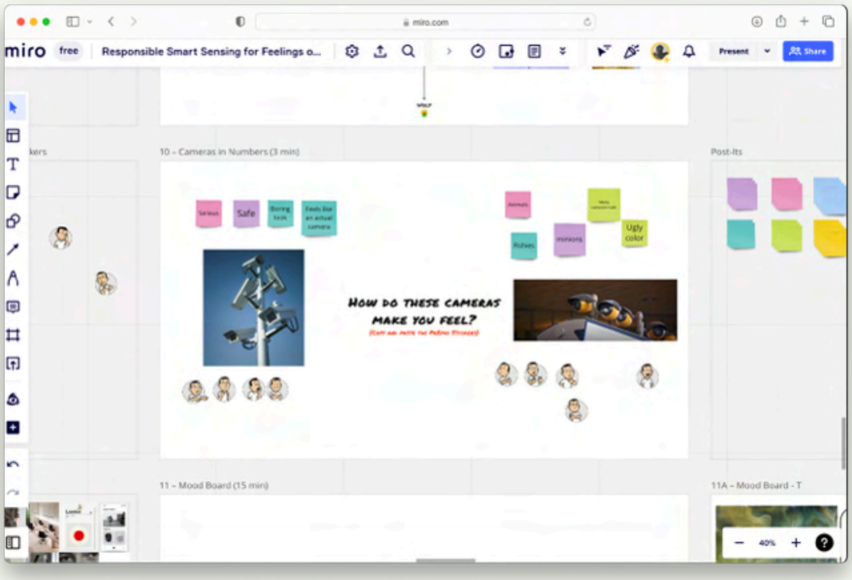


Fig. 28: Steps 6-10 (~20 min.)
PrEmo was used to analyse and evaluate current camera sensor designs and configurations.

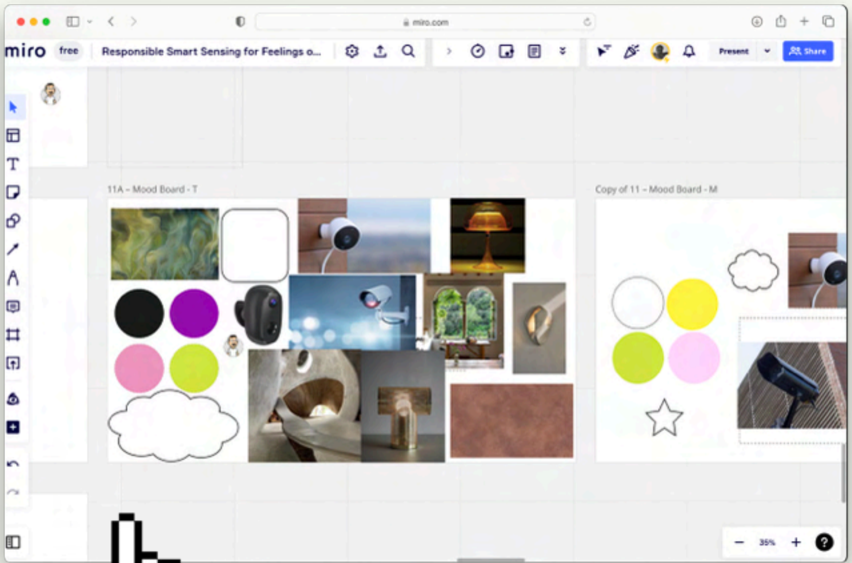


Fig. 29: Steps 11 and 12 (~20 min.)
After 10 preliminary steps of creative facilitation and brainstorming, the final product was a mood board capturing a desired aesthetic.

Insights
The final, co-created mood-boards rendered consistent results regarding the preference of aesthetic factors. Balance was reflected in a preference for symmetry and low visual contrast and weight against the environment. There was a preference for small scale and against strong directionality (movement) through the use of soft, rounded features (form), the positive association of which demonstrates the 'bouba/kiki effect' (Cwiek et al., 2021) as opposed to the negative association with harsh, sharp features with clear directionality.

Participants also preferred high consistency and predictability in desig (pattern) and a more matte, organic surface and material quality (texture), very much inspired by nature. This was further reinforced by the choice for soft, pastel colours resembling flowers, greenery and the ocean.

Evaluation
The workshop proved equally useful in the identification of relevant aesthetic features and points to improve upon for the subsequent workshop. Firstly, although the high consistency between mood boards can indicate a high level of unanimity, it is also evident that participants influenced and inspired each other's eventual mood boards. This would be problematic only if participants experienced low expressive privacy and felt the pressure to conform to certain choices.

Secondly, consistency between the co-created mood boards and aesthetics-related research validates the research as a foundation for this ideation stage. However, it can also be argued that this consistency implies a lack of experimentation and the development of truly novel solutions to the problem. It could therefore be the case that the co-creation workshop might be framed too narrowly on the aesthetic quality of camera sensors in the public space, rather than the desired perception of safety for the target user group.

A second workshop was initially planned for the implementation of feedback from the preliminary workshop. As such, the focus of the subsequent workshop will shift to the co-creation of a mood board representing the subjectively desired perception of safety.

5_1_4
Co-Creation Workshop 2
on Perception of Safety

Process
Based on the evaluation of the preliminary workshop, the structure of workshop #2 was simplified from 12 steps to a total of 10 steps. A sample size of n = 5 was used. After another brief introduction of the context surrounding this project, the LoR and its 5 main, project-crucial values served as the topics of steps 2-7. Inspired by the method of creative facilitation (Tassoul, 2005), techniques such as brainwriting, mindmapping, group discusssion and clustering were used to break down the values of actual safety, transparency, inclusiveness and privacy and autonomy. Again, participants were reminded and encouraged to think out loud and 'outside the box', with the intention of stimulating authenticity and eliminating demand characteristics.

After the preparatory phase of steps 1-7–including a 5 minute break, the co-creation phase of steps 8-10 followed. According to the feedback from the preliminary workshop, participants were asked to use their generated thoughts as a basis for a mood board that visually represents their desired feeling of safety. Due to the abstract and subjective nature of this task, some structure was once again provided through mood board templates and the addition of ~100 images that could be used as a starting point. After 15 minutes, the last 5 minutes of the workshop were spent debriefing and thanking the participants.

Insights
Immediately evident was the fact that the resultant mood boards varied by completion. 2 mood boards were simply collages of images, with the remaining 3 being significantly more developed and containing a range of colours, imagery, thoughts, ideas and associations.

Even from the less developed mood boards, a clear theme related to natural imagery and patterns emerged, similarly to the preliminary workshop. Plants, flowers, organic shapes, water, campfires and the sun were strong visual sub-themes. Colour choice partially reflected this in a preference for pastel–especially green and earth-tone colours, although CCP_4 included deep, warm colours in her mood board.

A trend not reflected specifically in this workshop was a clear demand for awareness, clarity and control. This was reprented through a sense of engagement and communication to one's surroundings, in which mutual understanding and consideration allowed for the formation of trust. For CCP_5, this trust and mutual understanding could be gained by knowing 'who the person behind the camera is'. Nature and natural imagery, as the antithesis of cold and emotionless machines, therefore symbolises a sense of simplicity, predictability and understanding that seems to be absent in the current interaction with– and perception of camera sensors.

“Seeing that people put effort into their environments & **trust people around them.**”

Mood Board Quote by Co-Creation Participant 4


miro
free
Responsible Smart Sensing for Feelings of...
9A – Mood Board (15 min)
9B – Mood Board Template
Inspiration
10 – Outro (5 min)

(Depiction)

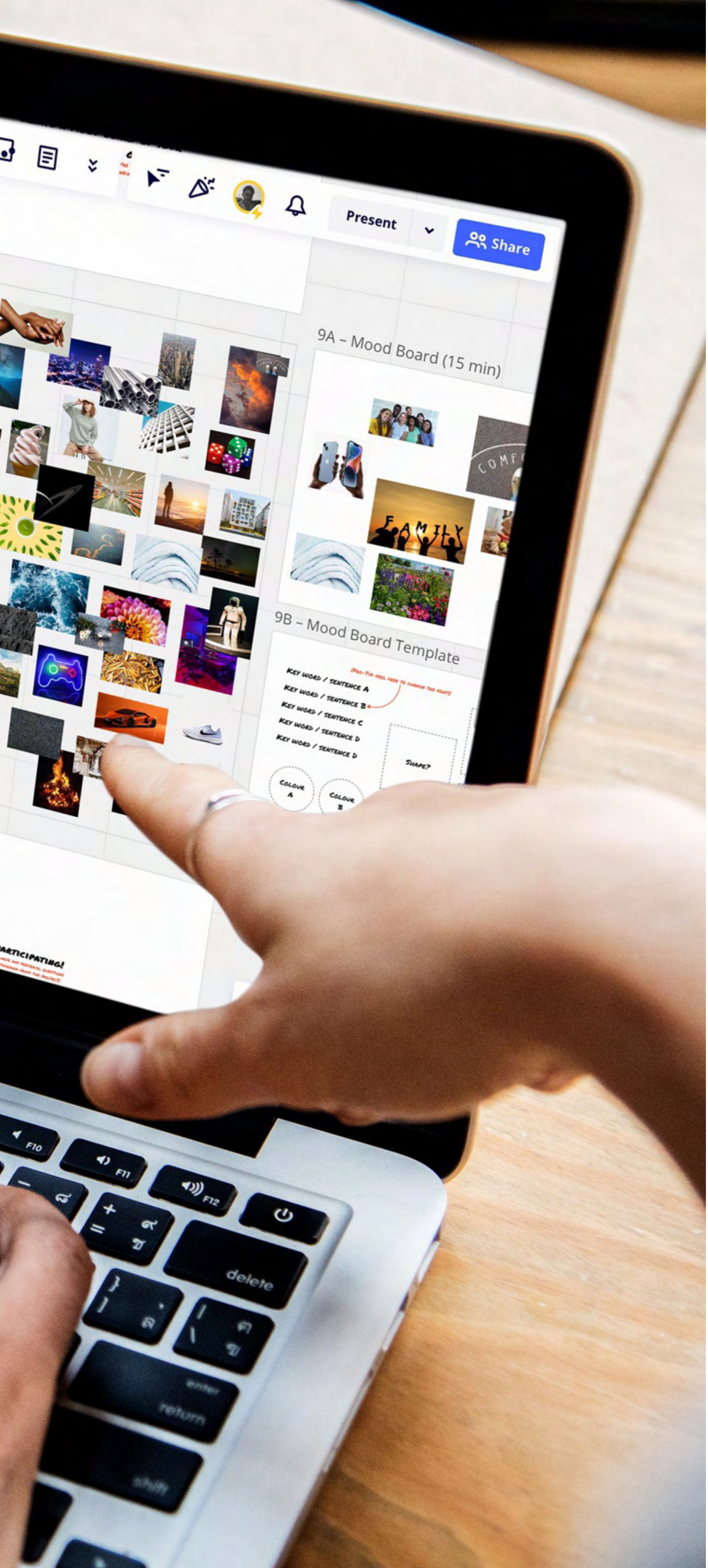


Fig. 30: Mood Board Co-Creation
Participants were provided with a board containing ~100 images that could be used as a starting point for the co-creation of their mood board.

Next Steps
From the co-created mood boards, visual themes and metaphors could be extracted and related to the aesthetic design principles identified previously. To collate and interpet this rich information for the subsequent concept development phase, a final mood board was created.

5_1_5
Mood Board

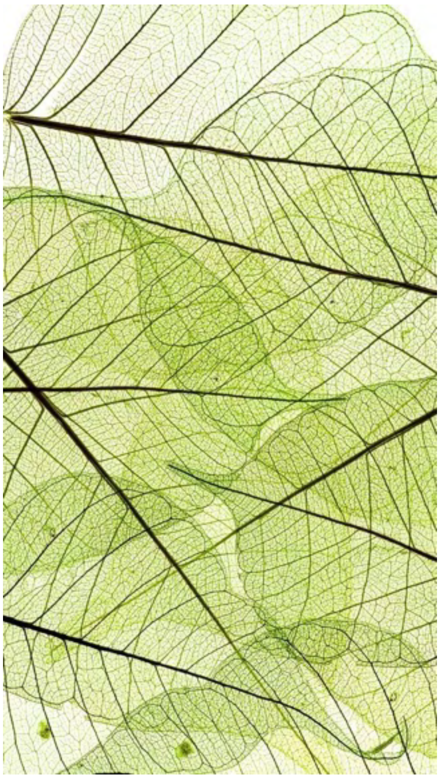


Fig. 31: Final Mood Board
From the co-created mood boards, visual themes and metaphors were extracted, from which a final mood board could be created.

5_2_0
Conceptualisation
CRL_2

5_2_1
Metaphors

From both the co-created mood boards and the resultant mood board in 5_1_5, 3 distinct, nature-inspired metaphors were extracted for the subsequent development of concepts: 1) fruit, 2) flowers and 3) birds. ‘Trees’ were used as an underlying metaphor for nature, connecting each of these aesthetic metaphors.





5_2_2
Stable Diffusion

Based on the resultant mood board, Stable Diffusion was used to generate some initial visual output to be quickly evaluated by the co-creation participants. For image generation, A positive and negative prompt were written.

Positive Prompt

Photo-realistic render of an [amber/white]-coloured, flower-shaped lighting post base made out of flowing, organic shapes. The base has 7 camera modules that extend outwards like branches, each module has a cctv camera attached to it, it's a sunny day in the city and people are walking by. Fujifilm.

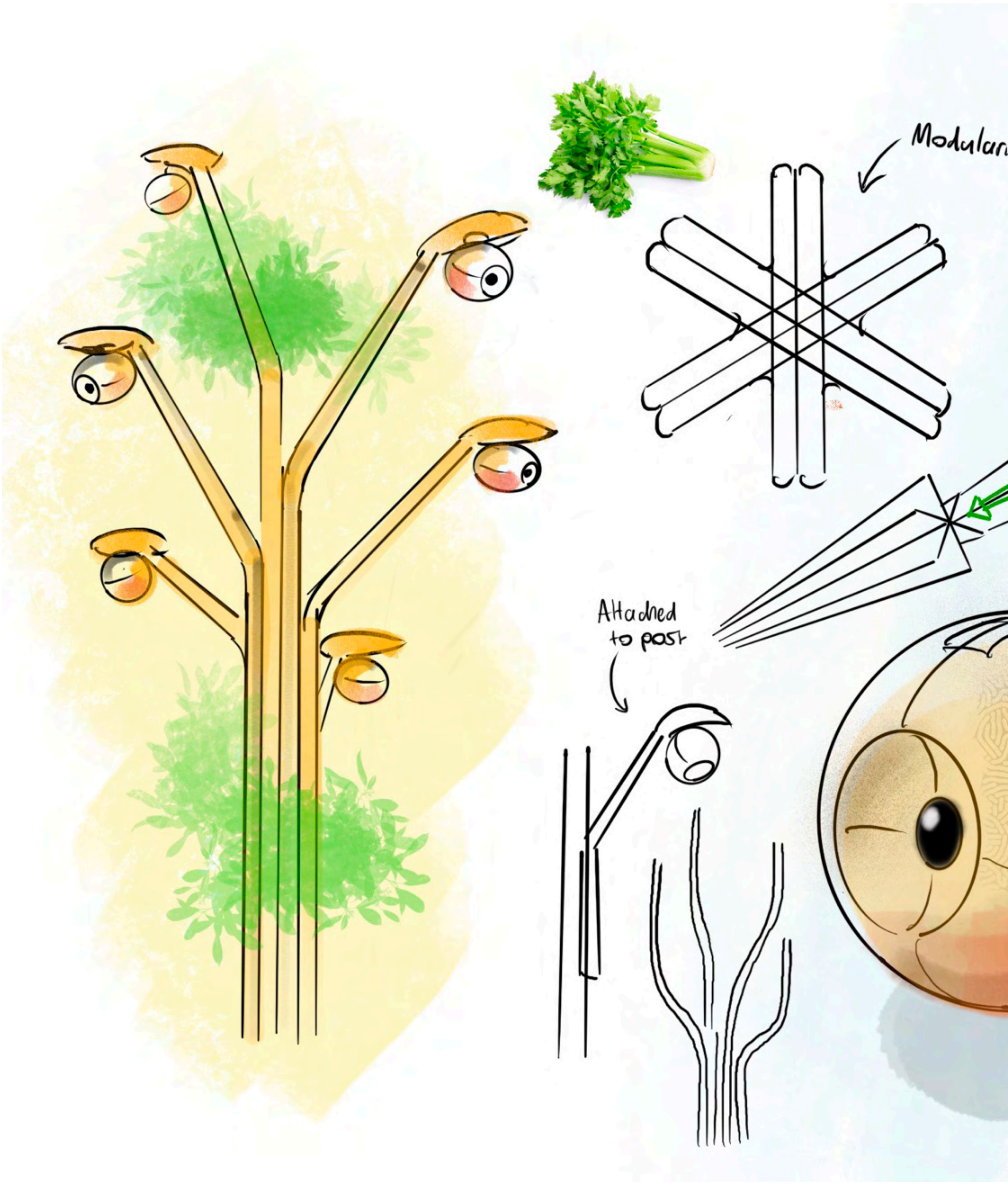
Negative Prompt

Rigid, sharp angles.

Feedback

CCP_4 immediately expressed enthusiasm about the generated images, stating: "I think that these 'aesthetic' shapes could contribute to a feeling of being in a valuable, enjoyable, safe environment". CCP_5 was also positive, although slightly more critical, saying: "I'd watch out for abstractness. An industrial style is beautiful but sometimes art pieces on the street get so wild and random that I think: 'why does art have to shock and cost so much when u can also do something socially beneficial such as helping the homeless'".

Fig. 32: Stable Diffusion
Visual output generated using Stable Diffusion for quick and easy, initial evaluation by the target user group.

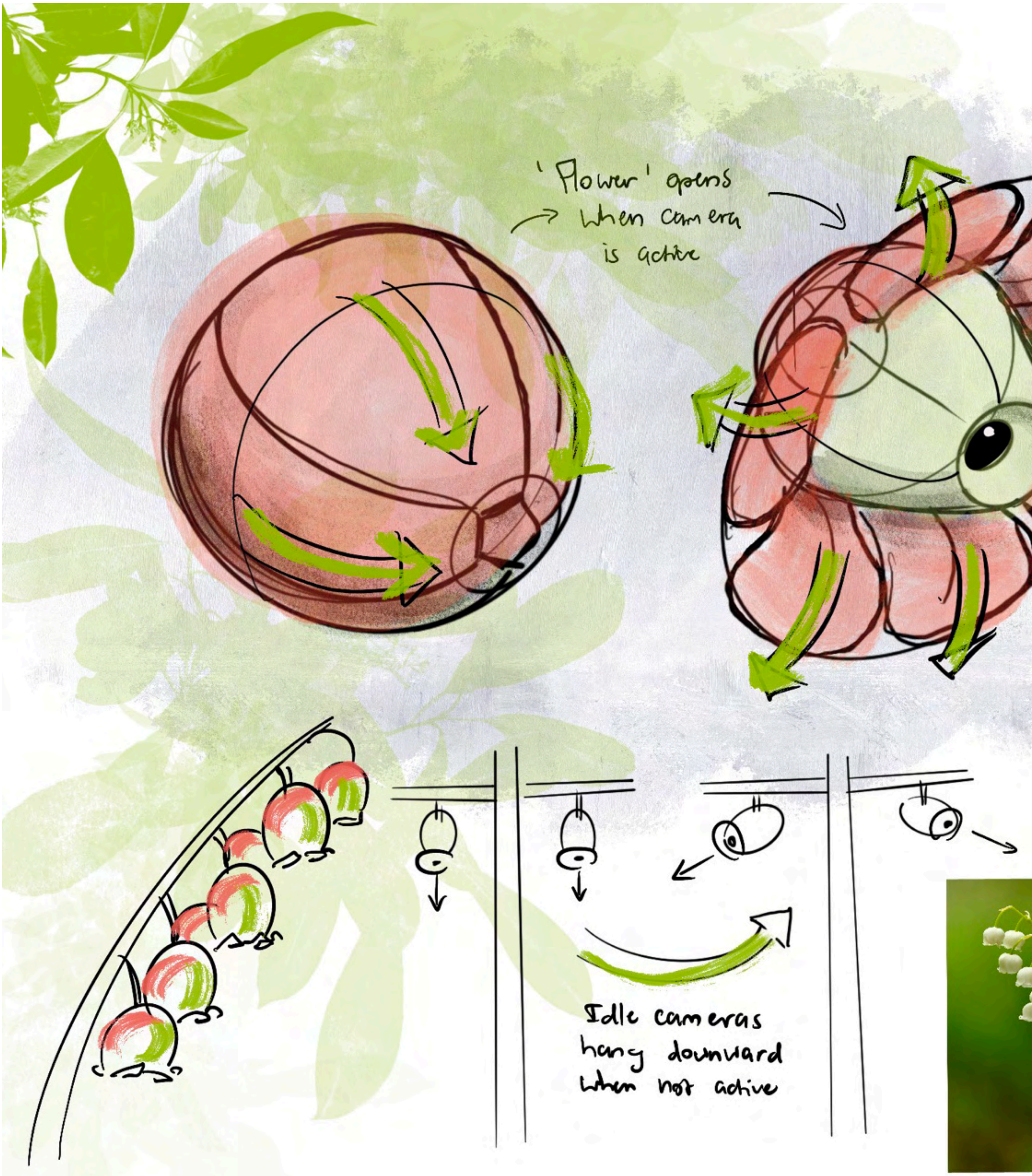


Modular
Attached
to post

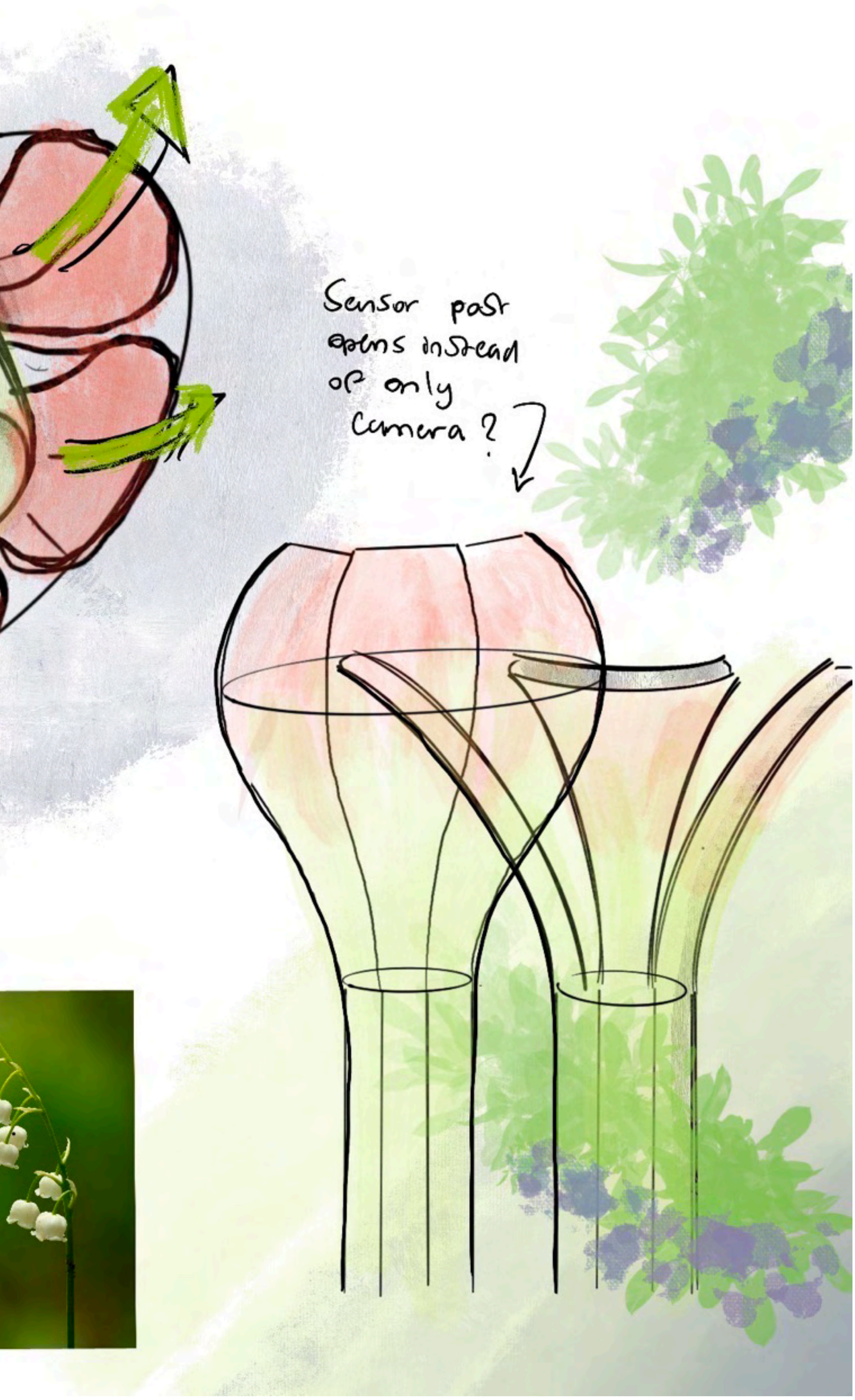
5_2_3
Concept_1
Low Hanging Fruit

Inspired by the organic and intuitive forms of a tree and the inherent unity in variety of its fruit, the Low Hanging Fruit concept aims to apply these aesthetic qualities to the multidirectional and modular nature of an installation of bullet cameras while also contributing visually to its surrounding public space.

