Reducing earthquake suffering

Solutions for Vulnerable Groups

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**Reducing Earthquake Suffering -
Solutions for Vulnerable Groups**

Korina Kljaić
5608244

Chair - dr. ir. Arjen Jansen
Mentor - dr. Simona Bianchi

Summary

The project's primary objective was to develop a solution aimed at reducing the suffering caused by earthquakes, particularly among vulnerable communities. Grounded in personal experience and an understanding of the consequences of seismic activity, the project sought to bridge the gap in affordable and accessible seismic-resistant measures.
Through a research approach encompassing different methods, a foundation for further exploration and design development was achieved. I delved into the historical context of earthquakes in Zagreb, touching upon the region's susceptibility to seismic events. After this I conducted interviews with people from Zagreb that have experienced stronger earthquakes. This background information formed a base for the next phases of the project.

From this research came the solution 'Embrace,' a wearable communication device for use during earthquakes. Embrace offers an alternative way of communication during seismic events, enabling individuals in affected areas to exchange vital information about their well-being and location, even when traditional communication infrastructure is compromised. This smart bracelet employs LoRa technology, capable of transmitting data over long distances with minimal energy consumption.
Embrace's communication scheme involves a network of base devices strategically placed every 10 kilometers, facilitating satellite communication between bracelets. This approach minimizes the bracelet's energy requirements and size, making it a practical and cost-effective solution.

In essence, Embrace focuses on disaster preparedness and response, particularly for vulnerable communities. Its affordability, friendly design, and comprehensive functionality combine to solve the problem of inability to communicate with others during earthquakes, and in such a way allows for decrease of stress and anxiety, as well as allowing for faster intervention in case of emergency help needed. By enhancing communication and connectivity, Embrace empowers individuals to seek help and offer support, ultimately contributing to safer and more resilient communities during seismic events.

Foreword

The motivation behind this project springs from a personal experience and a keen observation of the detrimental consequences of earthquakes on people›s lives. Three years ago, I personally experienced an earthquake in Croatia, which brought to light the devastating impact and long-lasting effects on communities. It became evident that there is a significant gap in the market when it comes to affordable solutions for individuals who cannot afford the current seismic-resistant measures available.

Witnessing firsthand the destruction caused by earthquakes and the subsequent challenges faced by those with limited resources, an idea began to take shape. The desire to address this pressing issue and provide viable solutions for people in similar circumstances became a driving force for this project. Seismic activity is a natural phenomenon that poses a substantial threat to human lives and infrastructure, with devastating consequences, particularly for vulnerable communities. The impacts of earthquakes are exacerbated for these groups, often lacking the resources and infrastructure necessary to withstand or recover from such disasters.

In the pursuit of safeguarding the well-being of these marginalized populations, this graduation design project takes on the challenge of developing a feasible and affordable solution to reduce the human suffering caused by seismic activity. The project aims to address the critical need to empower vulnerable communities with innovative solutions that enhance their resilience in the face of seismic events. Vulnerable groups, which can include low-income households, marginalized populations, and underserved regions, face heightened risks due to inadequate housing, limited access to resources, and restricted access to information and support systems. My goal is to bridge these disparities by creating a practical and accessible solution tailored to their specific needs.

This project aims to provide immediate relief during seismic events as well as establish a sustainable foundation for recovery and, in such a way, reduce human suffering. I will explore technologies, materials, and strategies, aiming for the proposed solution to be both affordable and ecologically responsible. I aspire to contribute to a more equitable and secure future for vulnerable communities, where the devastating impacts of seismic activity are mitigated, and human suffering is reduced.

My commitment is rooted in the belief that every individual and community, regardless of their socio-economic status, deserves the opportunity to thrive in an environment that prioritizes safety, security, and well-being.

Overview

Introduction

- Earthquakes in Zagreb
- Buildings of Zagreb
- Research Question

This chapter sets the stage for the project journey by delving into its foundational elements. It opens with a follow up to the description of the motivation behind the project, driven by an awareness of the challenges posed by seismic activity and a commitment to mitigating its impact. The historical context of Zagreb's earthquakes provides a backdrop, highlighting the region's vulnerability to these natural phenomena. As the chapter advances, it also focuses on the state of Zagreb's buildings, highlighting existing structural landscape.