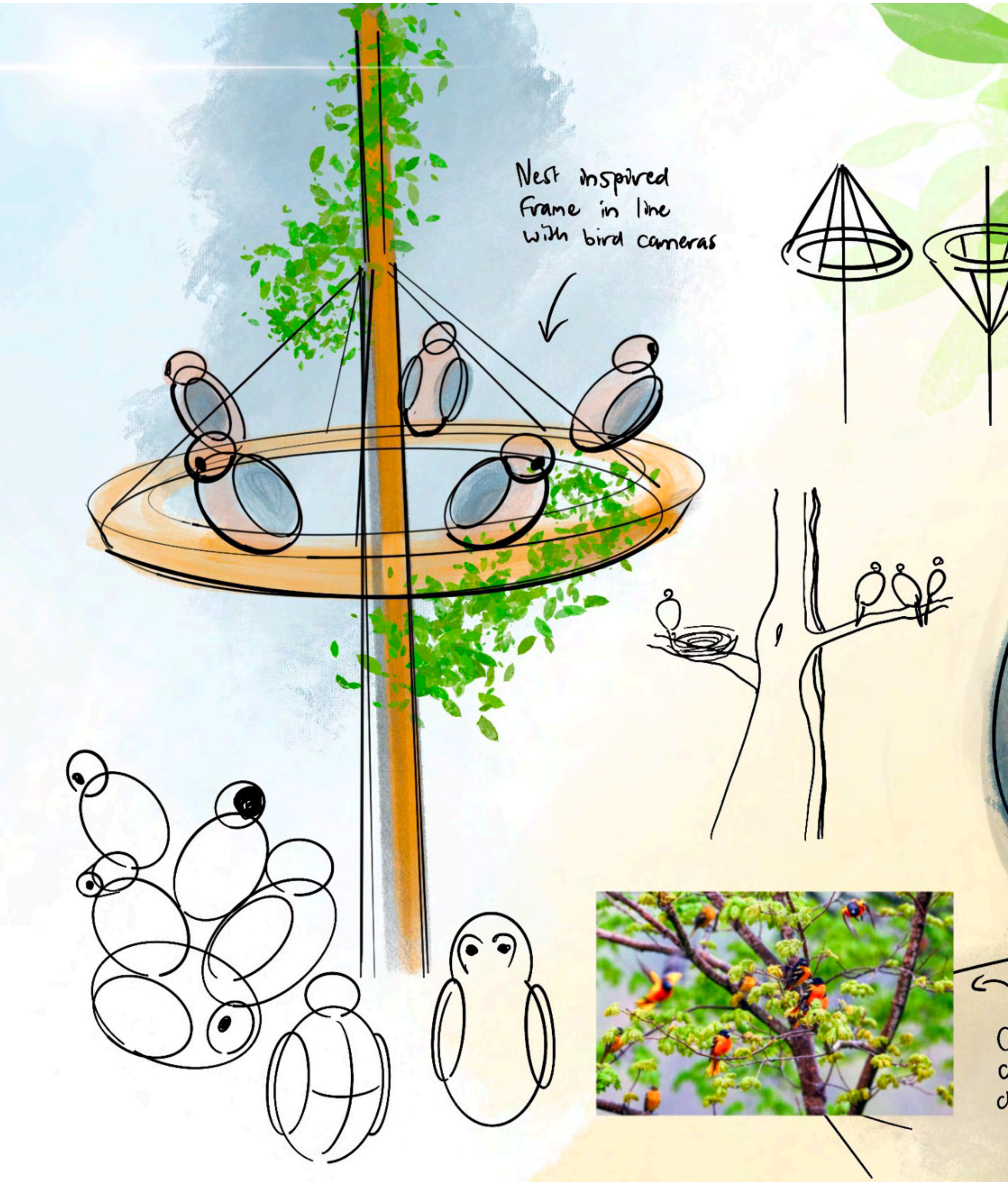
Similar to Het Oogje, harsh and intrusive directionality is softened into a smooth, rounded form, each attached by a modular arm that can be secured to up to 5 other arms in a number of different ways. This makes the camera sensor installation a unique ‘tree’, while still recognisably being part of a forest.


'Flower' opens
when camera
is active
Idle cameras
hang downward
when not active

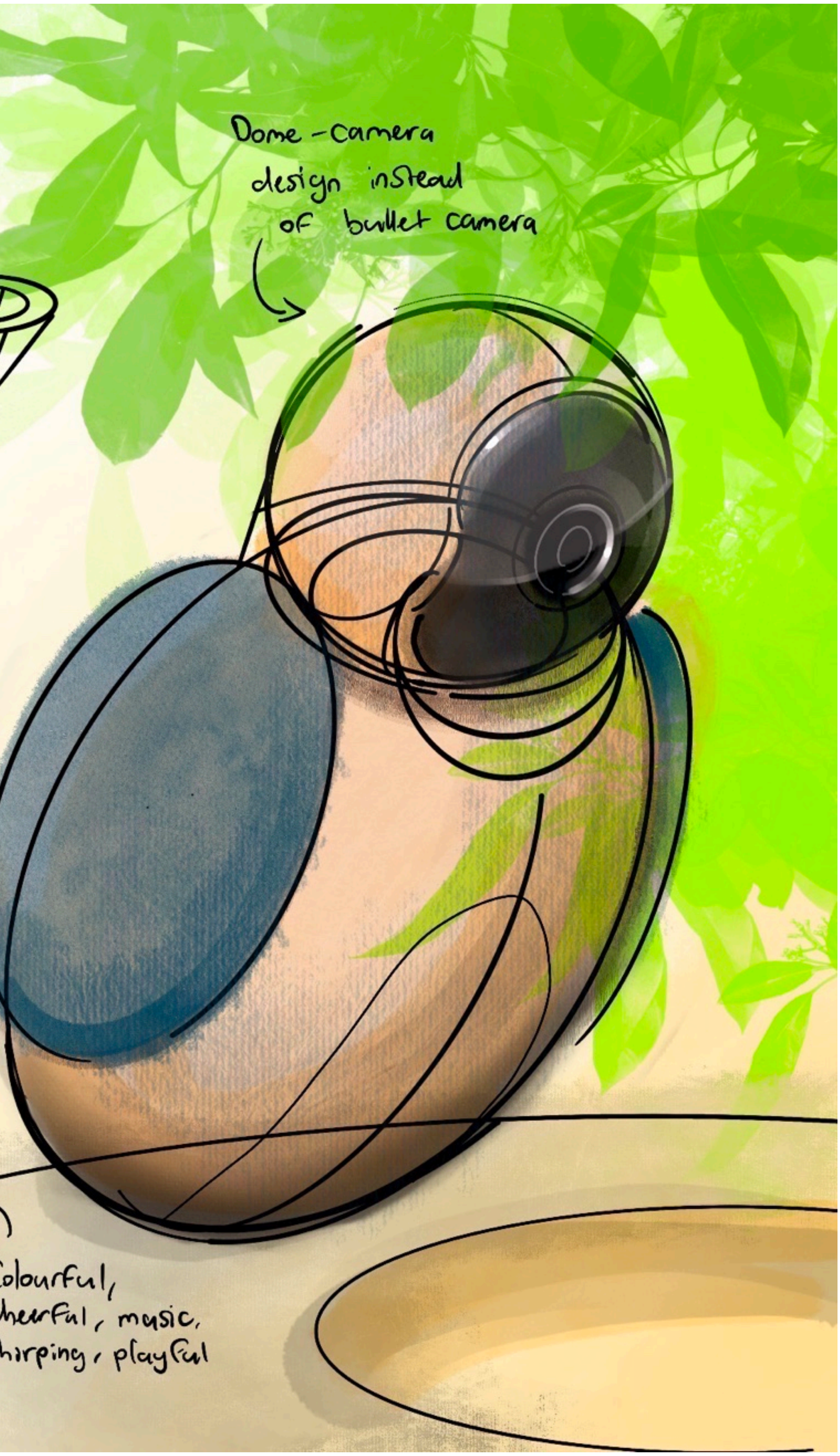
5_2_4
Concept_2
Lily of the Valley



The Lily of the Valley concept– as the name suggests, is inspired by the Lily of the Valley flower, both aesthetically and functionally. Again compatible with the metaphor of a tree, the extruded form of the bullet camera is transformed into a collapsable flower, either 1) blooming or 2) rising from its dormant, hanging position when the camera is active. Through its state, the Lily communicates to the citizen when it is active and when it is not.


Nest inspired
frame in line
with bird cameras

5_2_5
Concept_3
Bird's Eye View



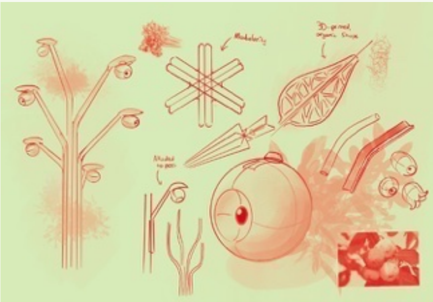
Although Bird's Eye View still works with the chosen natural metaphor of the tree, it explores a slightly different design direction by using fauna–specifically birds, as its main source of inspiration instead of flora such as fruit or flowers. Multiple, modular camera units, or 'birds' can be mounted on a disc-shaped frame, or 'bird's nest', creating a coherent but flexible design.

The main downside of the Bird's Eye View concept, however, is its incompatibility with bullet cameras by replacing these with dome cameras, which violates requirements AS_1, 2 and 3.

Fig. 33: Concept Sketching
Concepts were sketched digitally on Procreate using an iPad Pro with Apple Pencil, allowing for easier online communication with the user group.

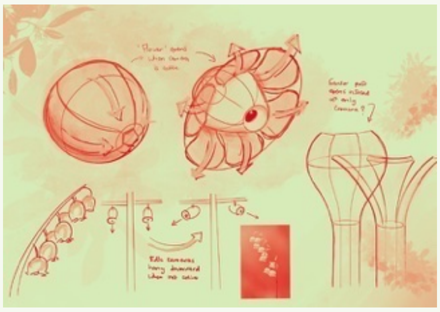
5_2_6
Initial Feedback

Concept_1
Low Hanging Fruit



Concept_1 was universally preferred over the other concepts when shown to members of the target user group and co-creation participants. This preference was primarily based on form and hue, with the concept resembling a peach in both of these aesthetic factors.

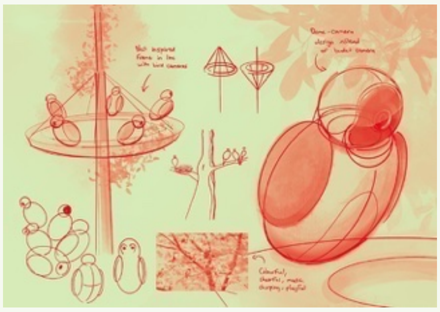
Concept_2
Lily of the Valley



CCP_6 provided some initial feedback, stating: "I do like the look of this but I'd be slightly apprehensive that it's 'over-feminising' women as you were focusing on that target group. Like that if you're female, everything has to be pink and flowers and purple and hearts and that sort of thing, if that makes sense?"

When asked what would improve the concept, she suggested: "Possibly the colour more, I do like the concept with the form but maybe a less typical petal form would work. The soft rounded shape adds also to the 'feminising' effect".

Concept_3
Bird's Eye View



Initial feedback on concept_3 was positive but moderate. CCP_6 was amused by the 'bird' and associated it with a robot character from an animated movie, stating: "I'm getting slight Eve vibes from WALL-E".

5_3_0
Proof of Concept
CRL_3

5_3_1
Comparison Criteria

To be able to meaningfully compare the 3 concepts with each other in the context of this design project and so arrive at a proof of concept, a list of evaluation criteria was set up in the form of a Weighted Objectives Table (WOT).

The criteria–or 'objectives', of the WOT were initially based on the aesthetic design factors, LoR and Value Principles. Additionally, the 'Most Advancad Yet Acceptable' (MAYA) principle (Hekkert et al., 2003) was included to assess the novelty of a concept, as well as its typicality or 'acceptability'. This was relevant to CCP_5's earlier concerns that a design can be negatively perceived as too 'wild' and 'shocking' in its novelty.

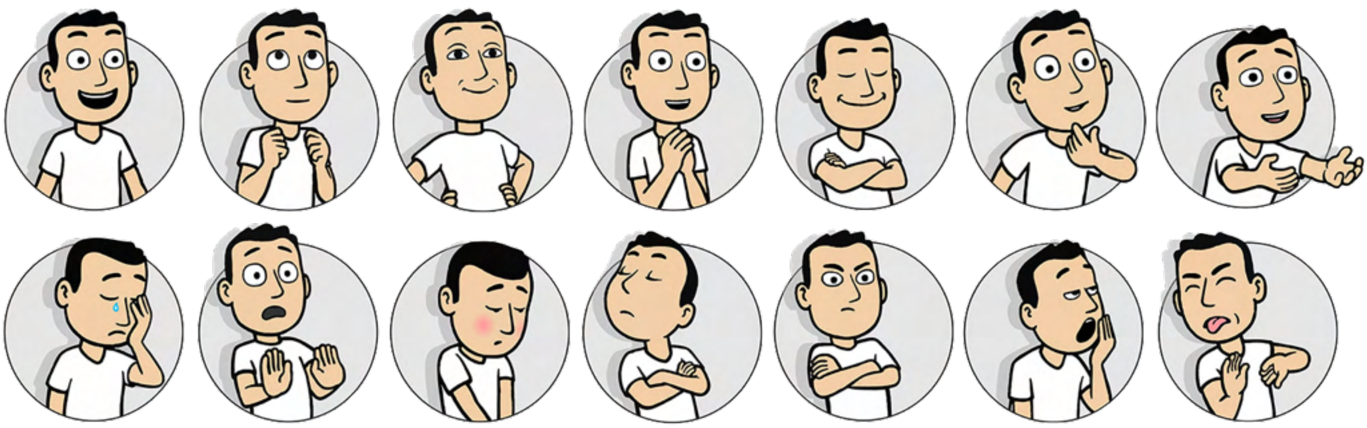
Furthermore, feasibility and generalisability were included as well to reflect advantages and disadvantages in the implementation process of the concepts. Here, feasibility refers to the ease of prototyping and manufacturability, and generalisability refers to the extent to which design elements of a specific concept can be applied to other concepts and designs.

For each of these comparison criteria, a weight is assigned to accurately reflect its respective signficance to the final design, further explained in 5_3_3. In this way, some criteria can be prioritised over others, allowing for a more nuanced comparison between the developed concepts.

Fig. 13: WOT
Criteria with corresponding weights and evaluation methods.

Criteria	Weight	Evaluation Method
Perception of Safety	20	PrEmo
Aesthetic Quality	15	Aesthetic Design Factors
Integrated Values	20	List of Requirements
In Line with Value Principles	15	Value Principles
Most Advanced Yet Acceptable (MAYA)	10	Estimated ranking
Feasibility	10	Estimated ranking
Generalisability	10	Estimated ranking
Total	**100**	

Fig. 34: PrEmo Emotions (Desmet, 2018)
Pictorial emotion scale measuring 7 positive and 7 negative emotions.



5_3_2 PrEmo

Measuring Emotions

As part of the concept evaluation and comparison process, the PrEmo Emotion Measurement Instrument (Desmet, 2018) to quantitatively assess and measure the emotional response of each concept as an indicator of perceived safety.

In this specific version of the toolkit, it includes 7 positive emotions (pride, admiration, joy, hope, satisfaction, desire, fascination) and 7 negative emotions (shame, contempt, sadness, fear, anger, disgust, boredom). These 14 emotions are considered by Desmet to "represent a solid cross-section of the human repertoire".

Application

From the sample of co-creation participants, CCP_1, 2 and 3 were asked to assign any of the PrEmo stickers in Fig. 34 to the 3 concepts. In this qualitative and preliminary step, co-creation participants were asked to explain their choices and emotional responses, ensuring accurate use of the PrEmo stickers and–most importantly, framing the participant's line of thought in the scope of emotional response and perception of safety. The participants' qualitative, emotional responses were then quantified by asking them to rate their respective perception of safety on a scale from 1-10 for each concept.

5_3_3
Weighted Objectives Table

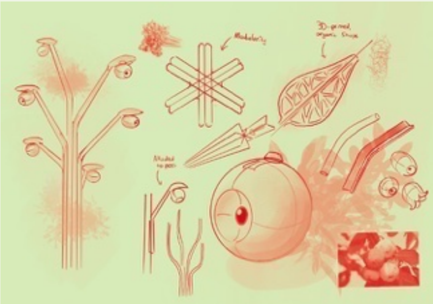
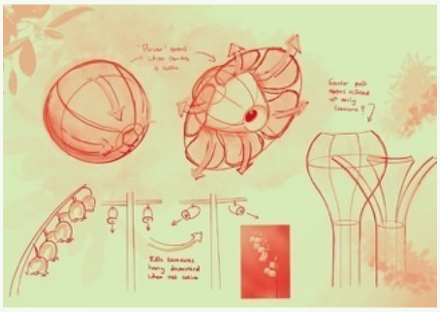
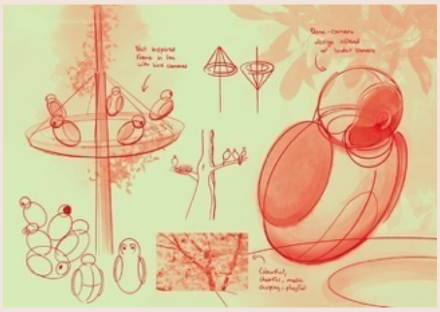
Weighted Objectives
For each criterium in the weighted objective table, a methor of quantitative evaluation was used to be able to arrive at an eventual concept score. This score differs per criterium and evaluation method; PrEmo uses a /14 score while the LoR uses a /12 score, for example. For MAYA, feasibility and generalisability, estimated ranking was used, converting a 1st, 2nd and 3rd ranking to a score of 80%, 60% and 40%, respectively.

The highest weight of 20 was assigned to Perception of Safety and Integrated Values, most directly related to the Design Vision. With a weight of 15, Aesthetic Quality and In Line with Value Principles are prioritised next, representing an effective means of achieving the Design Vision. Lastly, MAYA, Feasibility and Generalisability represent additional design concerns and feedback from the co-creation sample group.

In the last step, all scores are converted to a weighted score for each criterium that contribute to the final concept score out of a total of 100.

(Koenen, 2021)

Criteria	**Quantitative Evaluation Method**
Perception of Safety	PrEmo score
Aesthetic Quality	# of aesthetic factor design elements integrated
Integrated Values	# of LoR requirements fulfilled
In Line with Value Principles	# of value principles adhered to
MAYA	Estimated ranking
Feasibility	Estimated ranking
Generalisability	Estimated ranking
Total	

Concept_1 Low Hanging Fruit	**Concept_2** Lily of the Valley	**Concept_3** Bird's Eye View
		
7.8 /10 **15.6 /20**	6.8 /10 **13.6 /20**	6.3 /10 **12.6 /20**
17 /19 **13.4 /15**	16 /19 **12.6 /15**	17 /19 **13.4 /15**
12 /12 **20 /20**	10 /12 **16.7 /20**	8 /12 **13.3 /20**
18 /20 **13.5 /15**	17 /20 **12.8 /15**	16 /20 **12 /15**
1st **8 /10**	2nd **6 /10**	3rd **4 /10**
1st **8 /10**	3rd **4 /10**	2nd **6 /10**
2nd **6 /10**	1st **8 /10**	3rd **4 /10**
84.5 /100	**73.7 /100**	**65.3 /100**

5_3_4
Concept Evaluation

Results
According to the WOT and its criteria in 5_3_3, it is evident that Low Hanging Fruit is the winning concept with a final score of 84.5/100, compared to the 73.7/100 and 65.3/100 scores of Lily of the Valley and Bird's Eye View, respectively.

Out of the 7 total criteria used for the WOT, Low Hanging Fruit scored highest in 5, sharing a 1st place in Aesthetic Quality with Bird's Eye View and coming 2nd to Lily of the Valley in Generalisability. Bird's Eye View, on the other hand, mirrors the wins of Low Hanging Fruit in its losses, scoring lowest in 5 out of 7 criteria and placing 2nd to Low Hanging Fruit for Feasibility. Lily of the Valley is consistent in its placing 2nd–almost exclusively to Low Hanging Fruit, only scoring lowest twice for Aesthetic Quality and Feasibility.

Discussion
Interestingly, a prediction of this particular order of concept scores could be predicted from the initial co-creation participant feedback for each of these concepts. Here, Low Hanging Fruit appeared to have the most positive and enthusiastic reaction. Lily of the Valley was seen as a strong 2nd option, with most of its strengths in aesthetic appeal (not to be confused with the criterium Aesthetic Quality) just being outshined by Low Hanging Fruit.

Especially for Lily of the Valley, the Aesthetic Factors of colour and form seemed to influence its perception by the target user group. The choice of a flower was perceived as potentially leaning towards an 'over feminising' design approach, which was further reinforced by the use of a pink-ish colour and rounded petal shapes.

A major strength of Lily of the Valley, especially compared to Low Hanging Fruit, relates to the MAYA principle. Lily of the Valley appeared to strike the best balance between novelty–in its functionality and aesthetic design, and typicality–

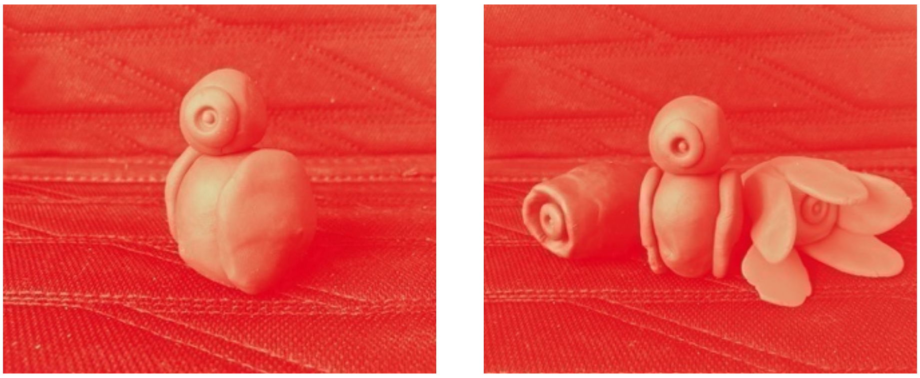


Fig. 35: Play Dough Models
Quick and easy play dough models to translate shape into form during conceptualisation.

its ‘normality’ and ability to be accepted as a design proposal. This was reflected by CCP_4: “Nice that it can close, communicates respect for privacy to me, makes me trust it more. Also looks original and aesthetically pleasing. However also looks a bit more fragile”.

Where Low Hanging Fruit can be considered a safe–or typical, choice in this regard, Bird’s Eye View was generally viewed by the co-creation participants to be too novel. Participants were unsure what to associate the design with exactly and expressed careful skepticism. CCP_4 stated: “camera birds make me think of that ‘pigeons are government drones’ conspiracy, they do not look friendly but rather as something intruding, kind of like the ‘secret camera hidden in teddy bear’ trope”. CCP_5 shared this view: “[Bird’s Eye View] is a bit agressive ... due to the leaning object. A solid little pigeon that towers over you”.

Next Steps
Although it is evident that Low Hanging Fruit scores higher according to the WOT, it can be considered–both from a personal stance and target user group feedback, to also be the safest and most typical choice.

Considering 1) the higher novelty and potential of Lily of the Valley to score even higher than Low Hanging Fruit on the WOT, and 2) current criticism of Lily of the Valley relating primarily to aesthetic factors such as form and hue, the decision was made to further develop concept_2: Lily of the Valley in the following product design phase of the project.

(Qu, 2019)

6_0_0

Product Design

With the selection of a concept and completion of levels 1-3, this chapter outlines the refinement and embodiment of the concept into a final design and prototype, to be used in a final user evaluation and criticised for further redesign requirements and future recommendations.

6_1_0
Component Validation
CRL_4

6_1_1
Camera Dimensions

According to the identifie value of actual safety and its corresponding requirement AS_3, the eventual design has to be compatible with standard bullet camera design dimensions. The next logical step was therefore to determine these dimensions.

Bullet Cameras
As seen in the technical drawings of Fig. 36 and 37, bullet cameras come in a variety of shapes and sizes. Camera housing length and width (or diameter) were the most important dimensions to identify in ensuring design compatibility. Although width and diameter was found to be fairly regular at around 79-156.9mm, housing length ranged from a compact 244.1mm to a relatively long 485.5mm for bullet cameras with long range viewing and zooming capabilities. This range of lengths is further exaggerated by the excluding the mounting bracket from this total length (as seen in Fig. 37), reducing the minimum length to as little as 153.1mm.

Dome Cameras
Generally being a more spatially compact alternative to the bullet camera–excluding technical specifications, a look was also taken at the dimensions of dome cameras to explore additional compatibility options.

As seen in Fig. 38, the dimensions of a standard dome camera can easily fall within a 120mm^3 volume, with a width of 111mm and a height of 82.4mm. According to these dimensions, there is a realistic possibility for allow for standard dome camera compatability as well.

Modular Approach
Considering the dimensions for bullet cameras as the most influential drivers for the eventual design, a modular system can be adopted instead of a one-size-fits all approach. Thus, a version 1.0 can be designed–compatible to standard and compact bullet cameras (and potentially dome cameras) within L = 250mm and ø = 125mm, that can be modularly adapted to accommodate longer and more advanced bullet camera types.

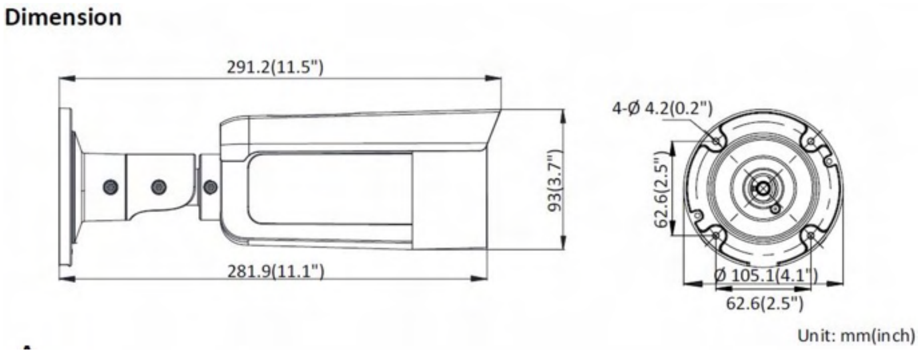


Fig. 36: Bullet Cam. Dimensions 1 (A1 Security Cameras, n.d.)
Technical drawings and dimensions of compact bullet camera design 1. Mounting bracket length is included in the total length.

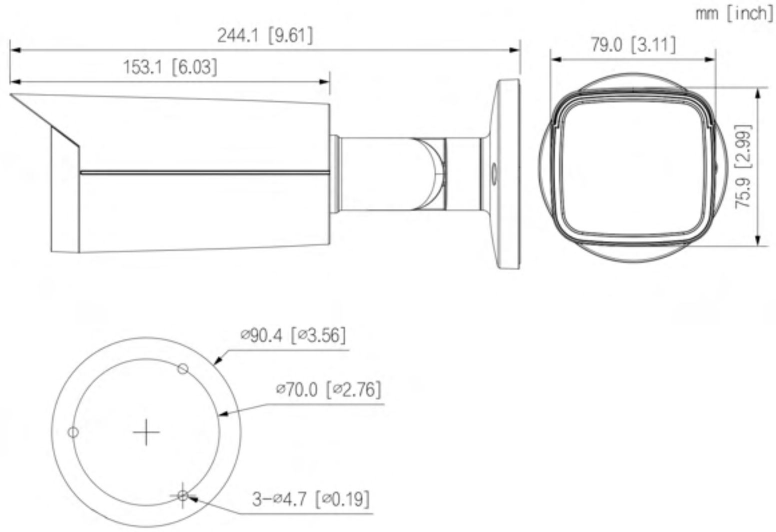


Fig. 37: Bullet Cam. Dimensions 2 (CCTV Kits, n.d.)
Technical drawings and dimensions of compact bullet camera design 2. Housing length is given at 153.1mm.

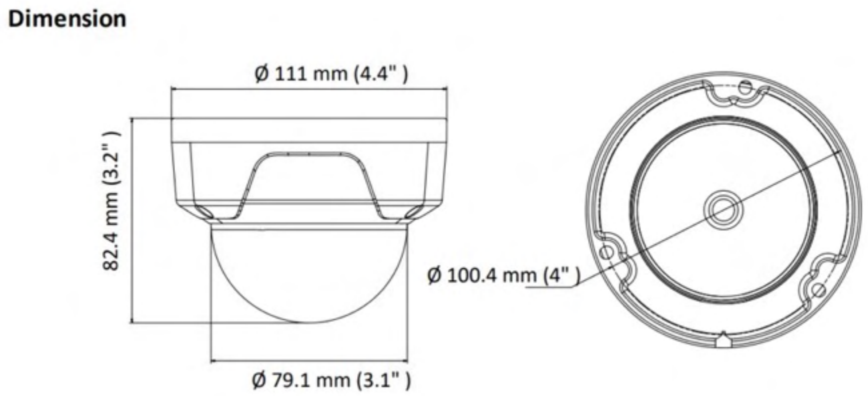


Fig. 38: Dome Cam. Dimensions 1 (CCTV Kits, n.d.)
Technical drawing and dimensions of a standard dome camera design, indicating high potential for compatibility, although not a requirement.

Fig. 39: Dome Cam. Dimensions 2
Personal study of the measurements and dimensions of a large dome camera, ~220mm height and ~180mm diameter.

Fig. 40: Blooming Flower Night
Night light designed by J. Suter (2023) to be easily 3D printed with minimal material and component costs.

6_1_2
Blooming Mechanism

To further realise the Lily of the Valley concept, a mechanism has to be developed to allow for the opening and closing of the 'petals' illustrated in the design. To complete this step, a 3 different 'blooming' mechanisms were analysed and evaluated.

Blooming Flower Night Light
The first of these mechanisms was designed by J. Suter (2023) as a night light that could easily be 3D printed recreationally with minimal material and component costs. The Blooming Flower Night Light uses a 5-petal configuration that envelops an LED lamp when closed (see Fig. 41). Each of these petals has 2 joints, 1 connected to the lower receptacle–which is directly connected to the other 4 petals. The second joint connects to a linkage that in turn is joined to a linkage star, which indirectly also connects to the other 4 petals. This linkage star is pushed upwards or pulled downwards by a push rod driven by a servo motor poisitioned in the base.

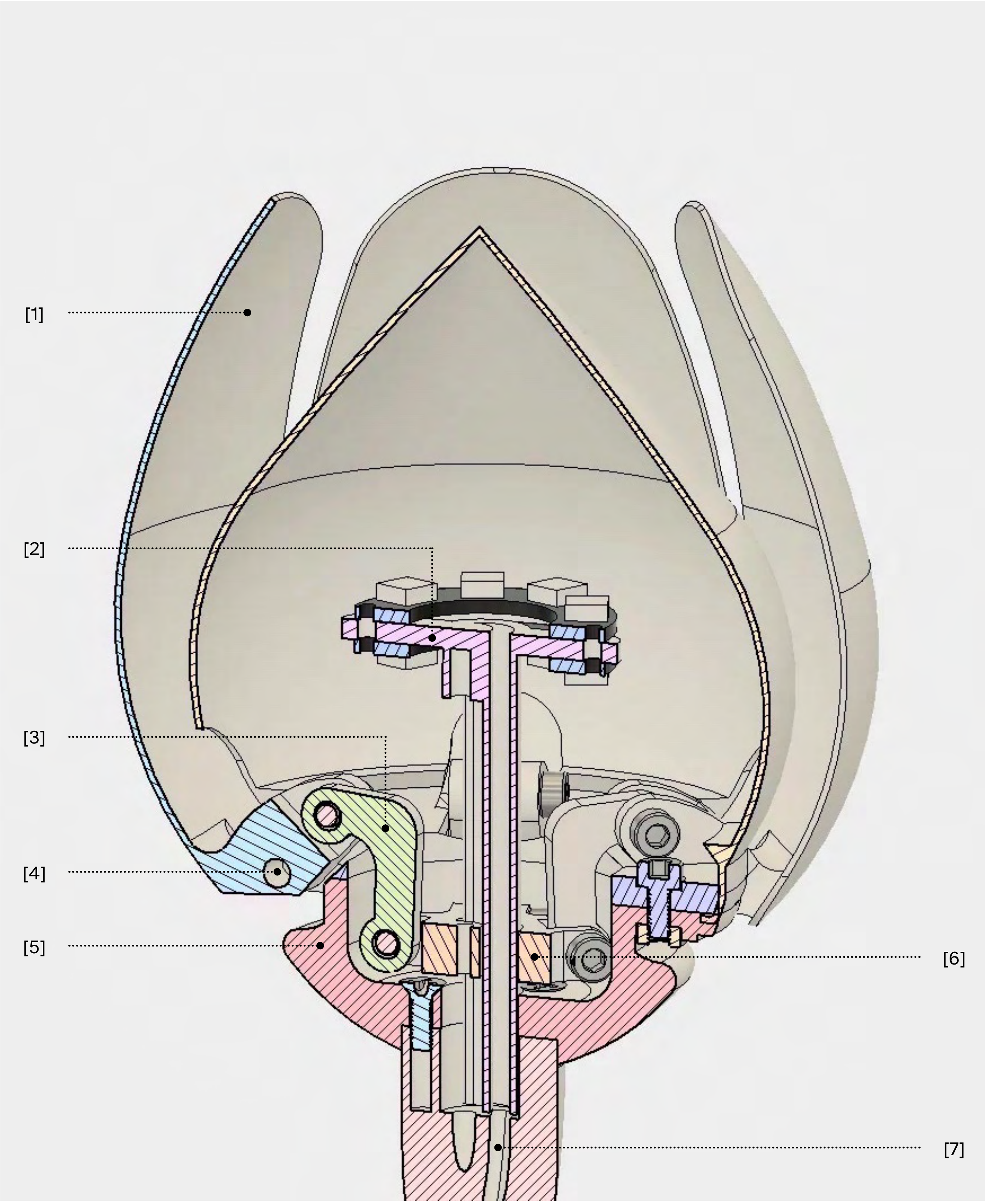


Fig. 41: Blooming Flower Night Light Mechanism, Section View (Suter, 2023)
Petals [1] are connected to the lower receptable [5] and a linkage star [6], which mechanically opens the petals through the use of a push rod.

[1] Petal
[2] LED attachment ring
[3] Petal linkage
[4] Petal pivot joint
[5] Lower receptacle
[6] Linkage star
[7] Wiring tunnel

Fig. 42: Blooming Flower Night Light, Deconstructed View (Suter, 2023)
Previously labelled parts [1-7] of the blooming mechanism alongside other parts of the night light.

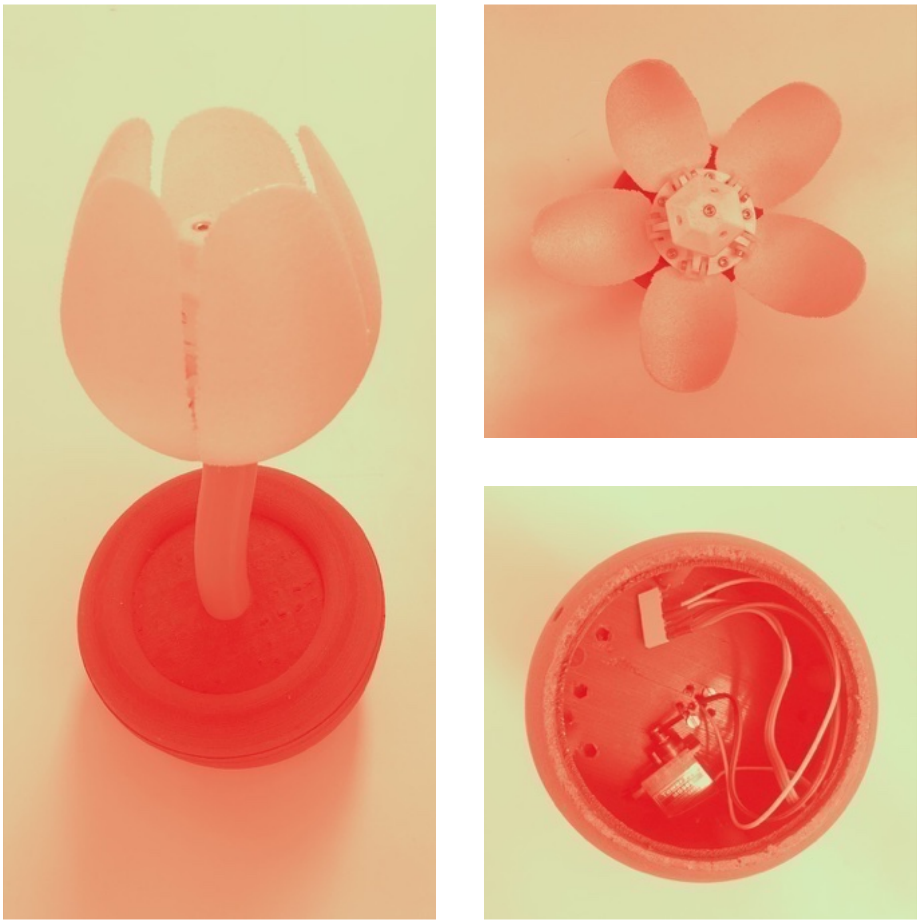


Fig. 43: Blooming Flower Night Light, 3D Printed Prototype
Detail shots of the night light in a closed state (left), open state (top right) and its electrical wiring and servo actuator (bottom right).

The Flower Box

The Flower Box–a 3D-printable designed by a Youtuber under the name of ‘JL2579’ (2019), uses an iris mechanism to open and close a container (see Fig. 44). Additionally, the Flower Box mechanism is specifically designed to resemble the shape of a flower when opened, with each iris blade resembling an individual petal. In this way, the ‘blooming’ mechanism is as compact as possible, while still respecting the metaphor of a flower.

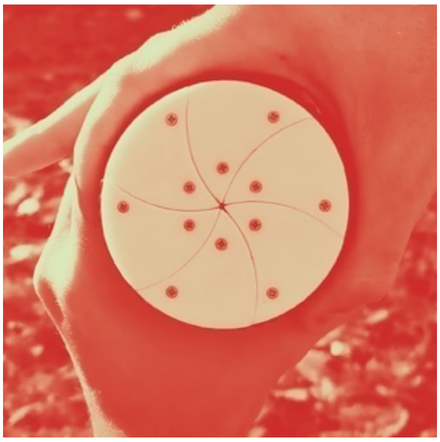


Fig. 44: The Flower Box, Iris Mechanism (JL2579, 2019)
An iris mechanism resembling the shape of a flower when opened.

Fig. 45: Robotic Flower, Finished Look
Robotic Flower unfolding as a finished, realistic-looking flower.

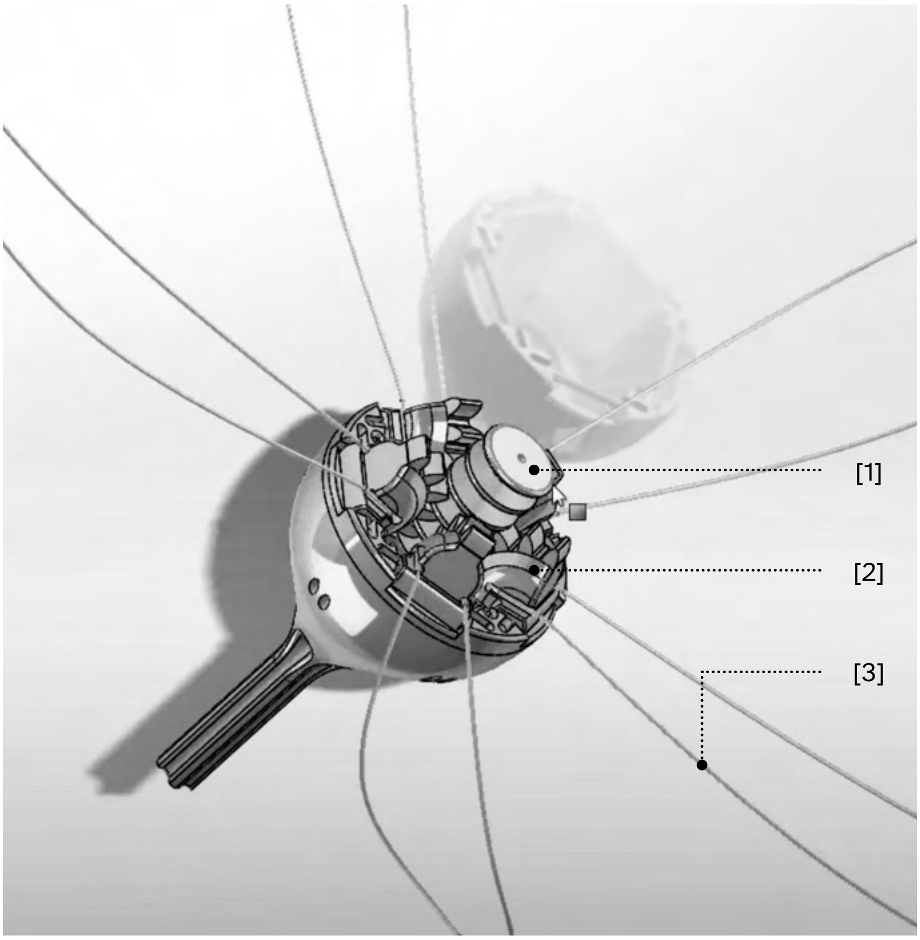


Fig. 46: Robotic Flower, Rack and Pinion Gear Mechanism (Leo's Bag of Tricks, 2021)
Petals [3] attached to pinion gears [2], in turn connected to a central, cylindrical rack gear [1].

Robotic Flower

The last mechanism type that was explored–named the 'Robotic Flower', is designed by yet another Youtuber by the name of 'Leo's Bag of Tricks' (2021). In this compact and realistic flower design depicted in Fig. 46, a rack and pinion gear system is employed to open and close. Similarly to the Blooming Flower Night Stand, a servo motor and a push rod are once again used to drive the rack gear upwards, thereby rotating the 5 pinion gears and opening up the petals as a result. Electrical wiring for LED lighting can be applied through a tube running inside the rack gear.

Tab. 14: Harms & Benefits, Blooming Mechanisms
Identified harms and benefits for each of the analysed blooming mechamisms.

Mechanism	Benefits	Harms
Blooming Flower Night Light	+ Able to encase camera + Visually resembles a flower + High petal ROM + Space for camera wiring	- Actuator not in flower - Linkages difficult to optimise - Can only be actuated linearly
The Flower Box	+ High feasibility + Compact design	- Limited aesthetic impact - Limited novelty - Flower-form not obvious - No actuator included
Robotic Flower	+ Able to encase camera + Visually resembles a flower + High petal ROM + Space for camera wiring + Linear and rotational actuation possible	- Actuator not in flower

Mechanism Evaluation
Upon analysing the 3 different 'blooming' mechanisms, it becomes clear that the Blooming Flower Night Light and the Robotic Flower are very similar in their working principles. On the other hand, the Flower Box provides a less novel and more typical alternative, although not groundbreaking or even aesthetically impactful in its design.

When finally considering the ability to actuate the blooming mechanism both rotationally (through a pinion gear) and linearly (through the rack gear), the Robotic Flower becomes an easy choice for further development and implementation into the design.

6_1_3
Pinion Gear Optimisation

With the choice of a rack and pinion gear system for the blooming mechanism, this system would have to be adjusted and tailored to meet the needs and requirements of the design direction.

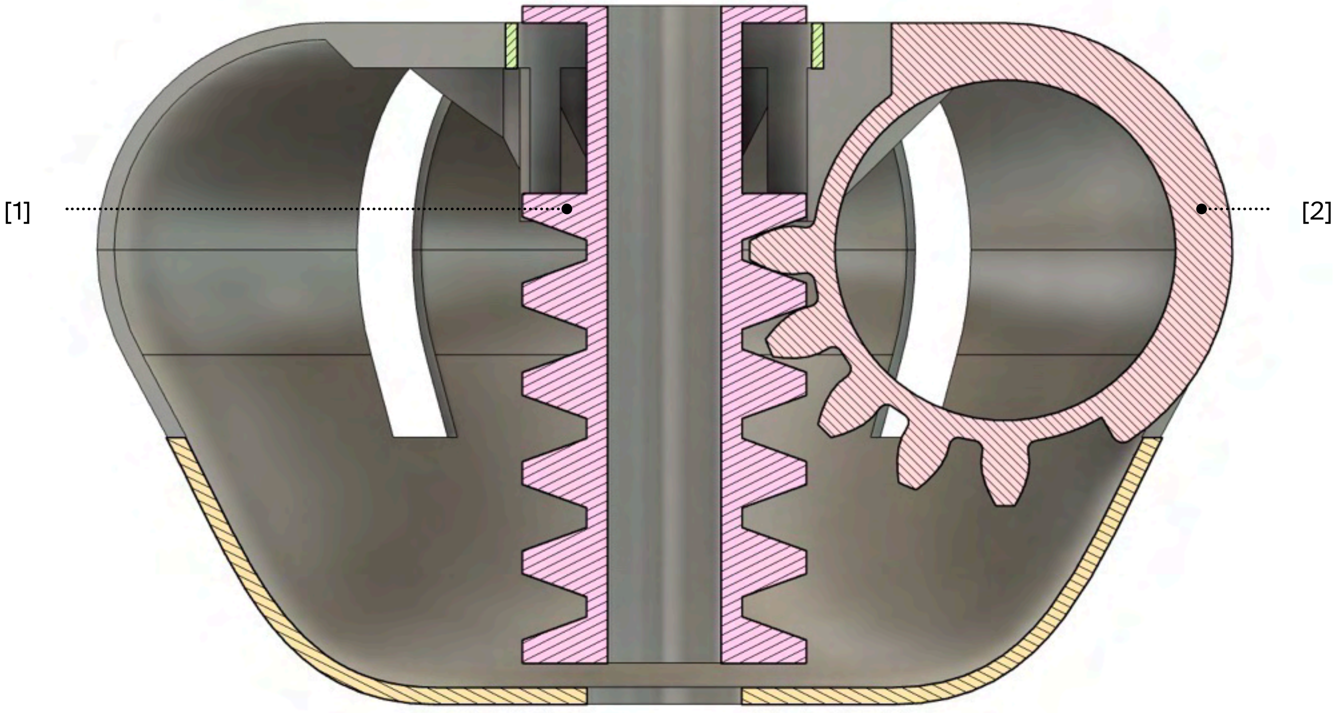
1 Rack, 6 Pinions
Ordinary rack and pinion gear systems usually consist of a 2-dimensional rack (in terms of profile) and a single pinion gear which usually drives the rack to convert rotational motion to linear motion. As can be seen with the Robotic Flower, the gear system would have to be adjusted to be able to integrate 6 separate pinion gears–each attached to an individual petal, connected to a 3-dimensional or cylindrical rack gear (see Fig. 47). The choice for 6 petals was determined through design inspiration and a preference for rotational symmetry, which eases the design phase significantly in comparison a 5-petal flower design.

Gear Setup
For the same reason, the rack gear was placed in 'inside' the 6 pinion gears surrounding it (see Fig. 48), instead of placing the 6 pinion gears in the middle to connect with a wider, surrounding, cylindrical rack gear with its gear teeth on the inside. Although a viable alternative, this set-up is higher in complexity and lacked ideation for how it would be actuated.

Gear Parameters
Aside from the gear number and setup, the individual gears themselves had to be optimised, too. The most efficient way to do this was to determine the parameters for the pinion gear first–as these are often standardised, and adjust the rack gear parameters accordingly. Complying with these industry standards, the gear pressure angle was set to 20°, backlash was kept at 0.00mm and the root fillet radius remained 1.588mm. Gear thickness and hole diameter were adjusted from 12.70mm to 12 and 6mm, respectively, allowing for a more compact design. Considering only 1/4 of the gear teeth would be used for the petals to unfold a maximum of 90°, tooth count would have to be a multiple of 4, starting at 16 teeth (as was the case with Robotic Flower). In the end, the choice for 16 teeth was made to maximise torque transmission to the rack gear and the attached camera unit.

Petal Unfolding Limit
A final consideration to make concerned the petal unfolding limit of the gear system. This was determined to be 90°, requiring the pinion gear to only have 5 teeth to interlock with the rack gear. Based on this unfolding limit, the initial shape of the housing for the gear system could be determined, as seen in the cross section in Fig. 47.

Fig. 47: Rack and Pinion Gear System, Y-Z Cross Section
Cylindrical rack gear [1] connected to 1 of 6 total pinion gears [2].



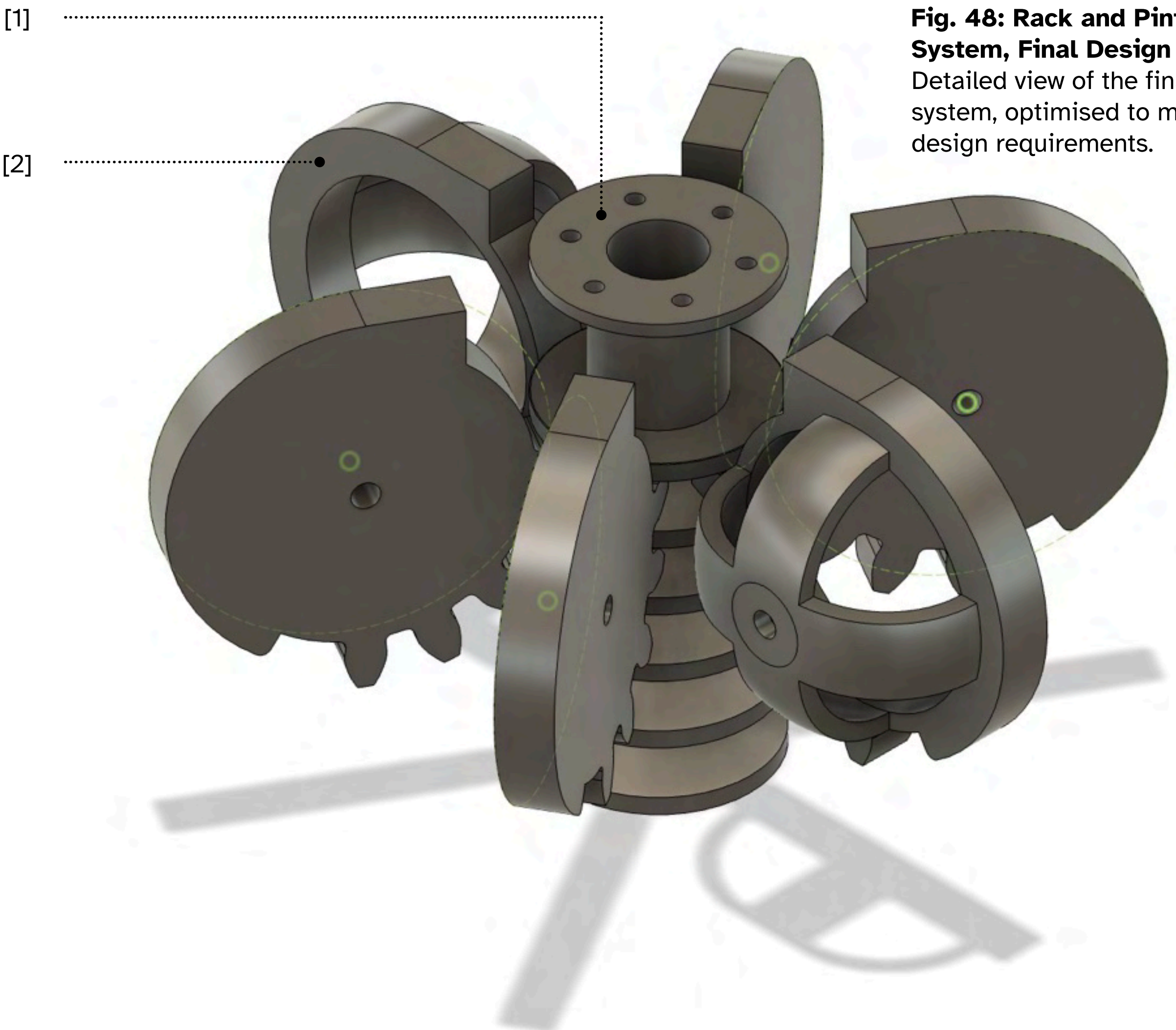


Fig. 48: Rack and Pinion Gear System, Final Design
Detailed view of the finalised gear system, optimised to meet all design requirements.

6_1_4
Actuator Integration

Rotational Actuation

A major question to address– and one on which the choice for a rack and pinion gear system was ultimately based, was the question of how the whole mechanism would ultimately be actuated. Using a rack and pinion gear system, the following 2 options existed to actuate the blooming mechanism:

1. The rack gear could drive the pinion gears, requiring linear actuation.
2. The pinion gear(s) could drive the rack gear, requiring rotational actuation.

Of these 2 options, rotational motion is significantly easier to actuate in terms of both simplicity and cost. Linear motion would either require the use of relative large, electric hydraulic pumps, or yet another rack and pinion gear system. The latter option would mean unnecessarily and inefficiently converting rotational to linear motion of the rack gear, to then ultimately convert to rotational motion again by spinning the pinion gears. For this reason, the choice was made to actuate 2 opposing pinion gears (to ensure symmetrical loading and redundancy).

These pinion gears were then modified to connect to the eventual actuators in a more spatially efficient manner as can be seen in Fig. 49, preventing the driven pinion gears and actuators from taking up significantly more space than the undriven pinion gears within the blooming mechanism.

Actuator Choice

Having settled on rotational acutation of 2 pinion gears. A choice would have to made regarding the type of rotational actuator, or motor. This choice came down to 3 options: 1) a DC motor, 2) a servo motor and 3) a stepper motor.