WIth this beginning of research, the chapter formulates the central research question, setting the tone for how this exploration will follow. In doing so, it establishes the direction for the report, starting the quest for innovative solutions to seismic challenges.

01

Earthquakes in Zagreb

In Zagreb's history, two significant earthquakes stand out as pivotal moments, each leaving its distinct mark on the capital of Croatia.

The earthquake of 1880, which occurred on November 9th, was a powerful seismic event estimated to be around magnitude 6.3. It had a devastating impact, resulting in significant damage to the city's infrastructure and architecture, especially the older, historic buildings that were not engineered to withstand seismic forces. This earthquake led to the collapse of numerous buildings and caused considerable human suffering, with casualties and injuries reported. The destruction was a catalyst for the subsequent reconstruction of Zagreb with a greater focus on earthquake-resistant building techniques. This seismic event remains a part of the city's collective memory and serves as a reminder of the importance of earthquake preparedness and resilient urban planning in a region prone to seismic activity.

Moreover, in 2020, on March 22, a significant earthquake with a magnitude of 5.5 on the Richter scale struck Zagreb, shaking the capital city of Croatia. The epicenter was located near the town of Markusevec, just north of Zagreb, and the tremors caused widespread damage to buildings and infrastructure, including historic structures in the city center.

The earthquake resulted in the collapse of rooftops, chimneys, and facades, posing a significant threat to public safety. Fortunately, there weren't many casualties, but many residents were left temporarily homeless, with some seeking refuge in emergency shelters. This seismic event served as a stark reminder of the earthquake risk in the region and prompted discussions on the need for better preparedness and building resilience. It also highlighted the importance of continuous monitoring and early warning systems to mitigate the impact of future earthquakes in Zagreb and its surrounding areas.

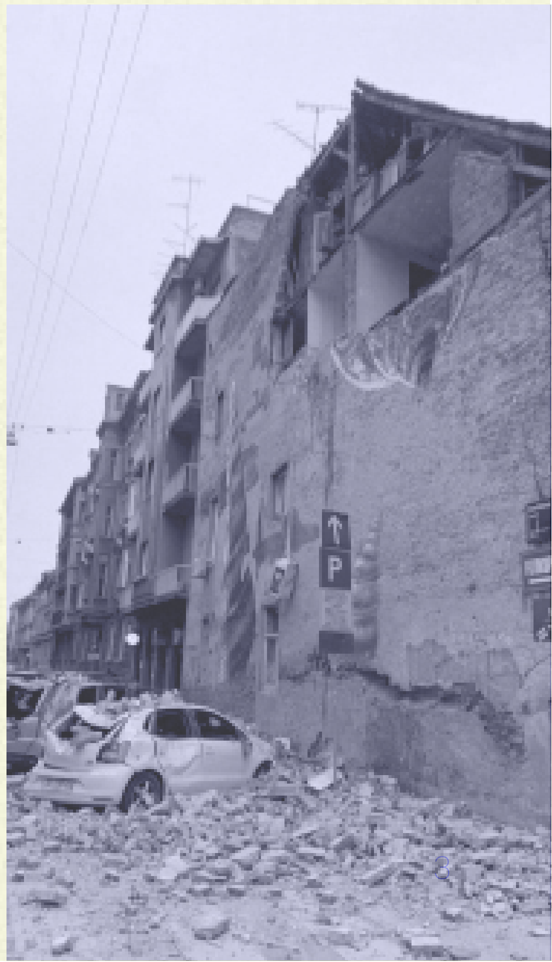
Figure 1. - Damage to the local church after the 1880. earthquake in Zagreb

Figure 2. - Epicenter of 2020. earthquake in Zagreb

Zagreb's susceptibility to seismic activity can be attributed to its geological features, primarily the presence of several fault lines under and near the city. The Medvednica Fault, situated to the northwest of Zagreb, has historically caused seismic activity, affecting nearby areas. Additionally, the nearby Sava Fault System, part of a larger tectonic boundary in the region, plays a role in the seismic activity experienced in Zagreb. The interactions between these fault systems can lead to increased seismic potential in the Zagreb area. Understanding the geology and the fault systems in and around Zagreb is crucial for earthquake preparedness and risk mitigation. The ongoing monitoring and research of the fault systems remain essential for improving the city's resilience to earthquakes.