DC (direct current) motors excell at high rotations per minute (RPM) and are widely used for applications such as computer cooling fans or RC cars (Hut, 2019). As this is neither a requirement nor a desirable property for the final design, this option was quickly ruled out.

Next, servo motors were considered as an actuator option. In line with the design needs, servo motors are designed to hold a specific position or rotation, with the maximum resistive force depending on the servo motor's torque rating. Rotation is not continuous and limited at 180°, which is more than enough for the 90° maximum pinion gear rotation of the petal unfolding limit.

Finally, stepper motors have most of the positive attributes of servo motors, while also allowing for continuous motion (although irrelevant for this design) and continuously maintaining a holding torque without the need of a power supply. Additionally, stepper motors are designed to prevent potential positioning errors, which is a crucial benefit to the blooming mechanism of the design. For these reasons, a stepper motor was ultimately chosen as actuator.

Fig. 49: Rack and Pinion Gear System, X-Y Cross Section
NEMA17 stepper motor [3] inside modified pinion gear [4].

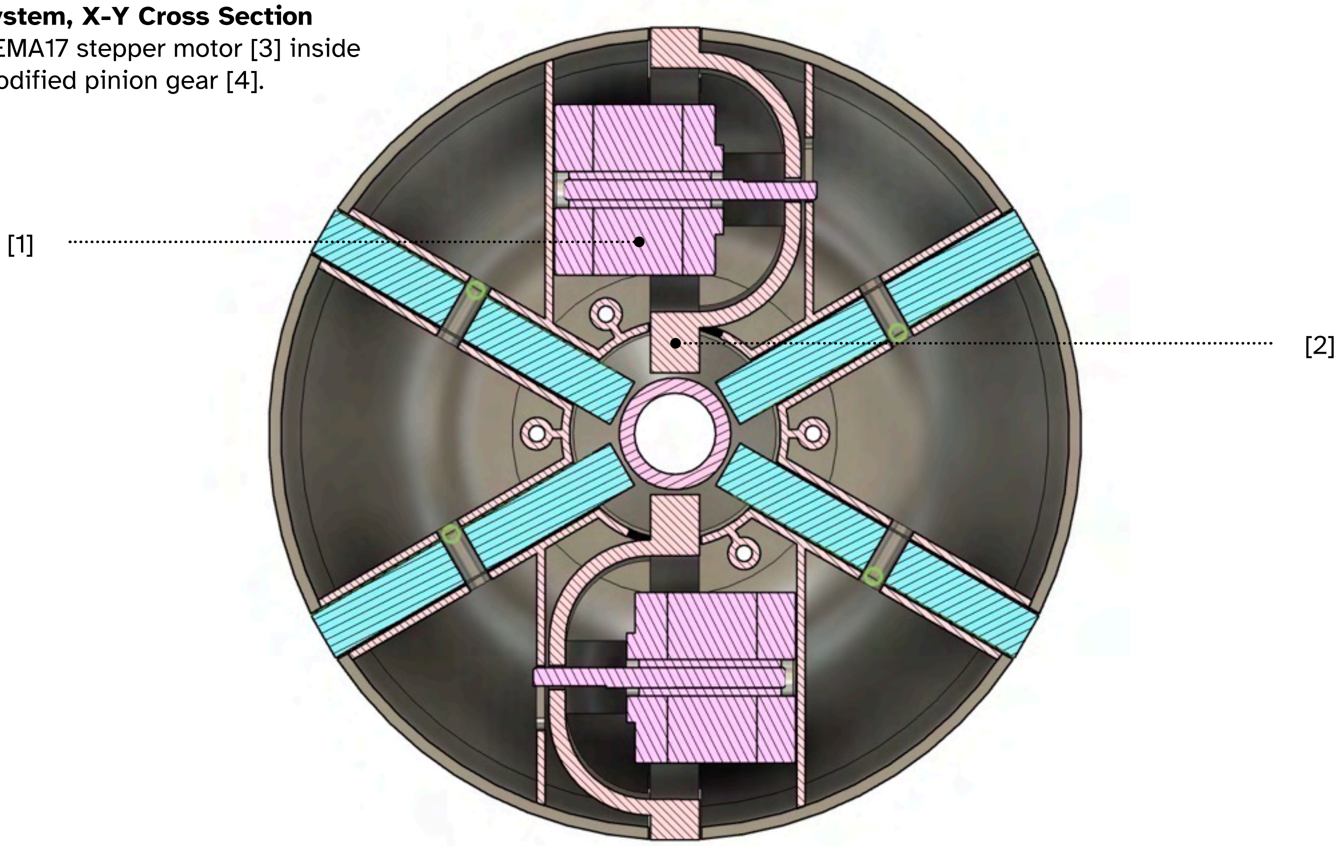
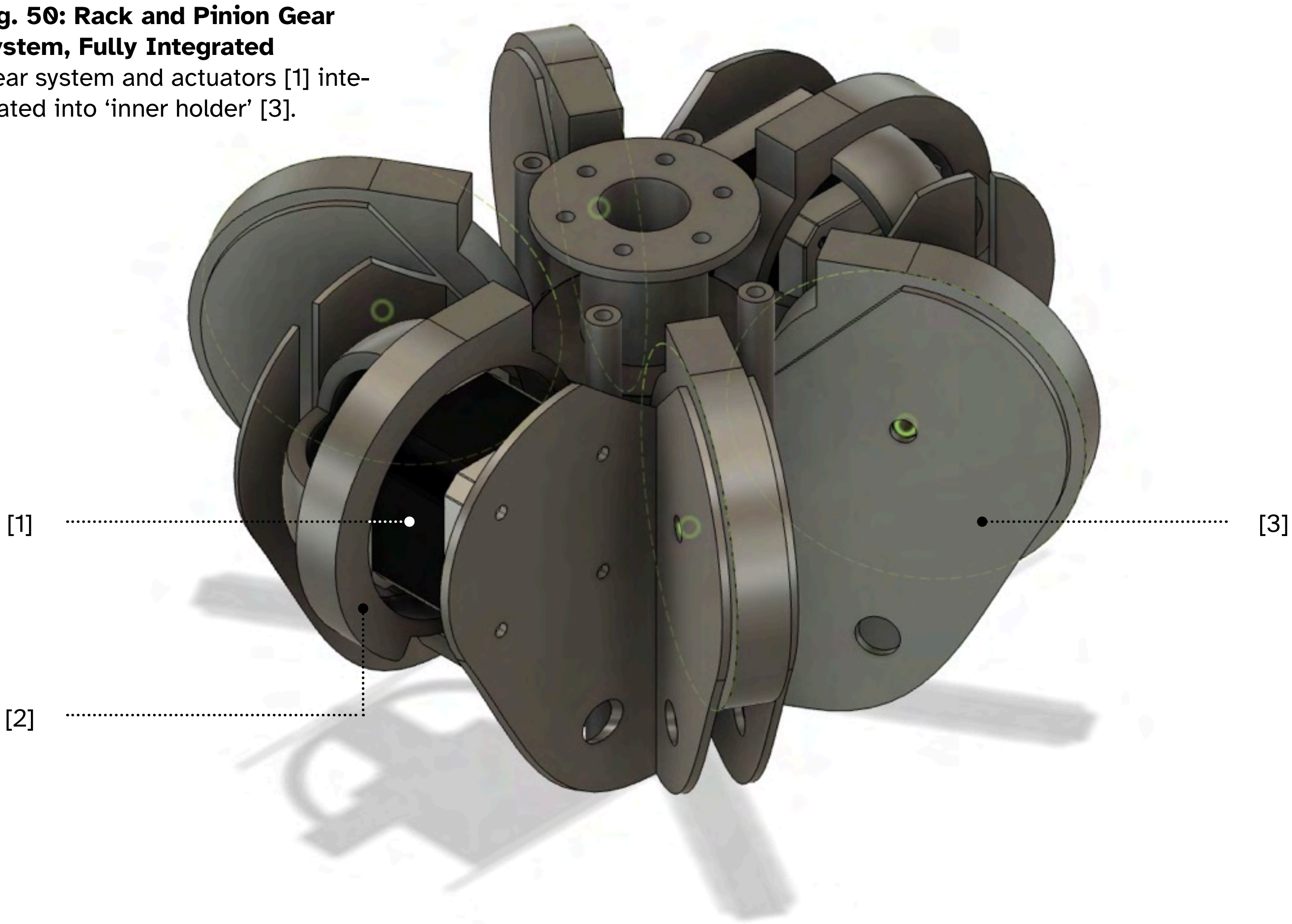


Fig. 50: Rack and Pinion Gear System, Fully Integrated
Gear system and actuators [1] integrated into 'inner holder' [3].



6_2_0
Simulated Validation
CRL_5

6_2_1
Petal Design

Basing the form of the flower 'bulb' (petals in a closed position) from the dimensions of the dome and bullet cameras in section 6_1_1, the simplest possible petal design could be created, as depicted at the top of Fig. 52. Using this petal as a template, more advanced petal designs were developed.

Here, inspiration was once again taken from nature. A Voronoi-patterned petal (left in Fig. 51) was the first of these design experiments, followed by traight- and curved-ribbon petal designs. A visual evaluation determined that the curved-ribbon petal design (right in Fig. 51) corresponded most with the Mood Board in section 5_1_5.

Fig. 51: Petal Designs
Voronoi (left) and curved-ribbon (right) designs for an individual petal, of which there are 6 in total.

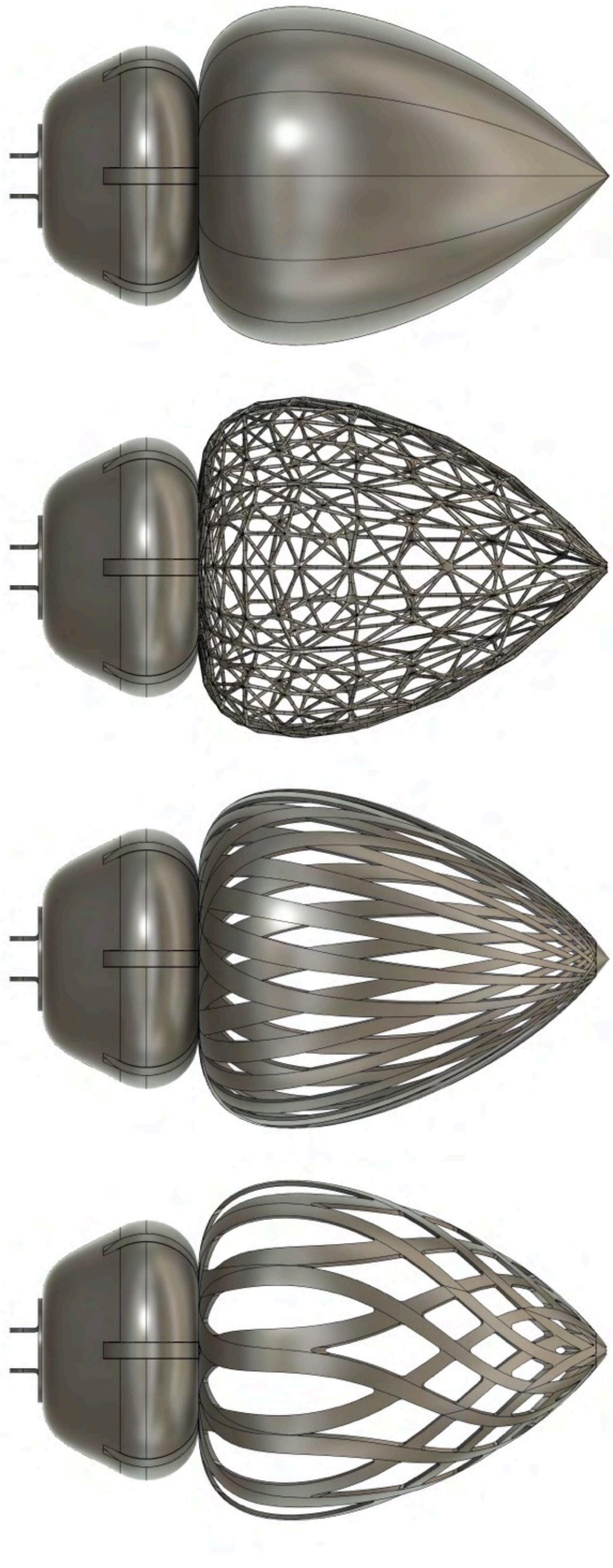


Fig. 52: ‘Bulb’ Designs
Simple, Voronoi, straight-ribbon and curved-ribbon petal designs when camera is in closed state.

6_2_2
Mechanical Prototype

Goal
In line with level_5 of the TRL scale, the ‘technology’ of the blooming mechanism and its components–namely the rack and pinion gears, needed to be validated as a design. In order to do so, a 0.5x scale mechanical prototype was constructed in the Model Making and Machine Lab (PMB) at the faculty of Industrial Design Engineering at TU Delft.

Due to their prismic form, the 6 pinion gears could easily be laser cut from 5mm plywood. The remaining housing and internal components were 3D printed from PLA or PETG, depending on availability.

Insights
Using foam to represent the volume of 2 NEMA17 stepper motors and metal wiring as a joining method between the inner ‘holder’ (see Fig. 54) and the 6 pinion gears, the rack and pinion gear systen and overall blooming mechanism was demonstrated to work as intended, allowing for the pinion gears–and by extension the petals, to rotate a full 90° as seen in Fig. 55.

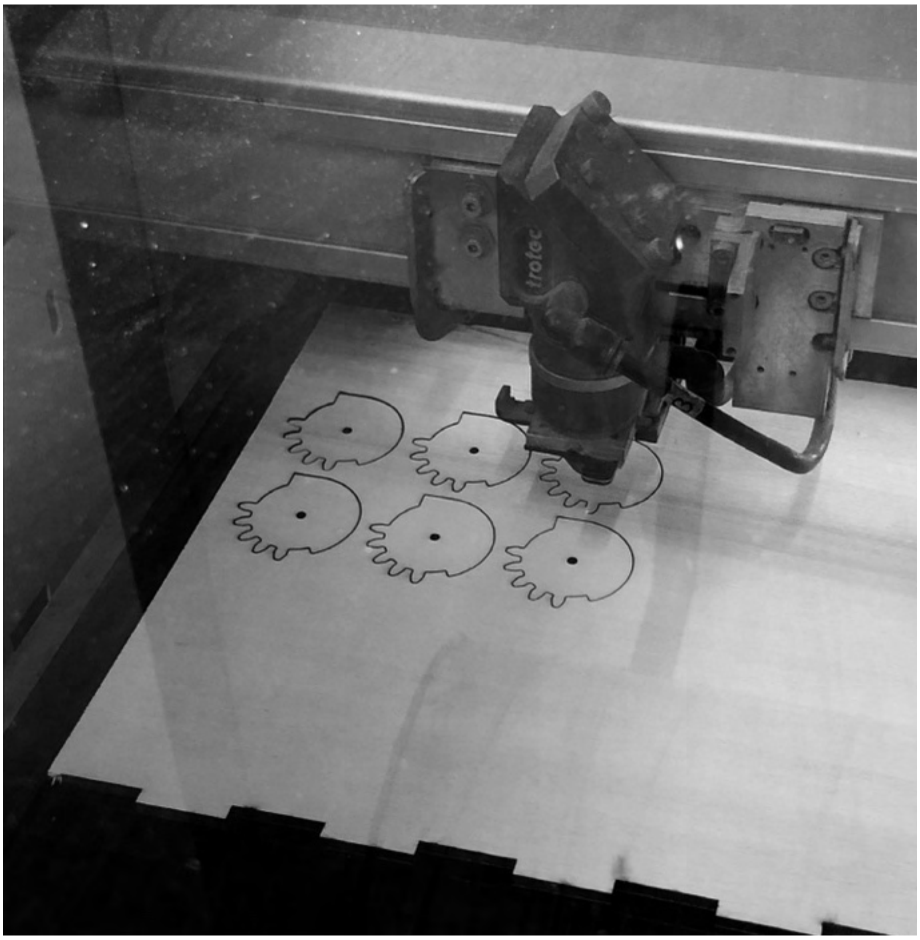


Fig. 53: Laser Cutting Pinion Gears
Pinion gears laser cut from 5mm plywood to be used for testing the mechanical prototype.

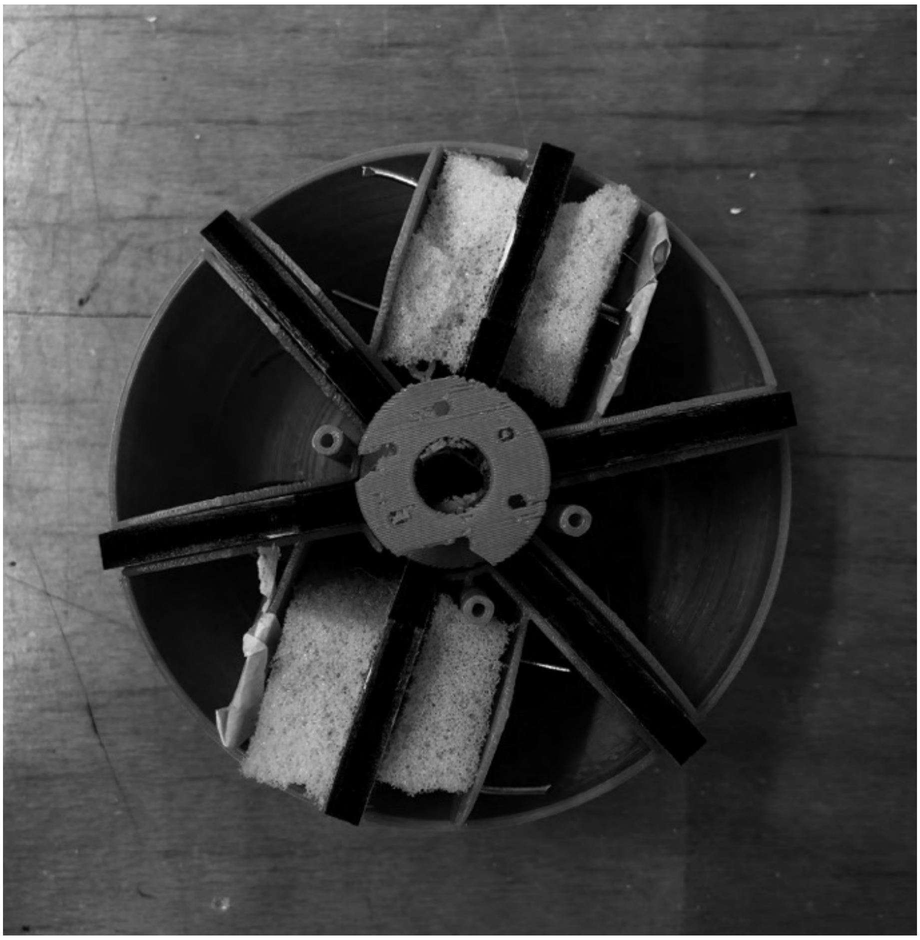


Fig. 54: Rack and Pinion Gear System Assembly
The rack and pinion gear system secured with metal wiring and assembled into the lower 'holder' housing.

Fig. 55: Blooming Mechanism Test
The full blooming mechanism, encased within the inner, lower and upper 'holders', tested for full range of motion.

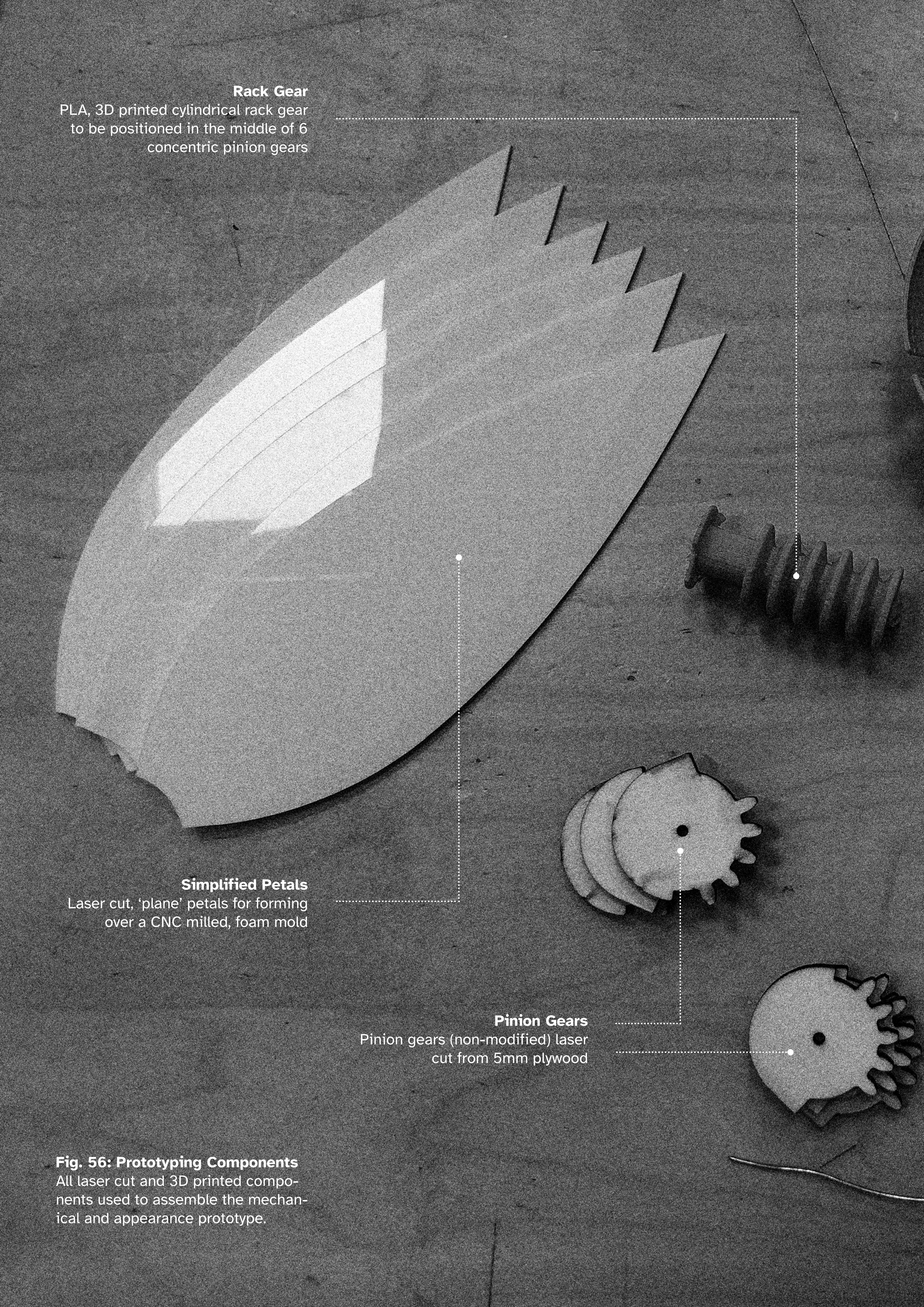


Fig. 56: Prototyping Components
All laser cut and 3D printed components used to assemble the mechanical and appearance prototype.


Lower Holder
PETG, 3D printed bottom part of the mechanism housing, or ‘lower holder’
Inner Holder
PETG, 3D printed inner frame, providing structural suppor to the upper and lower holder and securing the rack and pinion gears in place
Upper Holder
PLA, 3D printed top part of the mechanism housing, or ‘upper holder’
Gear Joints
Metal wire used to secure the pinion gears to the inner holder.

6_2_3
Appearance Prototype

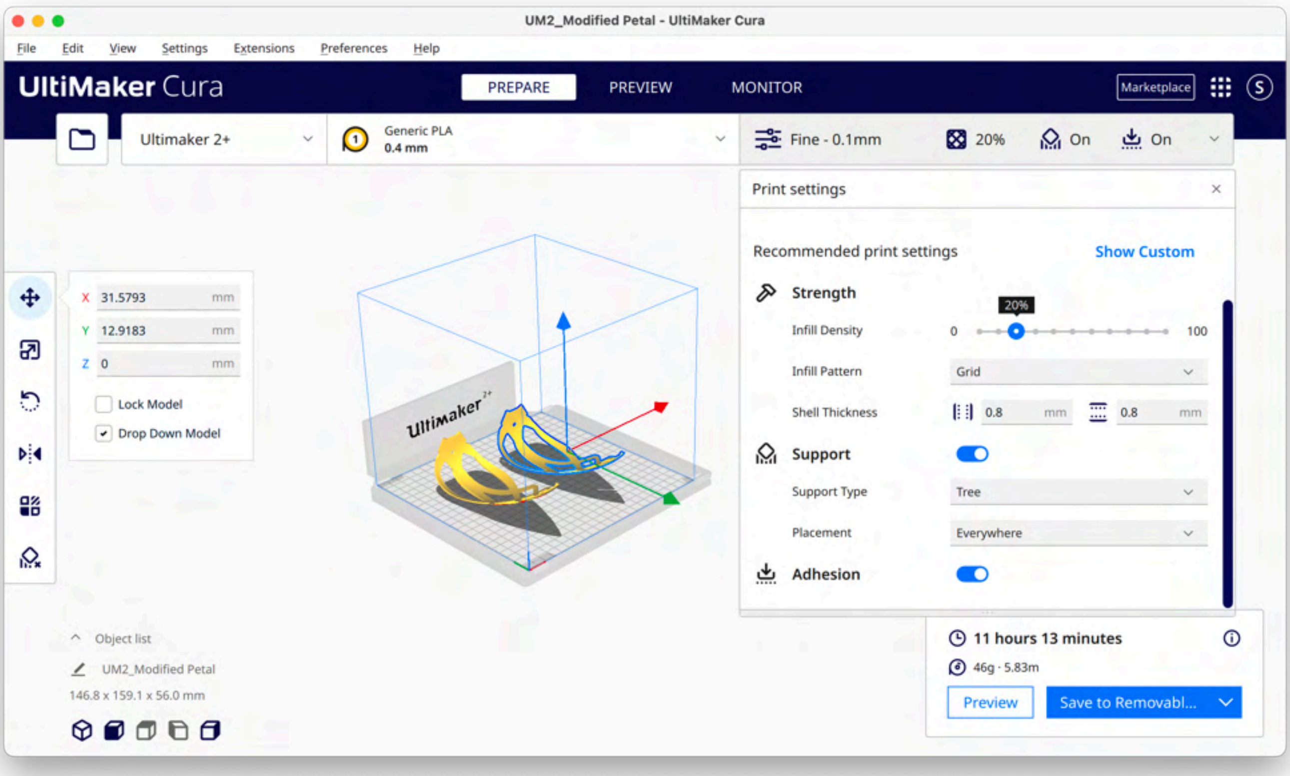
Fig. 57: UltiMaker Cura
2 Petals at 0.5x scale, 0.1 mm nozzle setting, 20% infill density and 'tree' support positioned to be 3D-printed using Ultimaker Cura.

Goal
Following the success of the mechanical prototype, the 0.5x components could subsequently be used for the creation of an appearance prototype to be used in the upcoming Product Usability Evaluation. The main component that remained to be prototyped were the petals, which also happened to be the most complicated parts to replicate.

For the petals, the initial plan was to once again use the UltiMaker 2+ as 3D printer, which were readily available at the PMB lab. Using Ultimaker Cura, the petals were positioned such that the printing time and necessary support structure were minimised.

Complications
Unfortunately, even in this 'optimised' position, the support structure proved too difficult to remove, further complicated by the fragile nature of the petals. Furthermore, removing the support structure revealed revealed surface imperfection which were inaccurate to the design.

A second plan was made in which the petals would be simplified, laser cut and thermoformed over a mold, CNC milled out of foam. Even so, clear imperfections remained in the symmetry and shape of the petals, severely limiting the appearance prototype from accurately representing the final design.



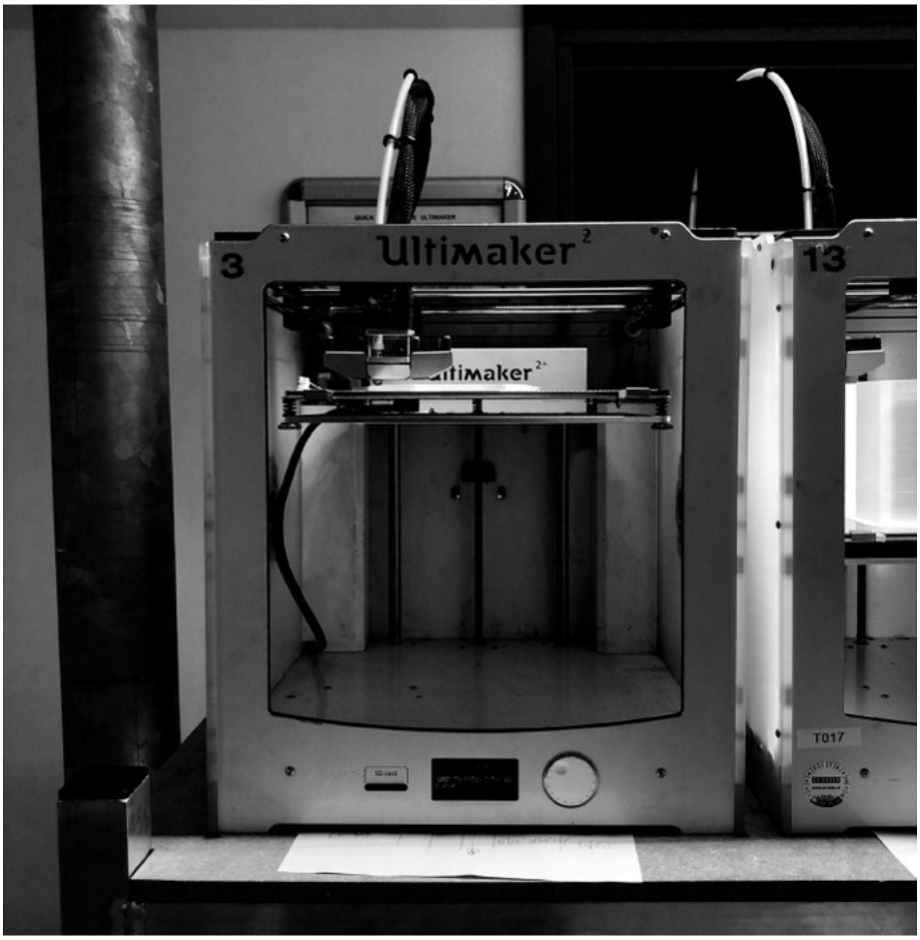


Fig. 58: UltiMaker 2+ 3D Printer
The UltiMaker 2+ with a 342x460 x580 mm volume was used to 3D print the petals at 0.5x scale using PLA filament.

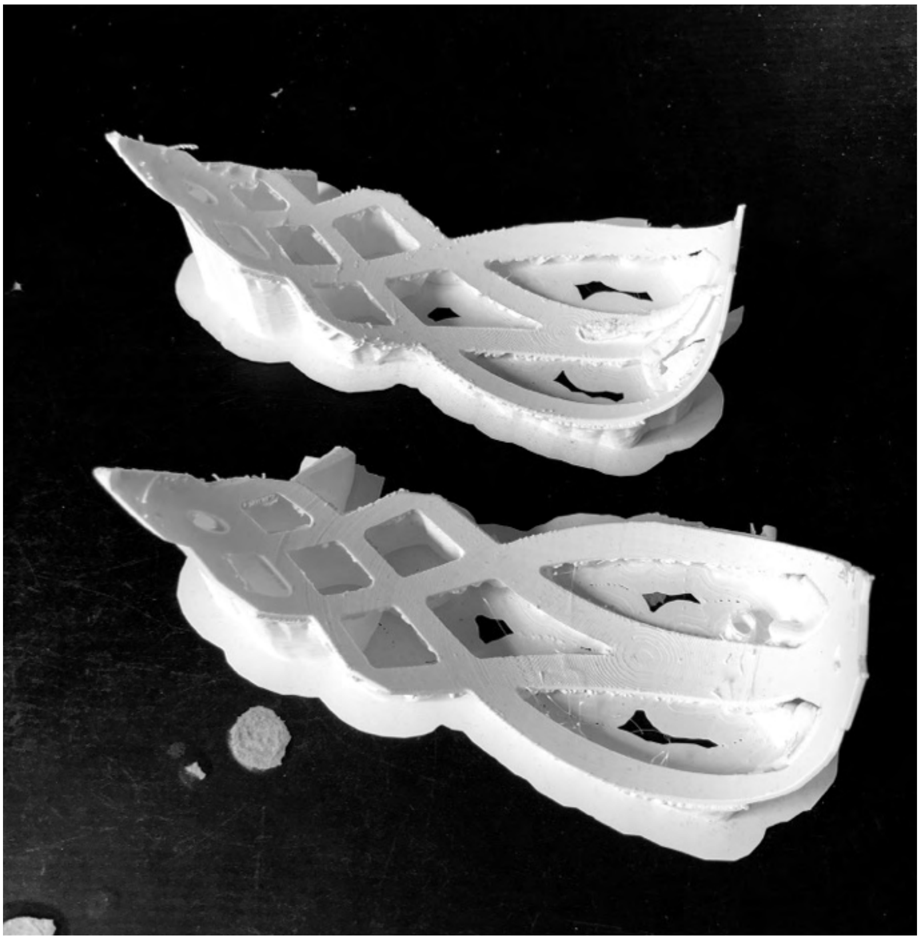


Fig. 59: 3D Printed Petals
The selected curved-ribbon petals 3D printed from PLA filament, proving very complicated to separate from the 'tree' support structure.

Fig. 60: Thermoforming
Laser cut, ‘plane’ petals, selected for ease of prototyping, thermoformed over a CNC milled, foam ‘bulb’ mold using a heat gun.

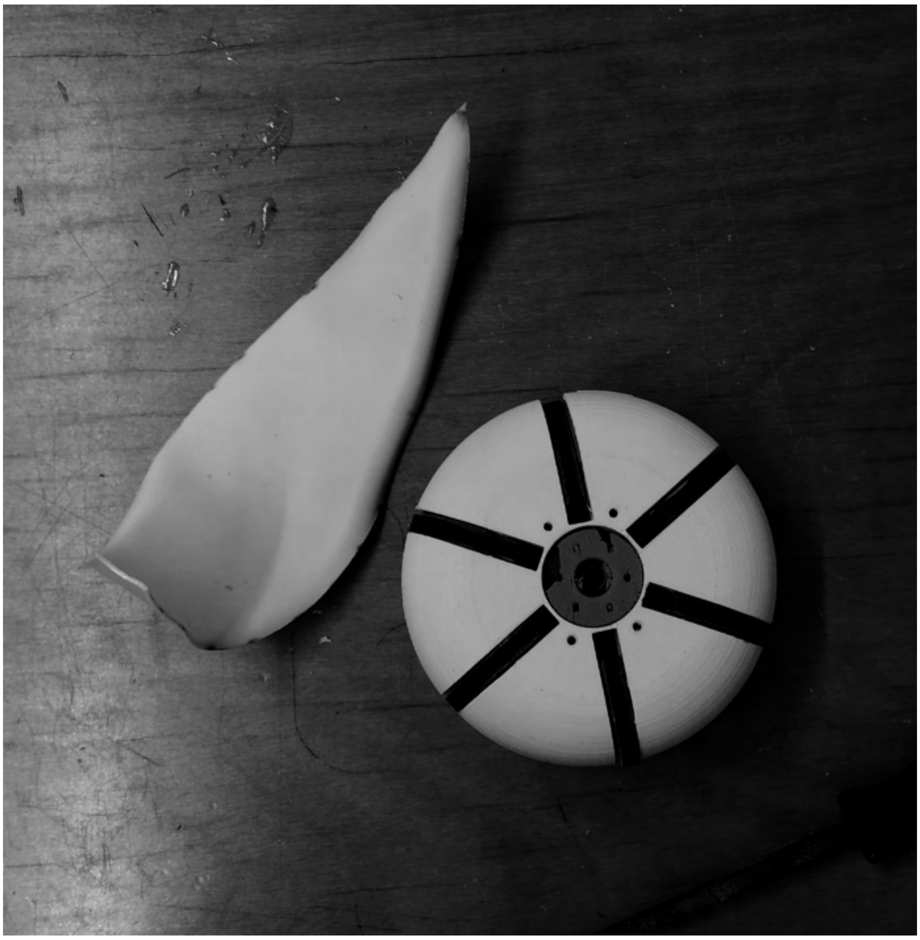


Fig. 61: Thermoformed Petal and Mechanism Assembly
End result of a thermoformed petal next to the rack and pinion gear system assembly at 0.5x scale.

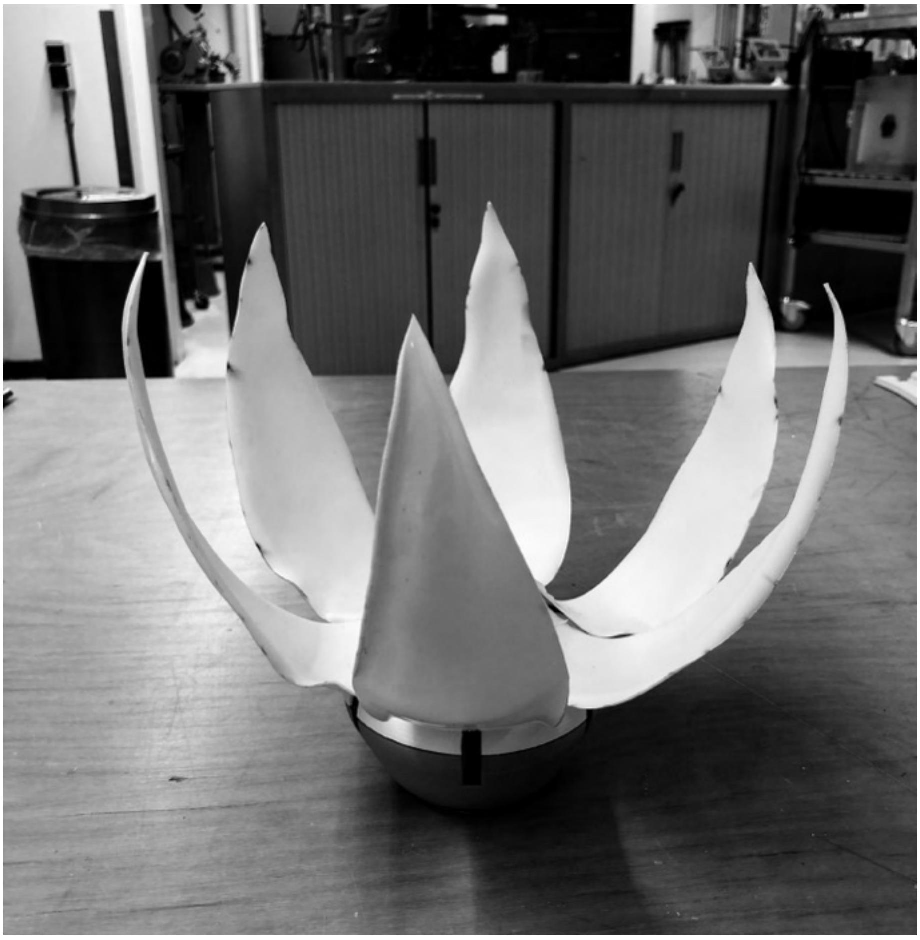


Fig. 62: Appearance Prototype, Side View
Final appearance prototype at 0.5x scale, with simplified petals at a fixed ~45° position.

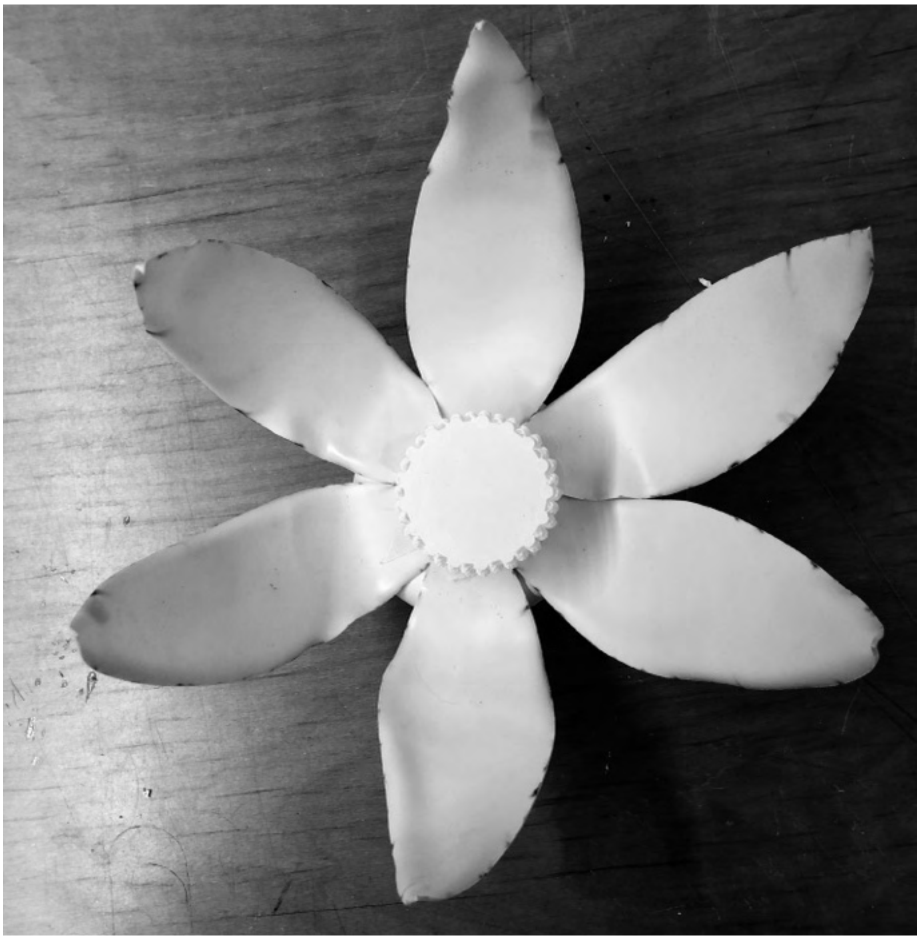


Fig. 63: Appearance Prototype, Top View
Final appearance prototype at 0.5x scale, with simplified petals fixed at ~45°, with thermoforming imperfections and asymmetry clearly visible.

6_2_4
Product Usability Evaluation

Having development of concept_2 into a mechanical- and appearance prototype, 3 key areas remained to be validated: 1) colour choice and 2) petal design–referring to the aesthetic factors of hue and form, respectively, and 3) contribution towards perceived safety–the principal value of this design project. These aspects of the design would be evaluated in a Product Usability Evaluation (PUE).

Participants
Combining the benefits of convenience–and representational sampling, a sample of 3 previous co-creation participants was used alongside a sample of 3 members of the Target User Group with no previous involvement in the project, for a total sample of n = 6, as seen in Tab. 15.

Appearance Prototype
Having verified the blooming mechanism and the rack and pinion gear system with the mechanical prototype, the initial plan was for the appearance prototype to play a crucial role in the PUE. However, considering the challenges associated with the appearance prototype, its representation of the final design (seen in Fig. 64) was limited. It was therefore decided to use it in support of 2D renders and an animation of the final design.

Process
The PUE participants were initially probed with general questions relating to their perceptions of safety and experience of public spaces. Product renders (see Fig. 64) and the appearance prototype were shown to the participants with PrEmo as a tool to assist in expressing and evoking a range of emotions. Participants were encouraged to ‘think out loud’ and to express any criticism they may have with the aim of preventing excessive ‘politeness’ to the main researcher. Based on initial observations and this participant feedback, an informal interview followed to ask follow-up questions.

Tab. 15: PUE Participant Demographics
The PUE sample consisted of participants from the co-creation session as well as from the TUG, without prior involvement in the project.

Sample	Participant	Age	Nationality	City of Residence
Co-Creation	PUEP_1	24	Dutch	Rotterdam
	PUEP_2	24	Dutch	Amsterdam
	PUEP_3	22	British	Loughborough
Target User Group	PUEP_4	24	Dutch	Amsterdam
	PUEP_5	23	Dutch	The Hague
	PUEP_6	24	Dutch	Delft

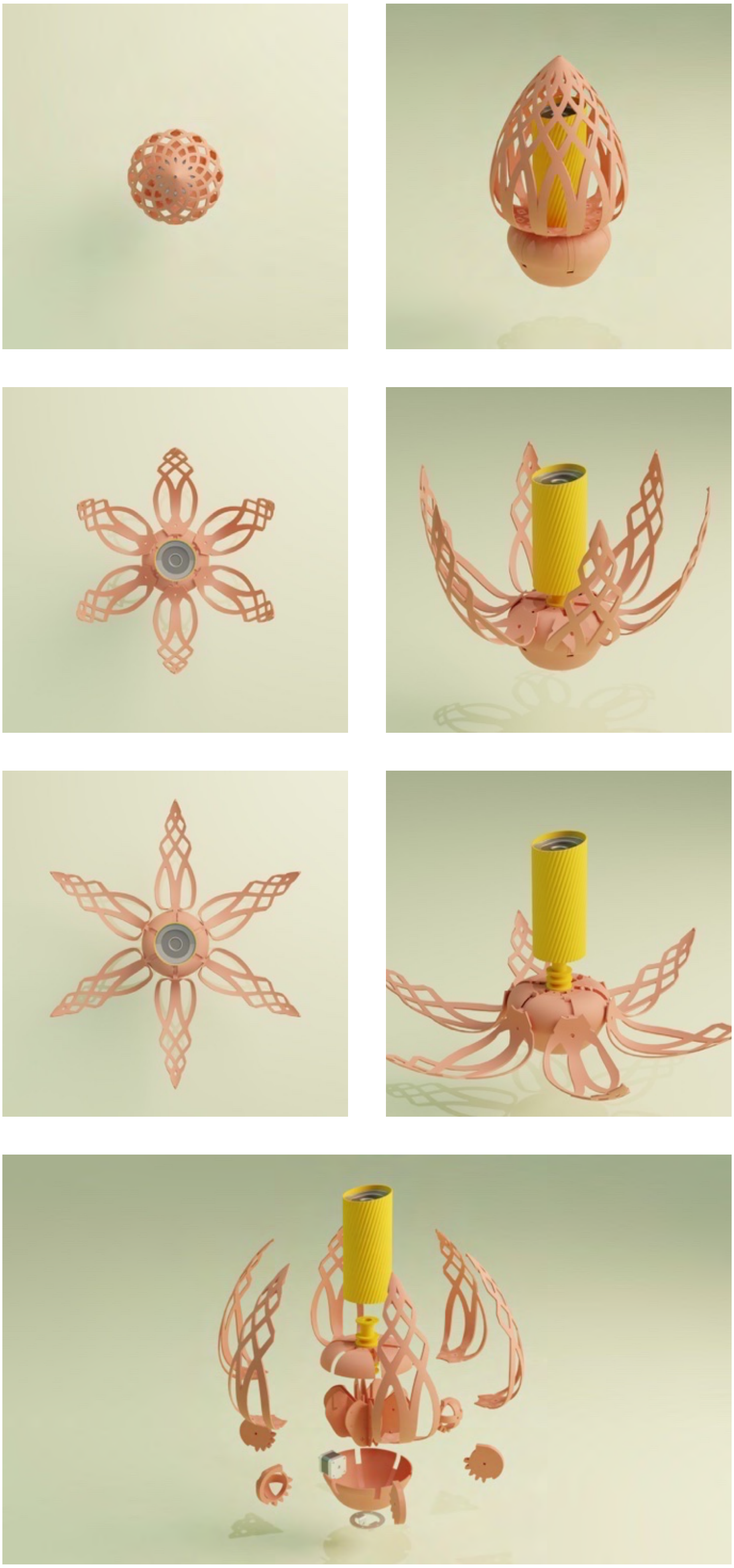


Fig. 64: Product Renders
Renders of the 3D Model used for the Product Usability Evaluation, supported by the appearance prototype.

Colour Choice
The choice of the 2 colours used–specifically their combination, proved to be somewhat controversial among participants. For PUEP_1 and 5, the pastel colours expressed "calmness, softness, inclusiveness" and prevented an "intimidating" look. PUEP_1 stated that she liked the "brighter" colour of the encased camera module, which was backed up by PUEP_6 and 3, stating respectively that the colour is "immediately noticeable" and that it is "appropriate, as it relates to safety measures".

On the other hand, PUEP_3 mentioned that the "peachy colour might be too feminine", suggesting a dark orange instead. PUEP_2 suggested a similar colour choice, expressing that the pink makes the colour contrast too low. Furthermore, she associated the "citrus" colour of the camera module with a toilet brush holder, partially due to its colour. PUEP_4 similarly suggested a different colour for the camera module, opting for a softer pink.

Petal Design
In line with the natural inspiration for the design aesthetics of the desing, the theme of 'citrus fruit' recurred when participants were asked about the petal design. Here, PUEP_1 associated the form of the closed petals with a citrus press, contrasting with the "unfinished cylinder" of the camera module. PUEP_2 expressed an identical sentiment; she liked the textural 'ribs' but would prefer a 'rounder' form.

The petals themselves had mixed reviews. Both PUEP_3 and 5 liked the "not overly 'flowerly'" form of the petals in a 0° and 90° position. However, PUEP_2 and 3 thought the petals looked "pointy" at 45°, and–according to both PUEP_3 and 6, reminiscent of a "Demogorgon" from the popular Netflix show 'Stranger Things' (see Fig. 65.). Interestingly, an identical association was made by the project supervisor prior to the evaluation. This was reinforced by PUEP_5 and 6 who shared further associations with a "spider" and even slight trypophobia.

On the positive side, PUEP_3 expressed that she interpreted the contrast in form between camera and petals, to make the camera presence more obvious to potential offenders. According to PUEP_4, the petal form "prevented confusion" over whether you feel watched or not, and "radiates softness", being a vast improvement over the "simple" design of conventional camera designs.

Perceived Safety
Despite the explicit associations with a monster and a phobia, overall participant perception of the design seemed to be positive. A reason for this contrast in perception might be that participants were deliberately encouraged to be critical and state potential 'negative' associations, which might have caused demand characteristics.

PUEP_5 expressed feeling safer due to her "fascination" with the novel design, stating that "it's a camera, but with more effort put into it", thereby equating this increased effort with an increased level of safety. PUEP_4 described this as a "more pleasant experience of being watched" and thereby a higher level of perceived safety.

PUEP_3 had a similar sentiment when the petals were in a closed position, whereas the petals came across as "fragile" when in an open position. Her perception of safety was therefore variable depending on the position of the petals. To add onto this, PUEP_6 stated that the "transparency" of still being able to see the camera when the petals are closed conveyed a sense of "safety and trust", aligning well with requirement T_1.

Fig. 65: 'Demogorgon' (Johnston, 2020)
'Demogorgon' monster from the popular Netflix show 'Stranger Things'.

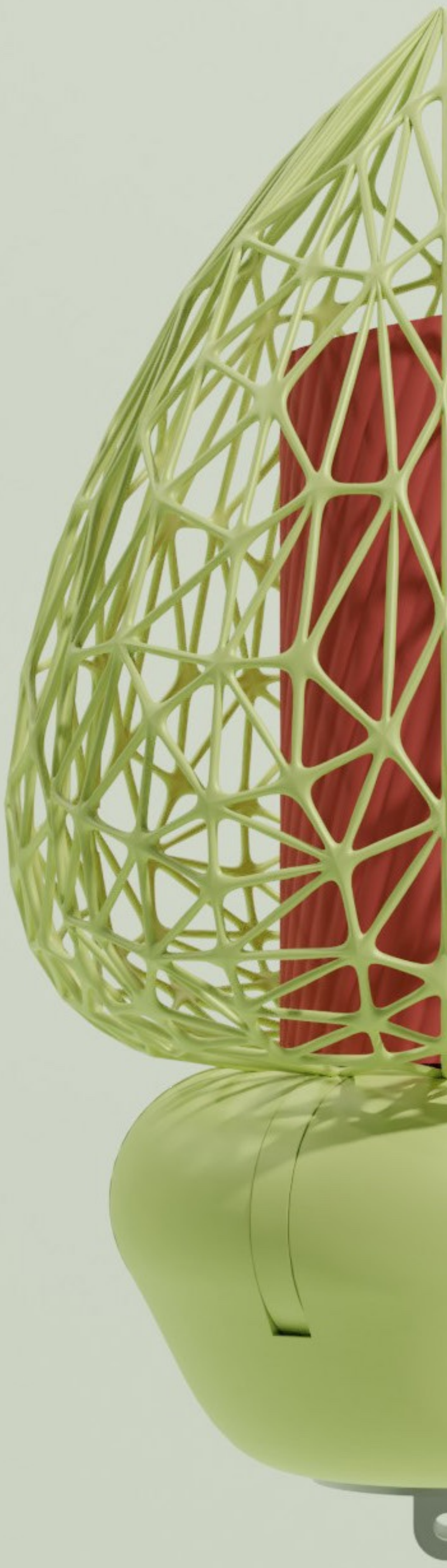
Redesign Requirements
From the PUE participant feedback, a number of redesign requirements can be proposed for the final design:
1. The colour choice will be changed to a complementary palette, creating more harmony between the colours used and preventing the palette from consisting entirely of pastel colours.
2. The choice of petal design will be changed to the Voronoi design (see Fig. 51) to eliminate current negative associations with 'pointiness', 'spiders' and 'monsters'.
3. Current positive effects of petal 'transparency' on perceived safety will be maintained, for which the Voronoi petal design is the most suitable option.