Later that same year, Zagreb experienced another earthquake, this time with its epicenter near the town of Petrinja. This earthquake registered a magnitude of 6.4 on the Richter scale, making it a powerful and shallow seismic event. It caused extensive damage to buildings and infrastructure in Zagreb, despite modern construction standards helping to mitigate the destruction to some extent. The event highlighted the ongoing vulnerability of older, historic buildings in the city center, with roofs, walls, and several important cultural and historical sites suffering damage. This earthquake underscored the need for enhanced seismic resilience.

Figure 3. - A collapsed wall and a ruined building in the city centre of Zagreb



Buildings of Zagreb

Architecture

Zagreb, the capital of Croatia, has a diverse architectural landscape that reflects its rich history and culture. The city's buildings encompass a wide range of styles, each contributing to its unique character.

In the city center, you'll find historic masonry buildings with substantial walls, often measuring around 60 to 70 centimeters in thickness. These structures typically feature wooden constructions and incorporate a mixture of materials, including small stones that serve as sound insulation, bulrush, and plaster. Many of these buildings date back to the 19th century, showcasing intricate architectural details that add to the city's charm.
The architectural landscape evolved over time, influenced by factors such as the 1880 earthquake. Before this seismic event, buildings often featured weak concrete construction, but afterward, the city shifted to reinforced concrete structures, following contemporary construction practices.

Today, Zagreb's building types vary, encompassing reinforced masonry, reinforced concrete houses and buildings, and even prefabricated wooden houses, all designed in compliance with modern building codes and standards.

However, the majority of buildings in the city center are characterized by masonry structures with substantial walls, wooden construction on top, and a mix of materials, including small stones and plaster.

Prior to 1968, Zagreb largely relied on buildings with relatively weak concrete structures, which had limitations in terms of seismic resilience. Post-1968, there has been a shift towards reinforced concrete constructions, in compliance with contemporary seismic safety standards, such as the Eurocode.
The problem of old and weak buildings still remains. This is accompanied by residents inability to properly take care of the buildings due to very steep maintenance prices. It's important to acknowledge that these are the most at-risk areas, susceptible to structural damage and collapse during seismic events.

These historical structures, typical of the city's core, may lack the seismic retrofitting required to withstand the potential seismic threats, highlighting the need for focused efforts in enhancing the earthquake resilience of these buildings.

Figure 4. - Historic buildings in the city centre, Jelacic Square

Figure 5. - Post 1968. buildings of Zagreb

Figure 6. - an example of an old historic city centre building, Miroslav Krleza insitute

Figure 7. - an old cit centre building, City Assembly

Figure 8. - a side wall of an old building in the city centre, incorrectly fixed after the earthquake

Figure 9. - an old building in the city centre, left with many damages after the earthquake

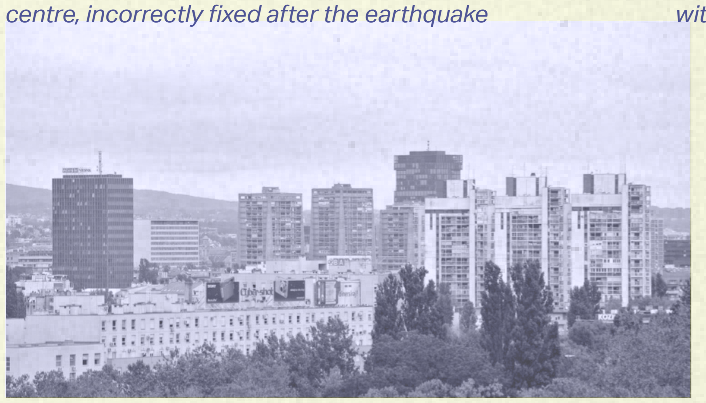


Figure 10. - an example of post 1968. buildings

Figure 11. - an example of post 1968. buildings

Figure 12. - private masonry house, without reinforcement

Figure 13. - private masonry house with little to no reinforcement

Figure 14. - damages in the Clinical hospital of Zagreb after the earthquake

Figure 15. - damages in a private home after the earthquake

Figure 16. - damages to an improperly built building in ZG

Figure 17. - damages to a hospital

Figure 18. - damaged outer walls of historic buildings, fallen on nearby cars in the city centre

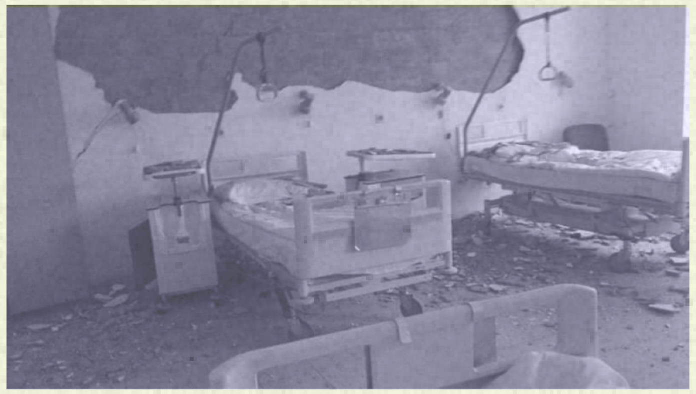


Figure 19. - damages to a hospital in Zagreb

Figure 20. - damages to an office, after the Zagreb earthquake

Figure 21. - damaged roofs due to old chimneys falling through

Figure 22. - old chimney fallen on the street of Zagreb city centre

Interview with a building engineer from Zagreb

In a quest to gain deeper insights into the seismic vulnerabilities of buildings in Zagreb, I conducted an interview with a seasoned building engineer and expert from the city. With a wealth of experience in designing houses for seismically active areas, inspecting existing structures, and estimating damage, this expert provided a unique perspective on the complex challenges faced by Zagreb's architectural landscape.

The interview shed light on the multifaceted reasons behind the structural damage experienced by buildings in the city center. While the age of the buildings and the use of subpar construction materials played a significant role, the expert emphasized additional contributing factors. One critical issue was the lack of proper care for these historic structures, allowing moisture to infiltrate basements and damage walls over time.

Improper renovations also surfaced as a key concern. These renovations, although well-intentioned, often led to the creation of soft floors, particularly on the ground level. The consequence of such modifications, the expert pointed out, could be detrimental, as they sometimes resulted in floor rotation. This rotation, he explained, could occur when the underlying structural grid (raster) was irregular, undermining the building's stability and seismic resilience.

The interview with this expert provided invaluable insights into the intricate web of challenges contributing to the seismic vulnerabilities of Zagreb's historic buildings. The knowledge gained through this conversation will serve as a valuable resource for the ongoing research and design efforts aimed at enhancing the earthquake resilience of Zagrebs inhabitants.

> "Zagreb was very lucky that the 2020. earthquake with the epicentre beneath the city was not stronget than 5.5 in intensity. If that had been the case, the whole city center would've been leveled with the ground."
>
> – ir. I. Kutija