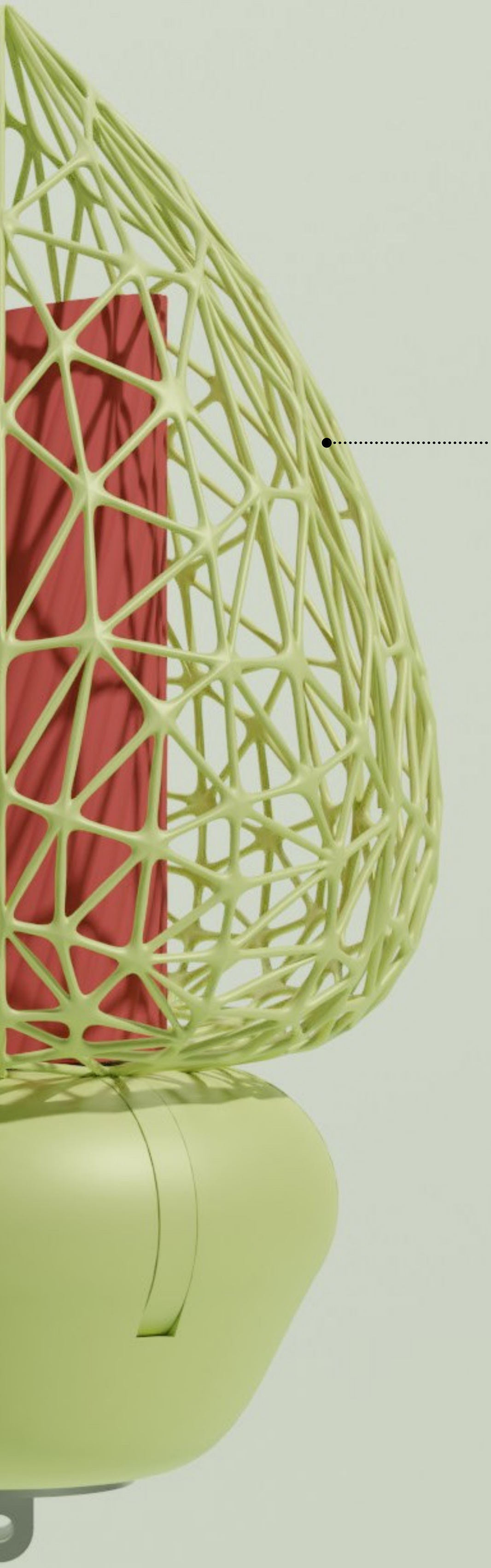
6_3_0
Final Design
CRL_6

6_3_1
BL0.0M

BL0.0M stems from the realisation that camera sensors are actively a part of the public space; we watch over them as much as they watch over us. A two-way street of information and observation.

BL0.1M, BL0.2M
BL0.0M is designed with an eye to the future, a version 0.0 intended to be adapted and updated through time by a continuous stream of public feedback and contestability.

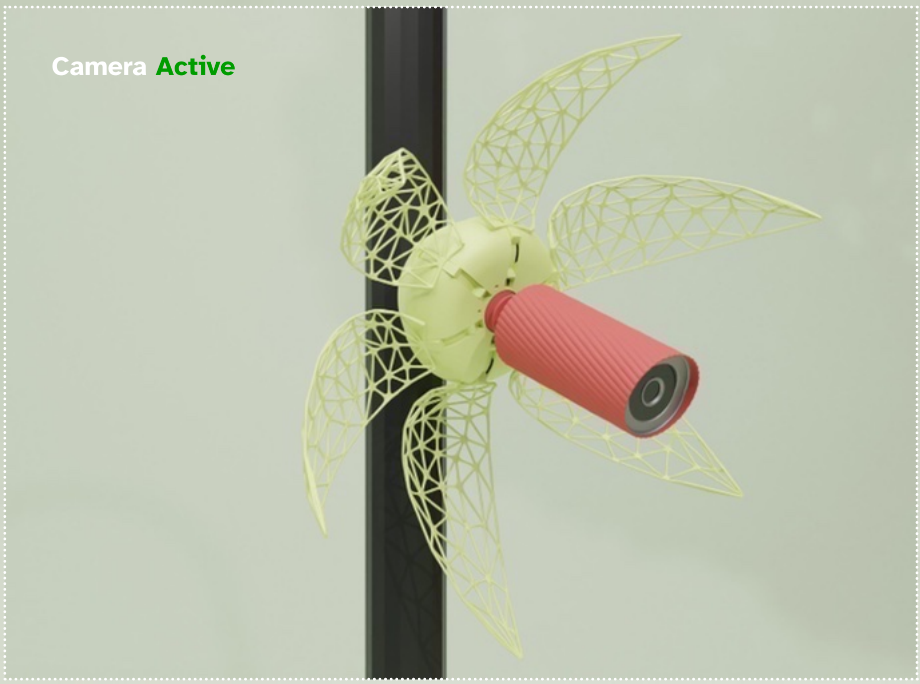


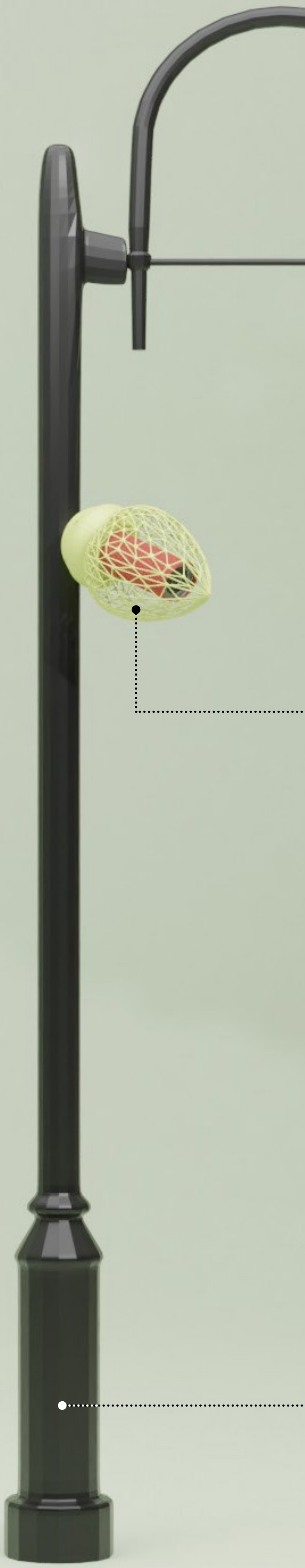


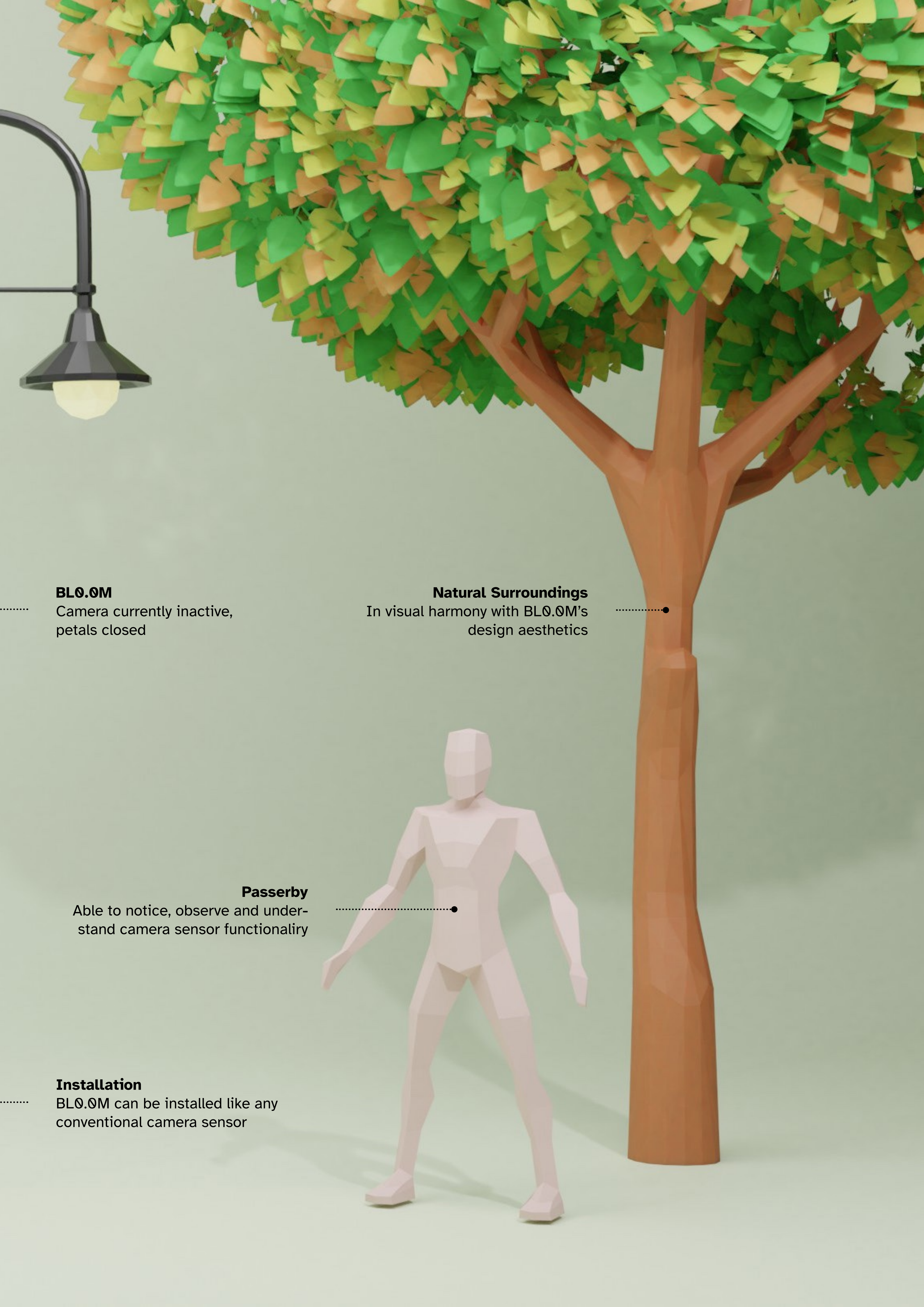
Organic Design
In contrast to the rigidity of previous camera sensors, BL0.0M uses organic, flowing forms in its design, blending in with the nature in its vicinity.

6_3_2
Part of the Environment

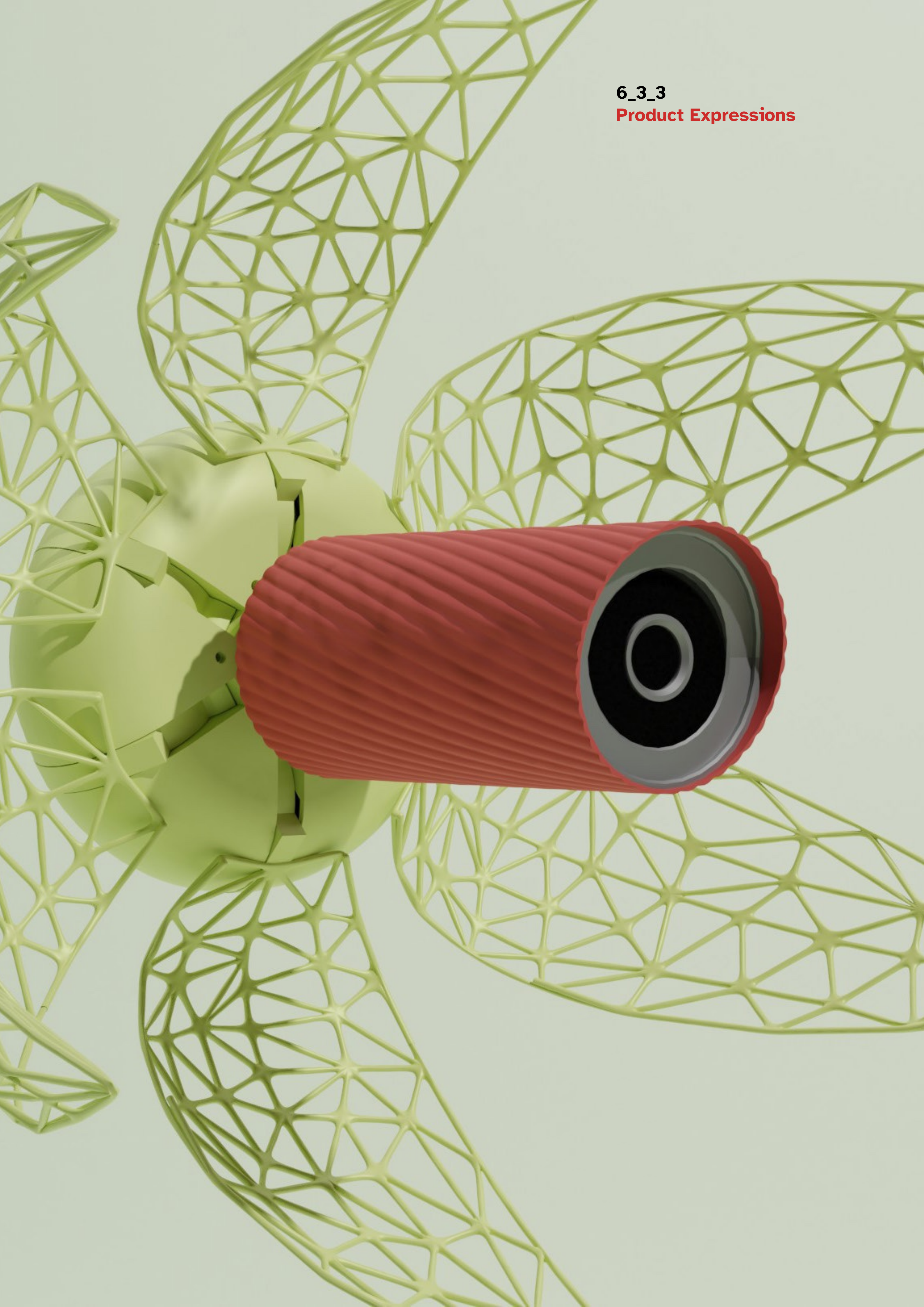
Upon activation of the camera sensor, BL0.0M lives up to its name; blooming open like a flower and communicating its functionality to passersby. When inactive, the petals physically close over the camera, blocking it from seeing anything when it's not supposed to.



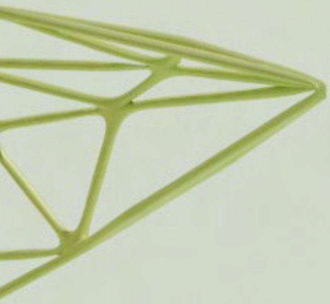


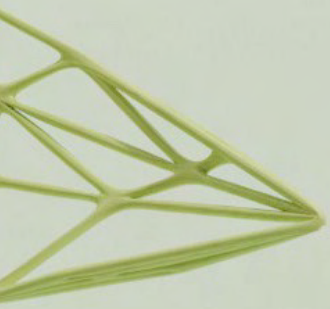

BL0.0M
Camera currently inactive, petals closed
Natural Surroundings
In visual harmony with BL0.0M's design aesthetics
Passerby
Able to notice, observe and understand camera sensor functionaliry
Installation
BL0.0M can be installed like any conventional camera sensor

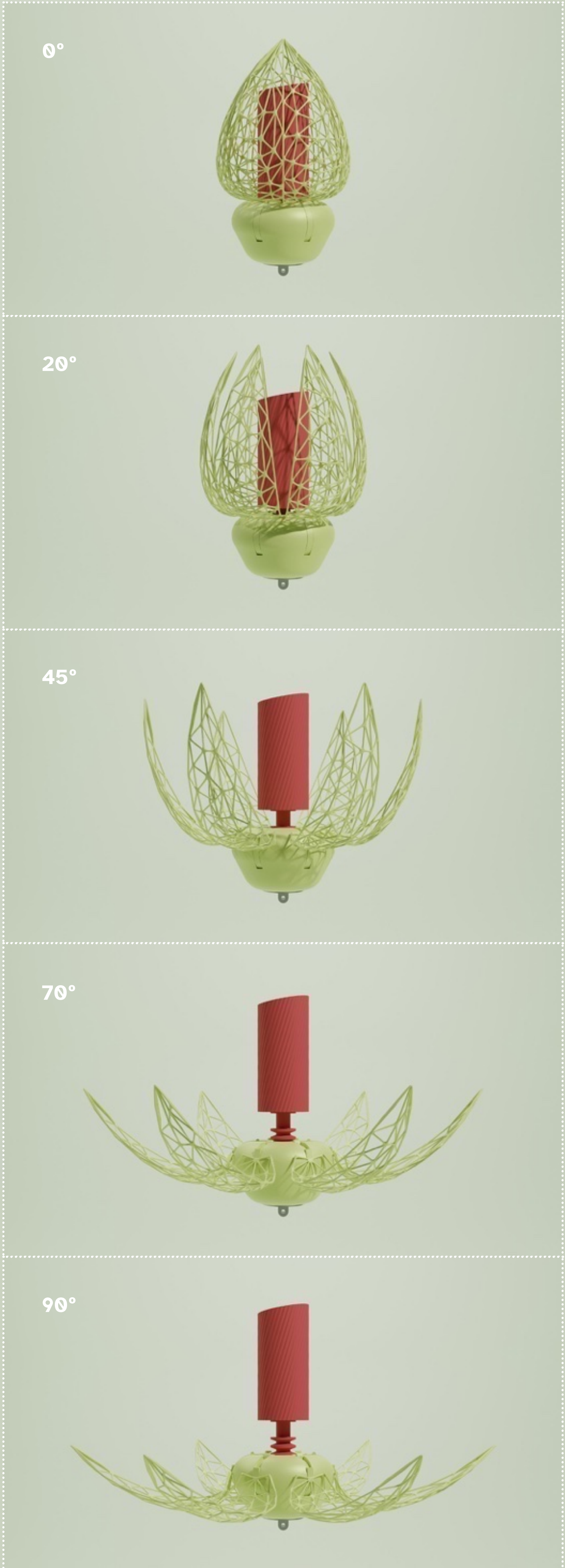
6_3_3
Product Expressions



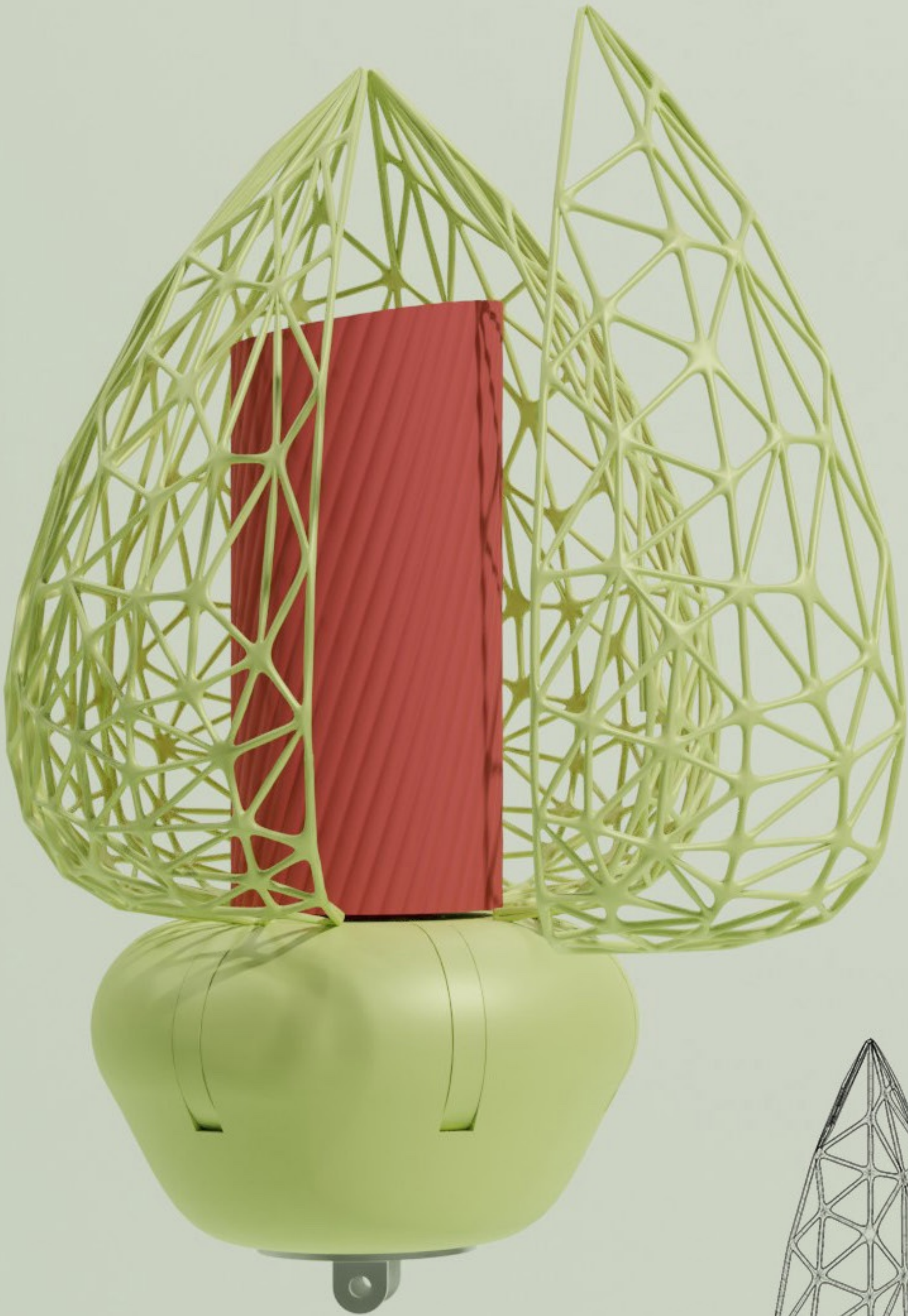
By adjusting the petals into different positions, a range of product expressions can be conveyed with just a single design.

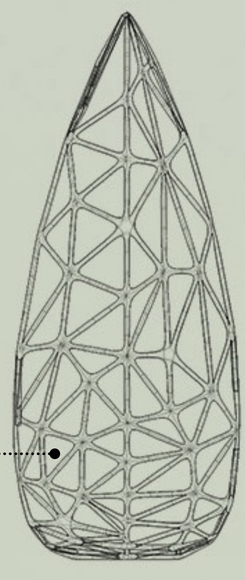






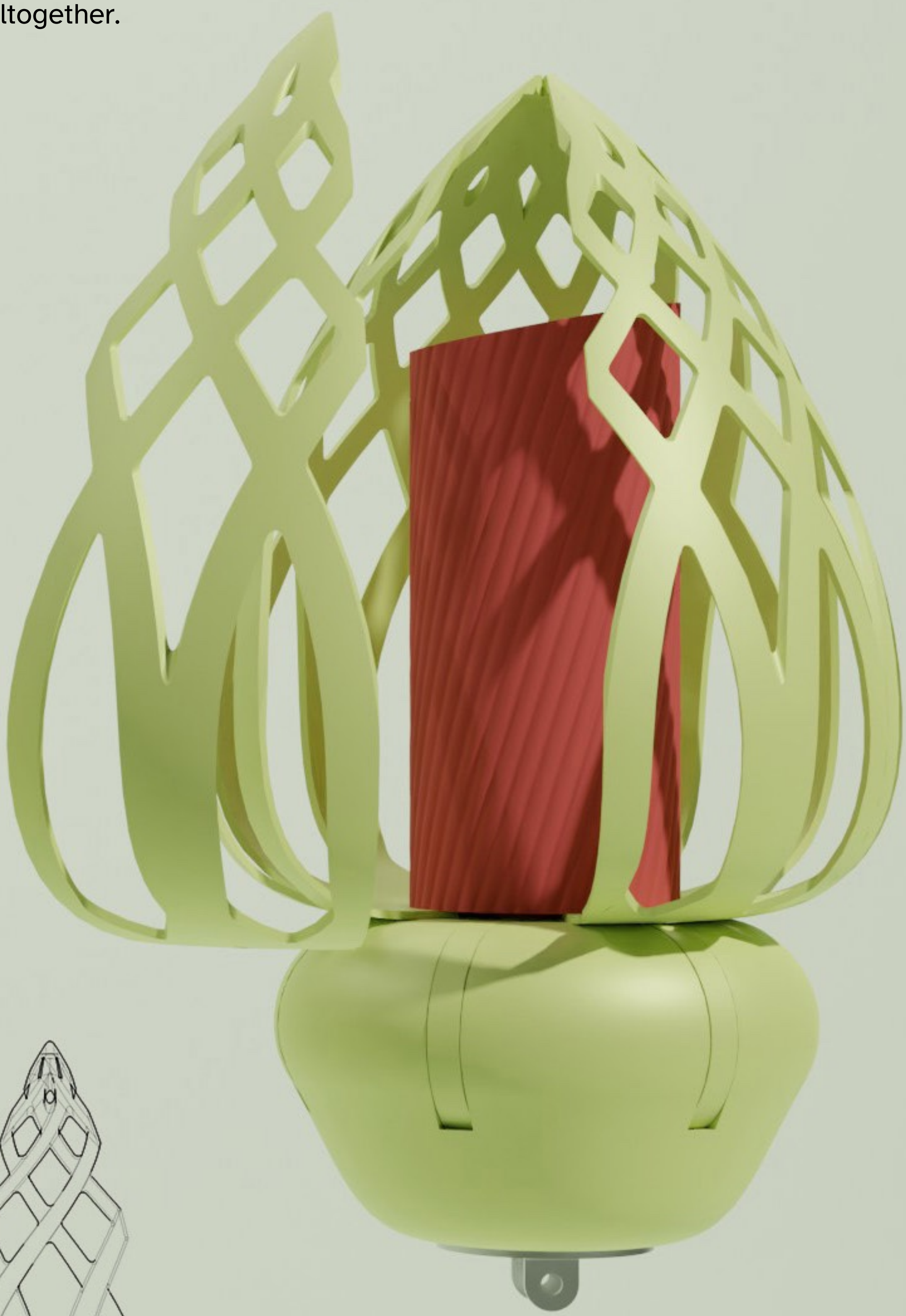
6_3_4
Petal Modularity

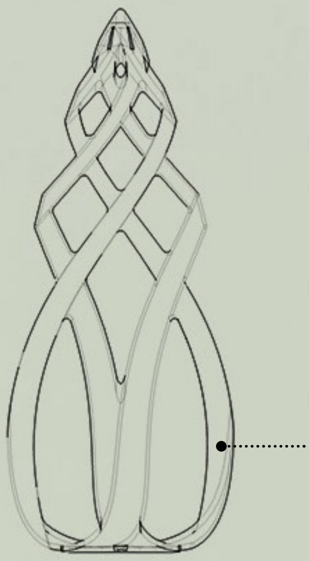




Voronoi Petal
Optional petal module

BL0.0M also breaks away from the uniformity of conventional camera sensors; its petal modules can easily be swapped out for a different design, creating a new range of product expressions altogether.

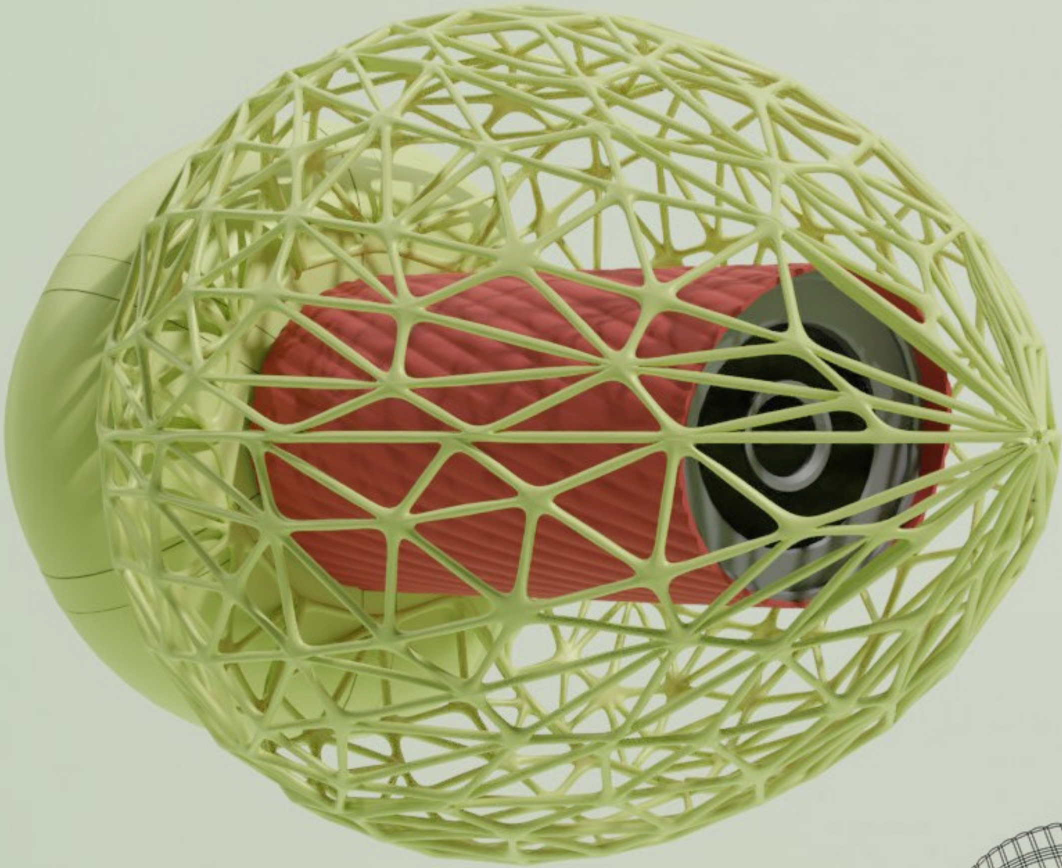


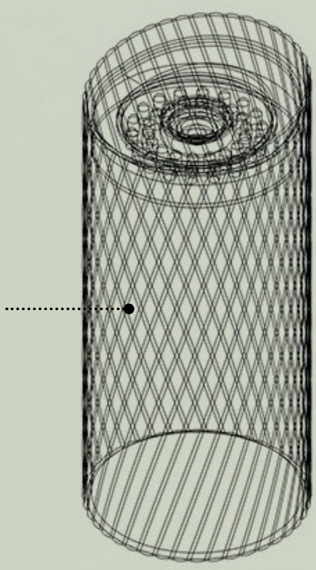


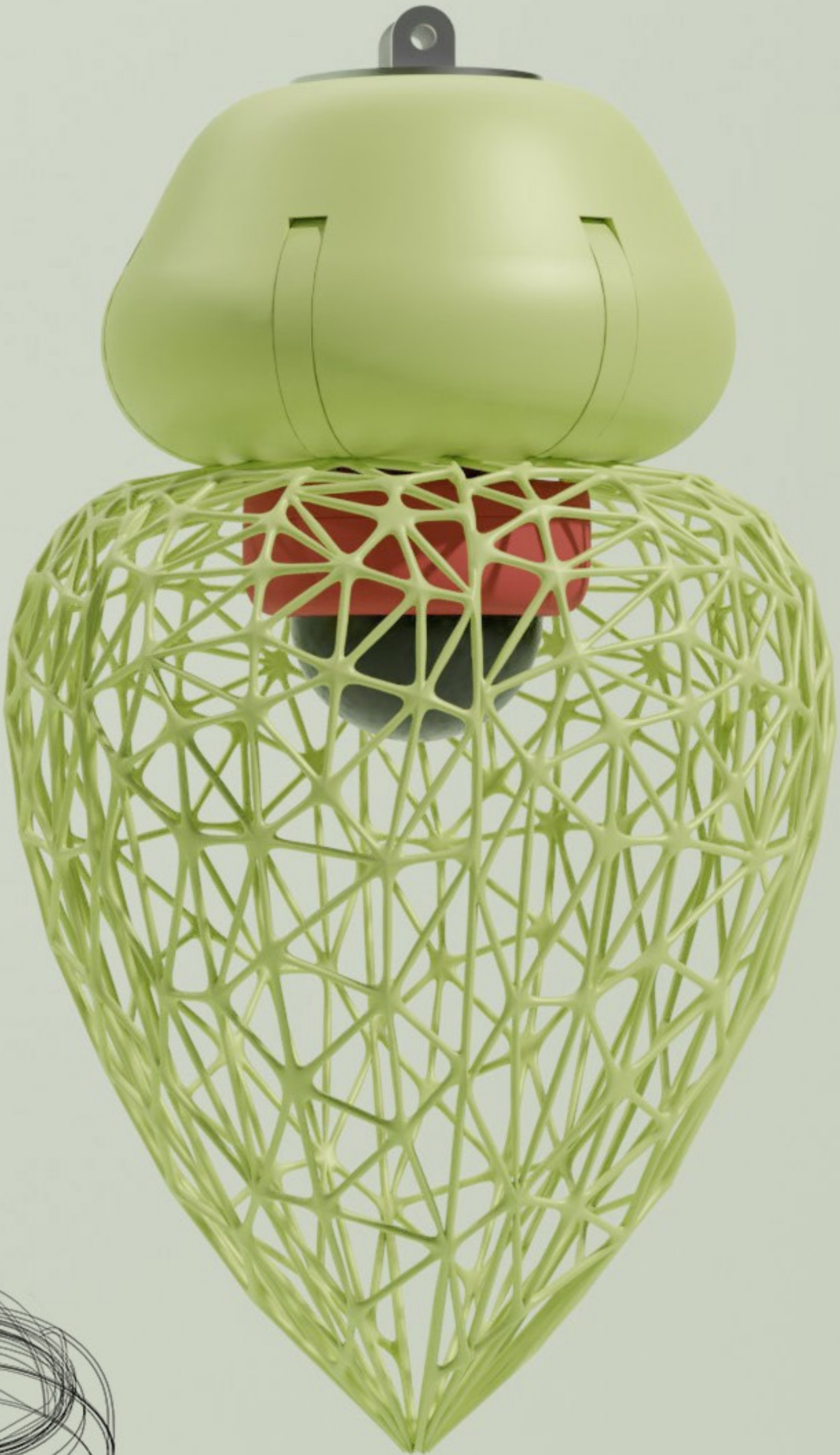
Curved-Ribbon Petal
Optional petal module

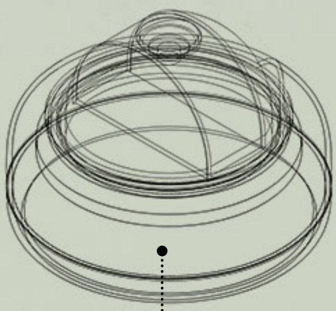
6_3_5
Camera Modularity

BL0.0Ms modularity even extends to its camera sensor module, accommodating both bullet- and dome camera models.









Dome Camera
Optional camera module

6_3_6

Exploded View

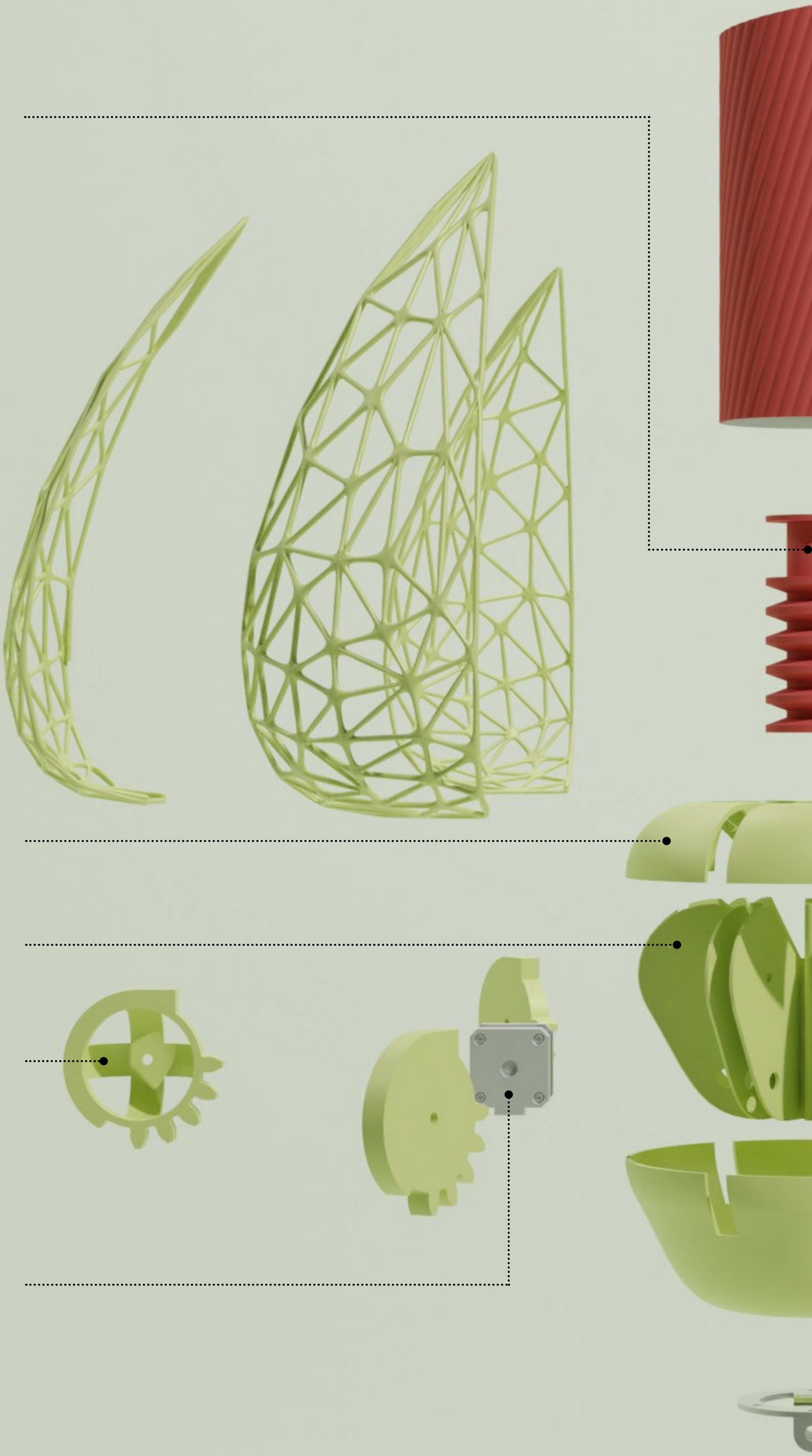
Cylindrical Rack Gear
Rack gear cylindrically connected to 6 surrounding pinion gears

Upper Housing
Top part of the mechanism housing

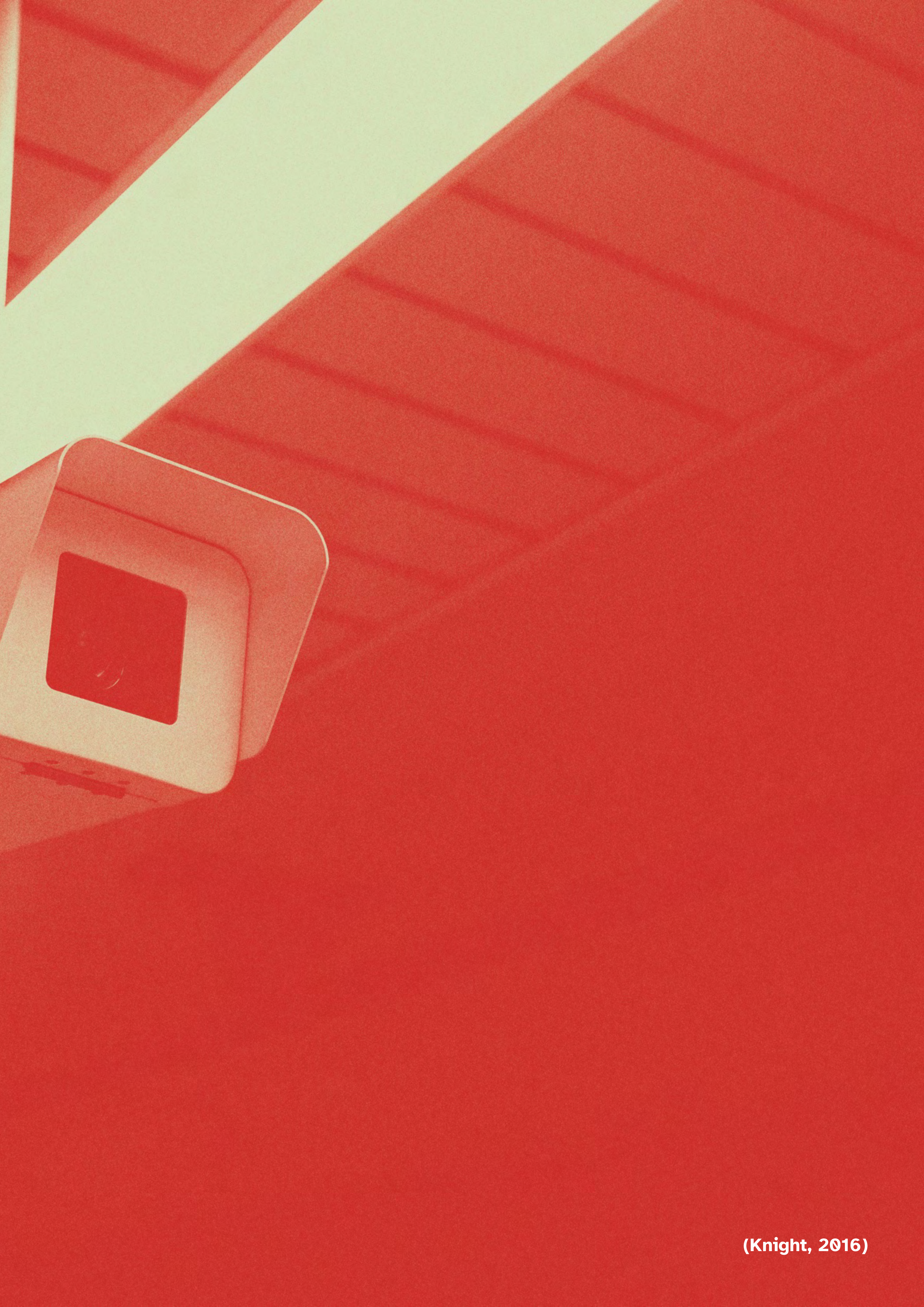
Inner Housing
Provides structural suppor to the upper and lower holder and securing the rack and pinion gears in place

Modified Pinion Gear
Pinion gear modified to attach to stepper motor actuators

Stepper Motor
NEMA-17 Stepper responsible for actuating the cylindrical rack and pinion gear system




Camera Module
Bullet camera, able to be swapped out for a dome camera module
Petal Module
1/6 Modular petals, able to be swapped out for a different design
Pinion Gear
1/6 Pinion gears attached to 1/6 petal modules
Lower Housing
Bottom part of the mechanism housing
Mounting Bracket
Mounting bracket allows for BL0.0M to be installed like any conventional camera sensor



(Knight, 2016)

7_0_0 Discussion & Evaluation

In this final chapter, the structures and guidelines used within this project are evaluated, along with a discussion and future recommendations about the project outcomes and aspects of the final design. To end with, a conclusion with respect to the Main Research Question and a personal reflection are given.

7_1_0
Project Evaluation

7_1_2
Value Principles
Eval_1

In the Research & Analysis phase, the Value Principles were identified from stakeholders such as the RSL and MoA and consequently used as guidelines for the project. This section evaluates the to what extent these Value Principles were implemented and 'fulfilled'.

Proportionality Principle
This project aimed to reduce the infringement of–specifically 'expressive', privacy, and did certainly not contribute in any way to the development of invasive smart sensing technology. However, P is still considered to be only partially fulfilled, as BL0.0M still relies on the use of camera sensors.

Design Justice Network Principles
The DJN principles were used to add a consideration of feminism and intersectionality, which proved very valuable in the identification of the TUG. This Target User Group could subsequently be understood, centered (DJN_2, 3 and 8), heard (DJN_6), facilitated (DJN_5) and collaborated with (DJN_4 and 7) through constant communication, co-creations sessions and the PUE.

However, the end result of this project can be argued to be very novel and new, working directly against DJN_10. Furthermore, although my role as designer was very often that of a facilitator with the TUG (as described in DJN_5), I did have the final say in every design decision, in which my personal biases–consciously and unconsciously, undoubtely will have had an influence.

TADA Principles
Derived from the Responsible Sensing Toolkit, the TADA principles are formulated–and resultantly used within this project, as goals to strive for rather than strict requirements. That being said, due to the use of a specific TUG, TADA_1 is only partially fulfilled, as the TUG cannot be said to represent all the citizens of Amsterdam.

CMS Goals
The CMS goals were useful for understanding the context of smart sensing and actual safety, but ultimately focus on crowd monitoring and therefore fall outside of the focus of this project. Still, the consideration of Aesthetic Design Factors allows for CMS_3 to be fulfilled.

Tab. 16: Evaluation, Value Principles
Evaluation of the implementation of Value Principles within the project.

ID	Description	Evaluation
P	The proportionality principle states that the degree of infringement of the individual interest must be proportionate to the intended legitimate purpose of the particular measure that is being used.	Partially fulfilled
DJN_1	We use design to sustain, heal, and empower our communities, as well as to seek liberation from exploitative and oppressive systems.	Fulfilled
DJN_2	We center the voices of those who are directly impacted by the outcomes of the design process.	Fulfilled
DJN_3	We prioritize design's impact on the community over the intentions of the designer.	Fulfilled
DJN_4	We view change as emergent from an accountable, accessible, and collaborative process, rather than as a point at the end of a process.	Fulfilled
DJN_5	We see the role of the designer as a facilitator rather than an expert.	Partially fulfilled
DJN_6	We believe that everyone is an expert based on their own lived experience, and that we all have unique and brilliant contributions to bring to a design process.	Fulfilled
DJN_7	We share design knowledge and tools with our communities.	Fulfilled
DJN_8	We work towards sustainable, community-led and -controlled outcomes.	Fulfilled
DJN_9	We work towards non-exploitative solutions that reconnect us to the earth and to each other.	Partially fulfilled
DJN_10	Before seeking new design solutions, we look for what is already working at the community level. We honor and uplift traditional, indigenous, and local knowledge and practices.	Not fulfilled
TADA_1	Legitimate and monitored: The residents of Amsterdam, visitors and users have control in the shaping of our digital city.	Partially fulfilled
TADA_2	Open and transparent: Transparency and openness are the basic criteria for the Amsterdam data values.	Fulfilled
TADA_3	From everyone for everyone: Data that local authorities, businesses and other organisations collect in and about the city is public property.	Fulfilled
TADA_4	Inclusive: Data must contribute towards an inclusive society. Take into account the differences between individuals and groups, without losing sight of equality.	Fulfilled
TADA_5	Control: Control over data increases the influence and freedom of the residents of Amsterdam and of visitors.	Fulfilled
TADA_6	Tailored to the people: Data contributes to human values and never has the last word.	Fulfilled
CMS_1	Avoiding and controlling unsafe situations.	Partially fulfilled
CMS_2	Good pedestrian accessibility of public functions and good traffic flow in a larger area around the busy locations.	Not fulfilled
CMS_3	A high-quality public space in which pedestrians feel welcome, safe and comfortable.	Fulfilled

7_1_3
List of Requirments
Eval_2

The LoR and its close relation with the Prioritised Value Network formed a set of concrete 'requirements' for the final design.

For actual safety, AS_1, 2 and 3 were considered non-negotiable and are each fulfilled. No design changes were made to the functionality of the camera sensor itself–also fulfilling P_1, and AS_3 is arguably more than fulfilled due to the additional compatibility with dome cameras. Through the application of the Aesthetic Design Factors, identification of a TUG, consideration of the CMS goals, T_2 and I_1, I_2, I_3 and P_2 are each respectively fulfilled, as well.

On the other hand, T_1 remains to be fulfilled, as BL0.0M's design currently does not extent to the communication of sensor type, owner, goal, whether or not personal data is collected, whether stationary/mobile and duration of activity.

Furthermore, both A_1 and 2 of the autonomy section of the LoR are only partially fulfilled as well. Although it can be strongly argued that the BL0.0M is more novel and noticeable than standard bullet and dome camera designs, whether this actually stimulates public feedback, criticism, contestibility (A_1) and further inquiry and public awareness (A_2) remains to be validated.

Tab. 17: Evaluation, LoR
Evaluation of the implementation of LoR requirements within the project.

ID	Requirement	Evaluation
AS_1	Camera sensor field of view is not limited (when active)	Fulfilled
AS_2	Quality of video footage is maintained (when active)	Fulfilled
AS_3	Compatible with standard bullet camera design	Fulfilled
T_1	Transparency about sensor type, owner, goal, whether or not personal data is collected, whether stationary/mobile and duration of activity	Not fulfilled
T_2	Aesthetically pleasing design that contributes visually to the aspects of urban form, clearness and management	Fulfilled
I_1	Universally perceptible and understandable design	Fulfilled
I_2	No exclusion of user groups prone to low perceived safety	Fulfilled
I_3	Designed in accordance with Amsterdam's policy regarding the public space and smart sensing	Fulfilled
P_1	No added infringement upon accessibility privacy	Fulfilled
P_2	Respectful and considerate of expressive privacy	Fulfilled
A_1	Encourages public feedback, criticism and contestibility	Partially fulfilled
A_2	Allows for further inquiry and generates public awareness	Partially fulfilled

7_1_4
Aesthetic Design Factors
Eval_3

Lastly, a look is taken at which Aesthetic Design Factors were considered, manipulated and therefore 'fulfilled' for the final design.

The first aesthetic factor to be fulfilled is 'balance', as the mechanical petals follow a 6-fold symmetry and are modular, allowing for unity in variety. The petals also fulfill the factor of 'movement', primarily by the ability to change position. 'Form' as an aesthetic factor is fulfilled through inspiration taken from nature as reflected in the Mood Board and by the 'function-follows-form' approach in which the functionality of the camera sensor is conveyed by the position of the petals.

Additionally, both the geometric and voronoi patterns of the petal design fulfill the Aesthetic Factor of 'pattern'. The evaluation of colour in the PUE and form and symmetry of the petals fulfill the factors of 'colour' and 'visual weight', respectively.

The Aesthetic Factors of 'scale' and 'texture' are only considered to be partially fulfilled, as there were no explicit considerations and evaluations of absolute size, relative size, surface quality or material choice in the product design phase of this project.

Tab. 18: Evaluation, Aesthetic Design Factors
Evaluation of the implementation of Aesthetic Design Factors within the project.

Aesthetic Factor	Design Elements	Evaluation
Balance	• Symmetry • Contrast • Unity in variety	Fulfilled
Movement	• Displacement • Directionality	Fulfilled
Scale	• Absolute size • Relative size	Partially fulfilled
Form	• 3-dimensional shape • Structure • Functionality	Fulfilled
Pattern	• Repetition • Consistency	Fulfilled
Texture	• Surface quality • Material choice	Partially fulfilled
Colour	• Hue • Saturation • Brightness	Fulfilled
Visual Weight	• Attention • Focal point	Fulfilled

7_2_0
Discussion & Future Recommendations

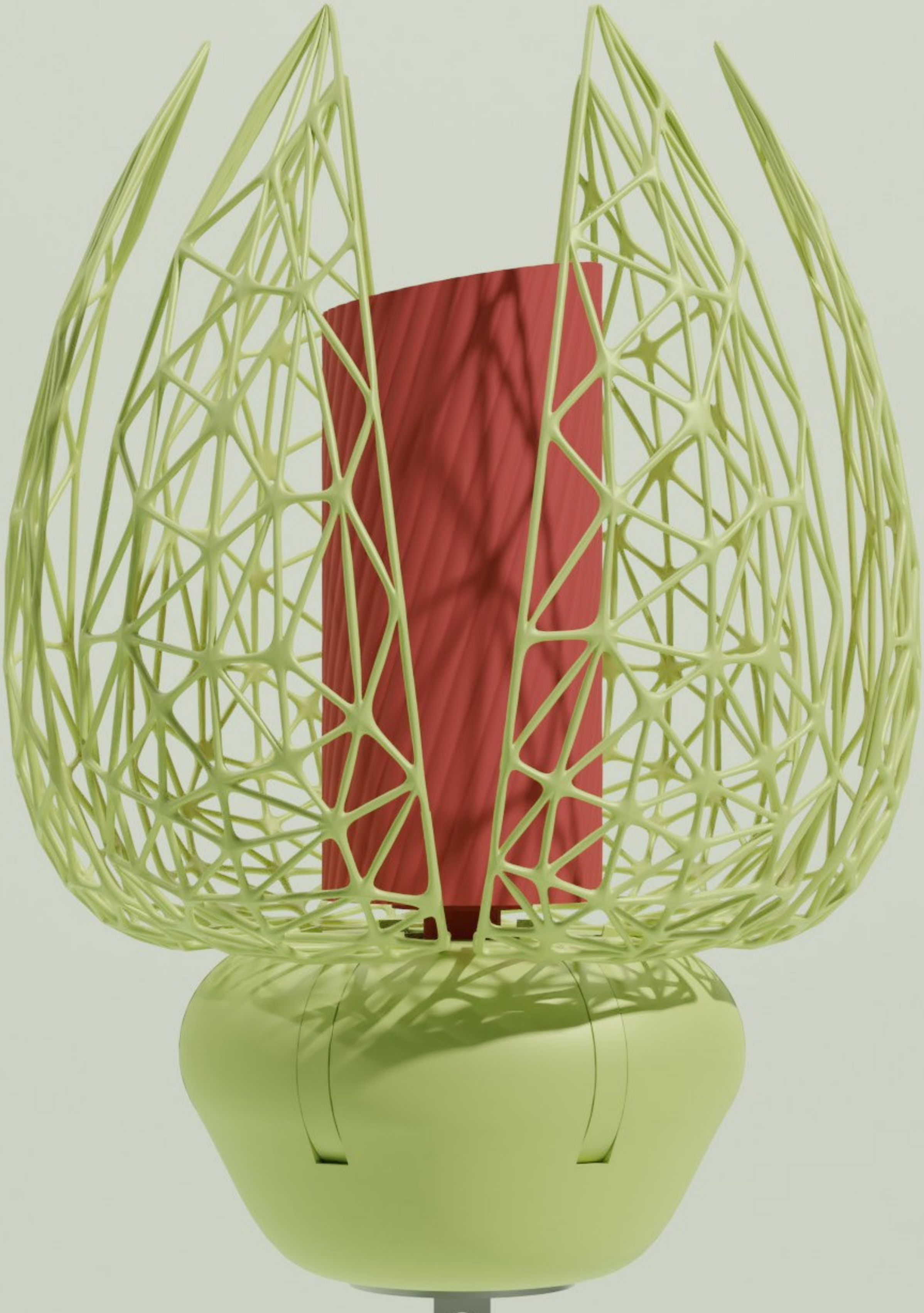
7_2_1
Petal Design

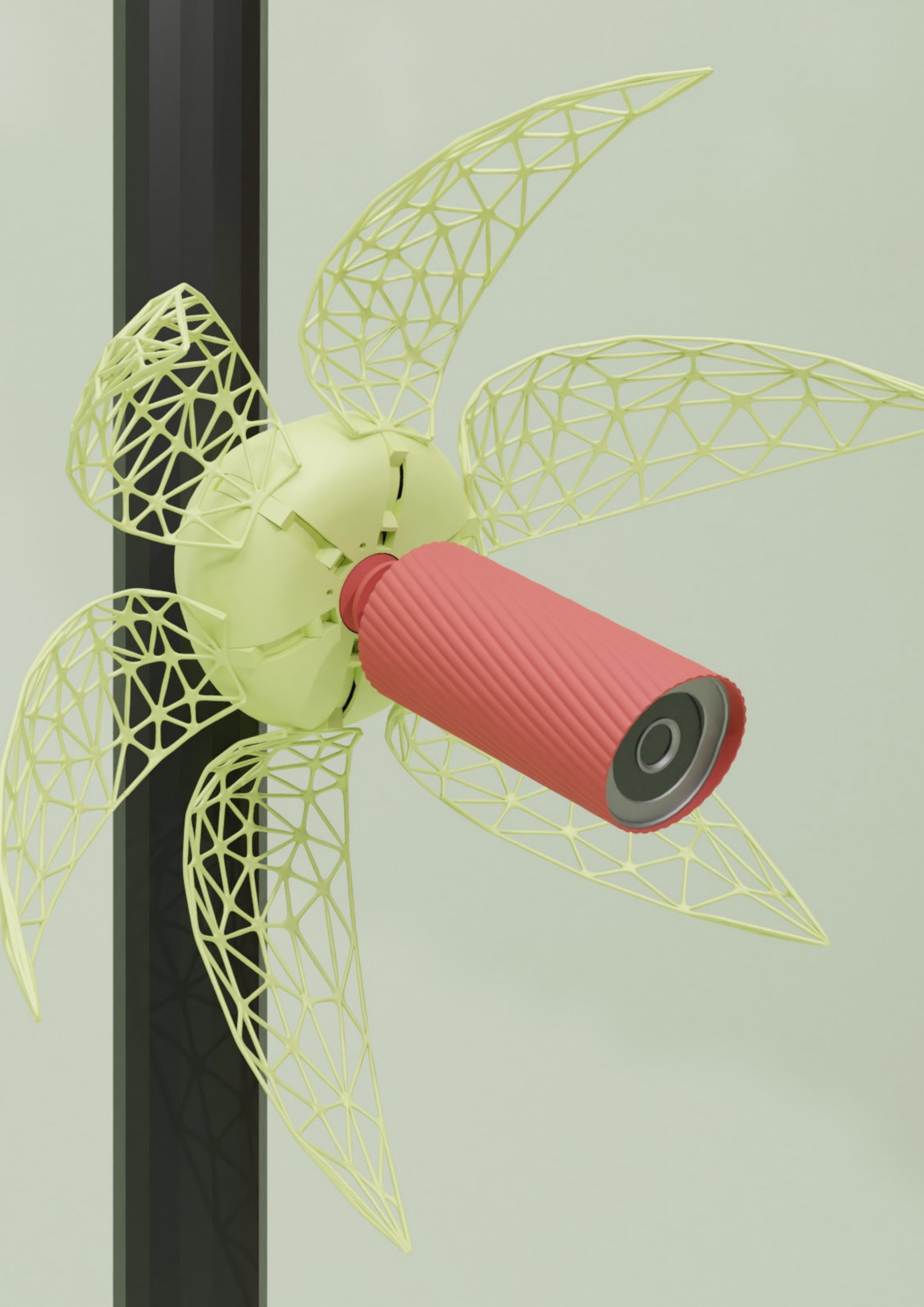
Expressions
It can be said that BL0.0M's defining product feature is its 'petals', for which both its design and perception involves a fair amount of subjectivity. The PUE not only showed this, but also revealed that the position of the petals and the resultant perceived 'expression' is highly subjective and variable according to the TUG, individual, or whichever TV show is popular at that time.

The effect of different petal designs and how these are positioned has the potential for an entirely separate assignment brief and research scope, which would certainly have been included into this graduation project if it were not for time constraints. However, the 'modular' nature of BL0.0M–with the petals designed as easily separable parts with multiple proposed design variations, does take the opportunity for future research and design alterations into account.

Design Inspiration
Another future recommendation would be to look at other metaphors or sources of inspiration for the design of the petals, as they are–as the name gives away, inspired by natural flowers. This specific project, with this specific TUG, and myself as the designer, arrived at this specific metaphor and eventually BL0.0M as the final design. However, a change in any of these factors might have resulted in an entirely different final design. There might even be a way to embrace the utilitarian, 'form-follows-function' design philosophy of current camera sensors, which is so heavily criticised within this project.

Citizens VS Criminals
Finally, an interesting area of future research would be to look at a petal design that balances between maximally reassuring the TUG while simultaneously intimidating and deterring potential criminals and threats. It may be the case that what could be perceived to be a 'scary' design is actually most effective at achieving high levels of perceived safety, although this remains to be validated.





7_2_2
Camera Sensors

Generalisability
From collaborating with the Responsible Sensing Lab and working with their toolkit it became very evident that the high prevalence of camera sensors used in public spaces inevitably comes with excessive and unnecessary invation of privacy. As a result, camera sensors were seen as an opportunity-rich area for improvement within this project.

An interesting question for future research would therefore be to how the design approach for BL0.0M could be used for other and newly developed sensor types, and whether such design could unintentionally and undesirably excuse and justify excessive use of camera sensors.

Bullet VS Dome
Regarding the camera sensor type–although bullet cameras were initially chosen as, the design scope was broadened to include dome cameras as well. Although this has the added benefit of BL0.0M being a more universal design, it also has added the risk of being a 'one-size-fits-all' solution that fails to make maximally benefit the current use and design of either bullet or dome cameras. A future recommendation would therefore be to focus more deeply on one camera sensor type, specifically bullet cameras, as the current design of these was found to be most detrimental to perceived safety with the TUG.

7_2_3
Blooming Mechanism

Design Alternatives
Although the 1st section of the Concept Development chapter was entirely dedicated to the identification, development and optimisation of the 'blooming mechanism' that was to be implemented into the final design, there is a whole range of design improvements and alterations that remain to be explored.

The use of more compact actuators could have made the mechanism much smaller. Using other materials might have allowed for a more compact gear system, or a compliant mechanism to be used instead. Such alterations could not only improve the working principle but potentially even the design aesthetics as well.

Shuttercam
Another key consideration is the similarities–and differences, between BL0.0M and Shuttercam. Both designs physically block the camera lense when the sensor is not in use; a key similarity. However, Shuttercam–much unlike the design philosophy of BL0.0M, has a very practical and utilitarian design; a key difference. The design and embodiment of a Shuttercam revolves around its feature function: shutting. There is no 'product expression' that is purposefully conveyed. A comparative study of these 2 design approaches would therefore not only be interesting, but also very useful in continuation of this project.

7_2_4
Target User Group

Internal Validity
When working with a TUG of n = 8–which often functioned as a focus group, the sample size can be considered too small to accurately represent the intended user group of heterosexual women aged 15-25, especially when factors like SE status and nativeness are left out.

Moreover, due to the use of convenience sampling, factors like place of residence, language and even age are limited in variety. This further exaggerates the specificity of the TUG worked with during this project. For higher internal valifity, a larger and more diverse TUG would be needed.

External Validity
The question then remains to what extent the findings from the TUG can be generalised to the rest of the population. With limited internal validity, external validity can be considered to be even more limited. However, for this project, external validity was intentionally limited to combat the potentially negative side-effects of unintended exclusion through intersectionality and a 'one-size-fits-all' solution. Therefore, external validity is not so much a problem to be fixed within the context of this project, but more so an interesting topic of future research, to see potential discrepancies or similarities.

7_2_5
Autonomy

As mentioned in the Project Evaluation, the 'autonomy' category of the List of Requirements is considered only 'partially fulfilled', as there are no explicit design elements that encourage public feedback, criticism, contestibility (A_1) and further inquiry and public awareness (A_2) in BL0.0M's current design.

Wow Factor
It can be strongly argued that the novel and–according to PUEP_5, "fascinating" design will generate a level of public awareness and associated feedback, criticism, and potentially even the motivation to inquire further and contest the design and use of camera sensors. However, this is yet to be validated in the future.

Signage
In the meantime, one design direction that could improve the 'autonomy' category of the LoR is the use of signage. This would allow for detailed information–such as sensor type, owner, goal, etc., to clearly be communicated and would even allow for the use of QR codes or similar applications to redirect users to the Sensory Register Website.

Version 0.0
Athough not directly included in this project, the very design philosophy behind BL0.0M is to encourage and lay the foundation for such explorations and developments. As the name suggests, BL0.0M is only version 0.0 in a timeline of future developments.

7_3_0
Conclusion

7_3_1
Recapping the Main Research Question

As stated in the initial assignment, this graduation project orginated from the broad aim of ‘enhancing the feeling of safety in public environments through the use of responsible sensing’.

In preparation for the Research & Analysis phase, this aim was reformulated into the Main Research Question:

How can smart sensing technology be (re)designed to contribute to perceived safety in public spaces?

7_3_2
Answering the Main Research Question

Perceived Safety
The feeling of safety is subjective and is continually influenced situationally, environmentally and socially. To this end, the design of a smart sensor cannot be ‘final’ or even static and must be responsive and adaptable to public criticism and contestability both in real time and in the long term.

Camera Sensors
People are most opinionated about– and acquainted with camera sensors. These are usually 1) the most invasive sensor type available and 2) the most widely used. Changing how camera sensors are designed and used therefore has a lasting impact on every other type of smart sensor.

Target User Group
Technology that is so closely linked to human behaviour in both its risks and benefits has to consider Human Readiness in its rapid development. The impact of technology on various, potentially vulnerable user groups must be an integral part of the research, design and implementation process. One such user group to consider is women aged 15-25.

Design Aesthetics
Smart sensors are inevitably a part of the public space and thereby influence perceived safety through urban form. Nature is an effective metaphor to use in harmonising the presence of the sensor with surrounding nature and its visual impact on public space.

A **continuously updatable, human-centered, aesthetically pleasing camera sensor** design

Short Answer to the Main Research Question

7_4_0
Personal Reflection

In the 5 month duration of this graduation project I have not only had the opportunity to learn and develop myself in many areas, but often even found myself forced to do so in order to make progress.
It is this continued progress; the continuous overcoming of sudden obstacles in one way or another, that I am most proud of for this project.

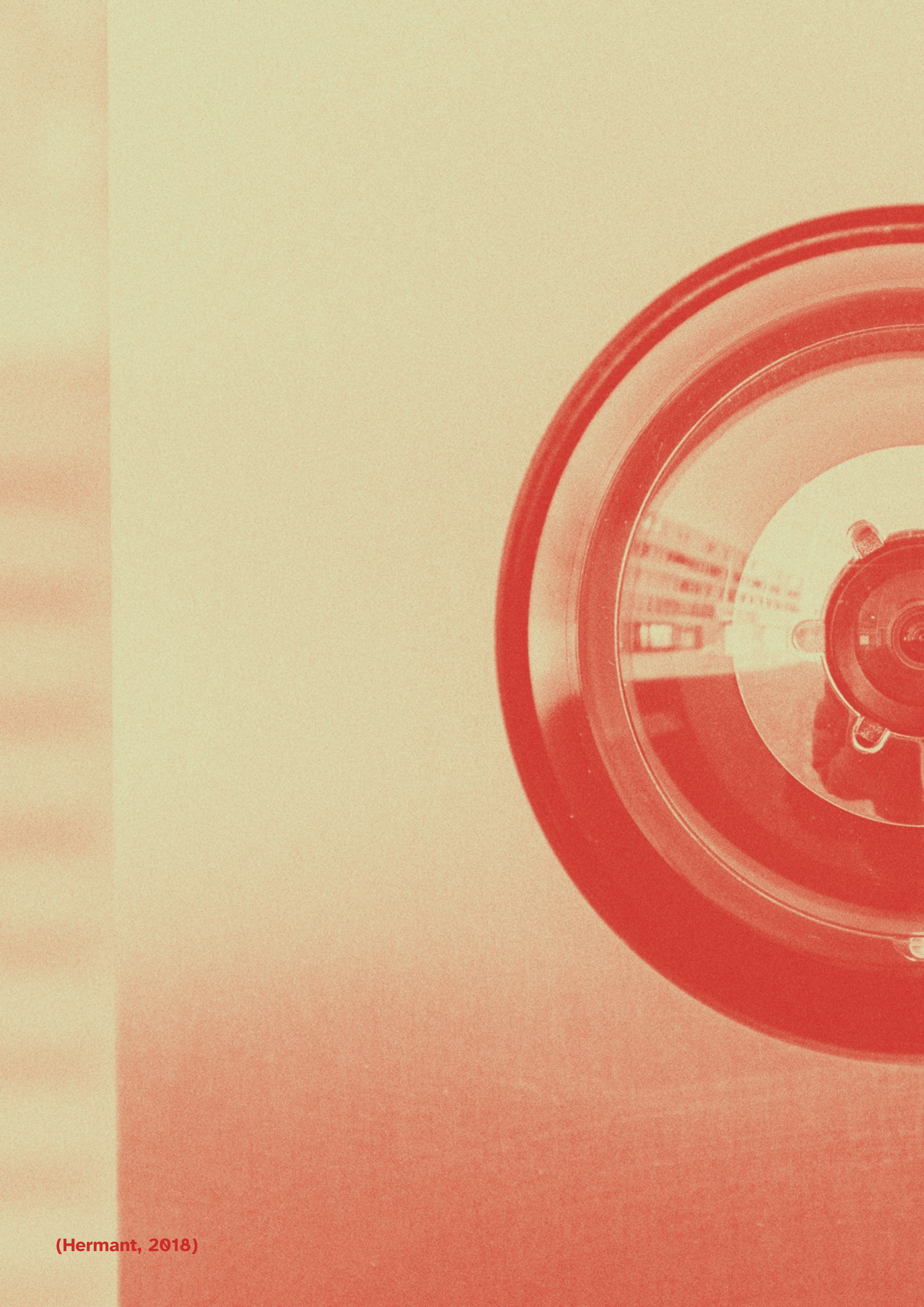
Even before the graduation Kick-Off, I had set a few goals for self-improvement. One such goal was to further develop my CAD skills, specifically with software like Blender and Fusion360. For one, the natural forms that resulted from the co-creation sessions and the mood board forced me into a steep learning curve in having to model organic-looking forms from blocky, geometric sketches and meshes. However, this was also partially a challenge that I put upon myself, to prove to myself that I was up to the task.

Of course, a side-effect of this ambition was the difficulty in prototyping such a model. Particularly the petal designs were a nightmare to 3D print, laser cut or thermoform, with unforeseen difficulties popping up every step along the way. Even so, the experience of making difficult but sure process, learning from the experts at the PMB, achieving a reasonable mechanical prototype and being able to accept the unsatisfactory state of the appearance prototype due to time constraints was a valuable experience in and of itself.

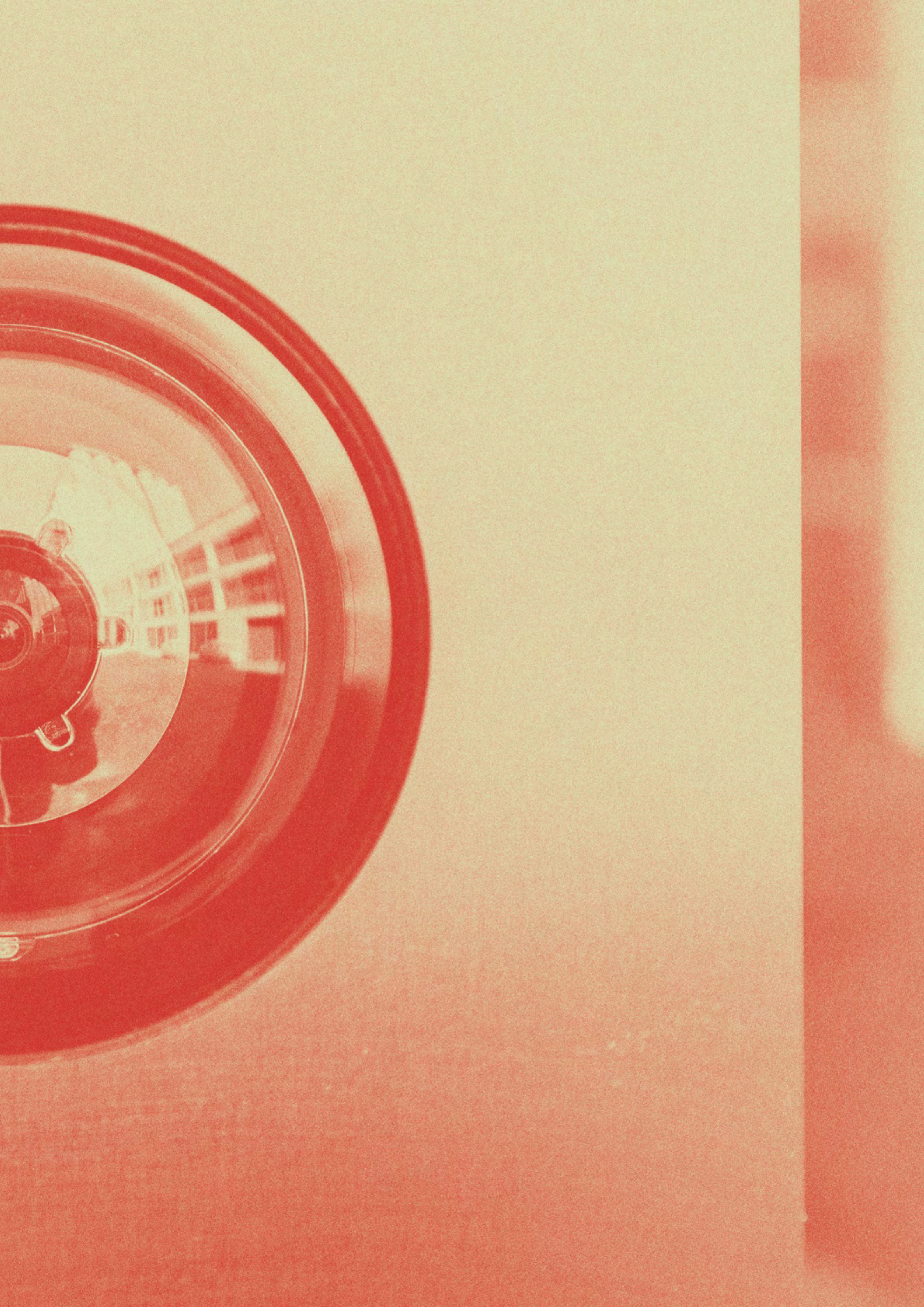
Another area of development was that of facilitation and communicating with a target user group. Knowing myself, this is something that I can find tedious and tend to therefore keep as brief and informal as possible. For this project, however, I forced myself to involve the TUG in an unavoidable and structured way through the use of 2 co-creation session and a Product Usabiliy Evaluation, which greatly helped to shape the final design.

The same can be said for conducting contextual research; a big step that I was wary of not to neglect in pursuit of immediate ideation and concept development. Although with hindsight, the project might have been slightly more research-focused than I would have preferred, it definitely helped me develop the skill of planning and structuring research, as well as applying this during the eventual design phase. Here, my supervisory team also contributed greatly in stimulating me to think critically of every step and decision I took along the way– however small, to be aware exactly of my influence on the project as a designer.

BL0.0M, the final design and end result of this graduation project, is a novel design that I even surprised myself with. It has a certain curiosity and 'conversation-starter' feel to it, which I see as a direct result of sticking to a strict but flexible structure and trusting the process every step along the way.



(Hermant, 2018)



8_0_0
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8_1_0
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8_1_1
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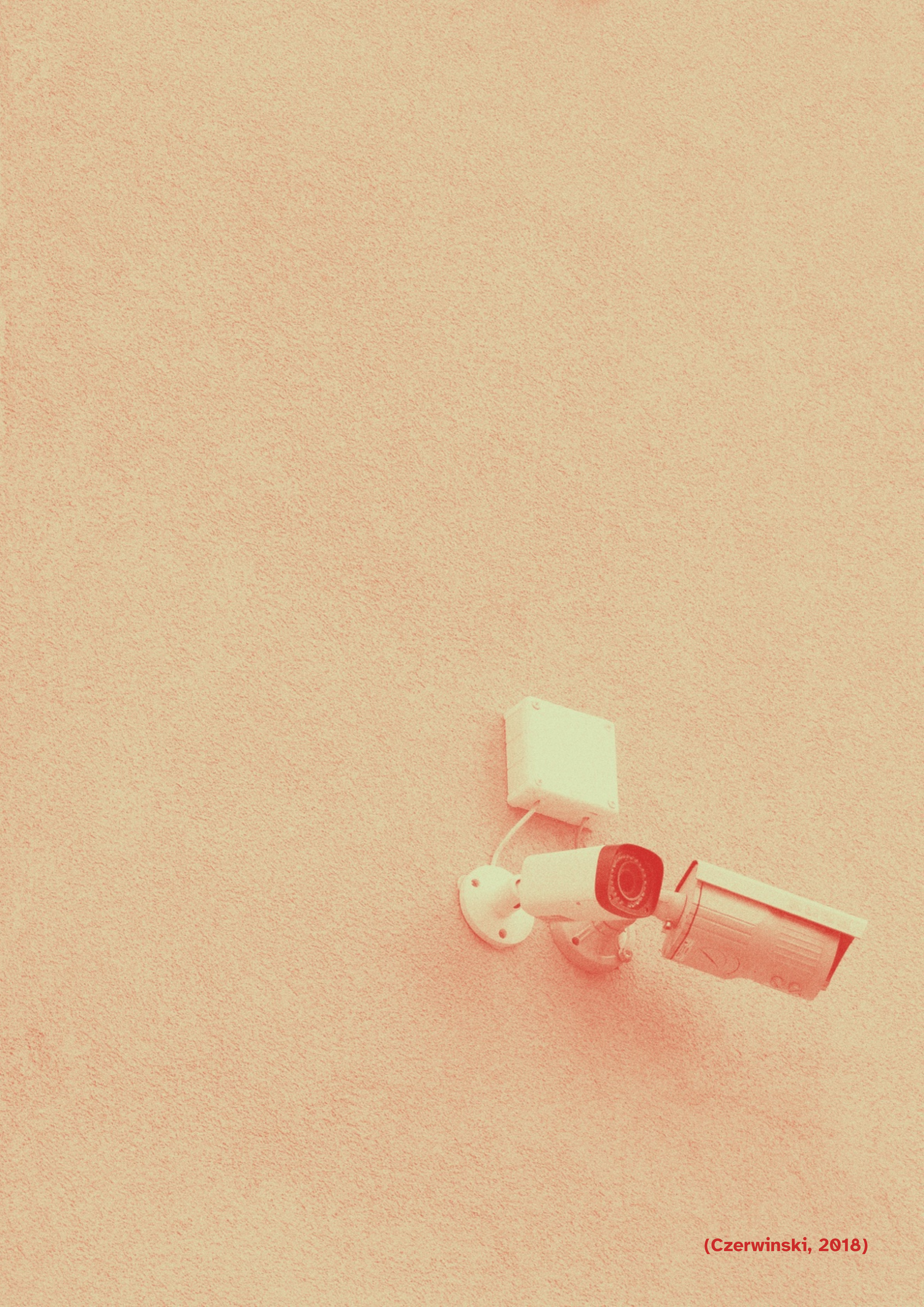

(Czerwinski, 2018)