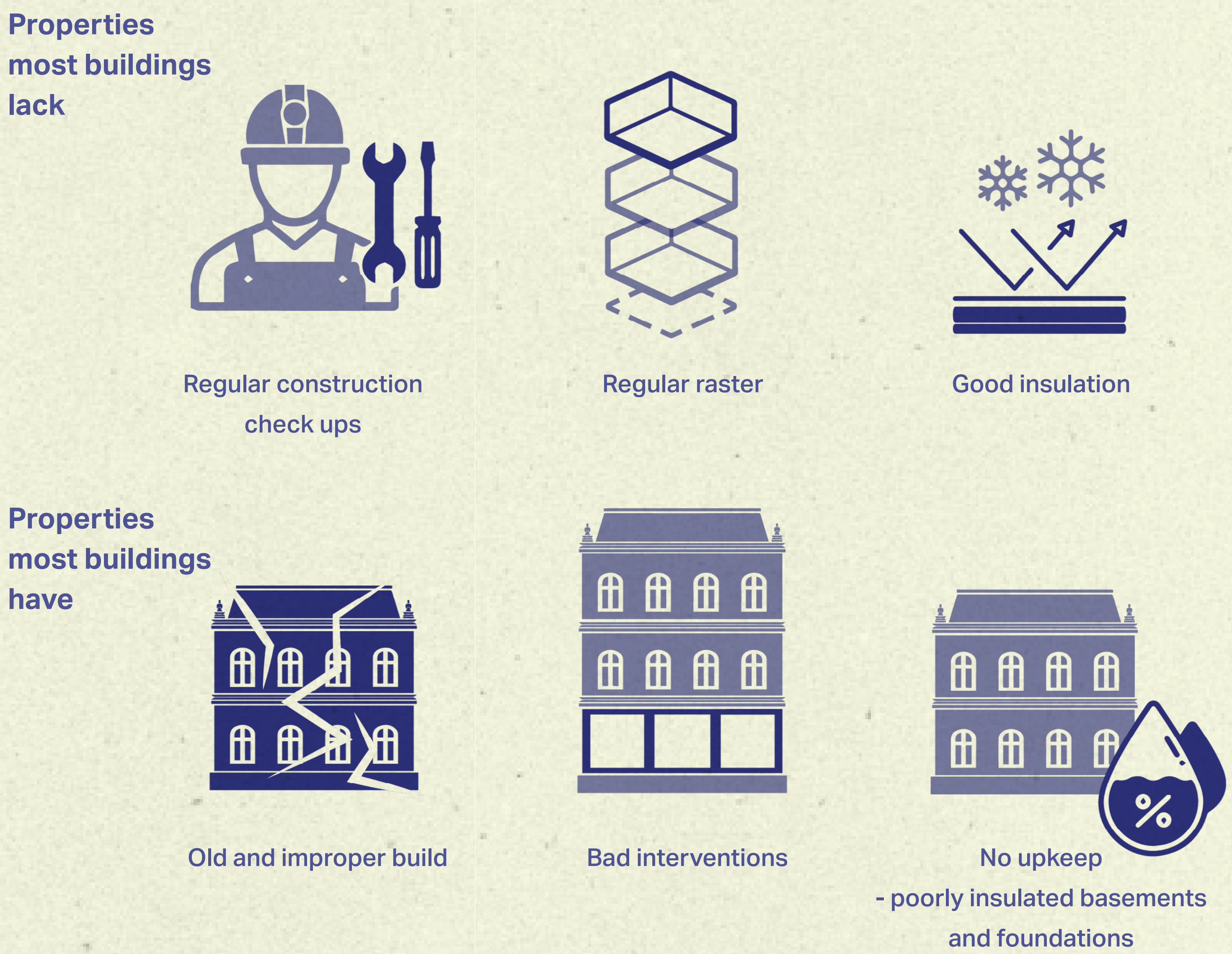


Figure 23. - Building properties in Zagreb

Research question

The main research question emerged from an observation of the living conditions and challenges faced by many residents in Zagreb, whose homes and lives are influenced by the seismic activity of the area. The research aims to offer a glimmer of hope and a potential path towards a safer, more secure future for the residents of Zagreb.

The main research question served as the starting point for the development of more specific sub-questions (*for full sub-question list, see Appendix*). These sub-questions helped tackle specific problems, and guided the research towards concrete and actionable findings. They included inquiries into the root causes of building collapse during seismic events, the primary causes of injury and loss of life, the factors contributing to human suffering in the aftermath of earthquakes, and the current state of available solutions. These questions allowed for a structured start of the research, and a look into multi-faceted challenges posed by seismic vulnerability, ultimately aiding in the formulation of effective strategies and designs to enhance the resilience and well-being of Zagreb's residents.

Figure 24. - Old building in the city centre of Zagreb after the 2020. earthquake, photo by Josip Regovic

How can a **cost-effective** and **aesthetically acceptable** solution be designed to **minimize the human suffering** experienced by individuals living in 19th century buildings in seismically active Zagreb?

Figure 25. - A mother and a daughter homeless after the 2020. earthquake in Zagreb, photo by Zeljko Lukunic

Background

- Approach
- Interviews

This chapter serves as a first step into the research process. Here, it's delved into the chosen approach that underpins further investigation, offering insight into the methods employed to gather essential data and insights. It places a particular emphasis on interviews, a primary source of firsthand information, which forms the basis of my research throughout the project.

This exploration of background information is an essential step before the subsequent phases of the concept development, guiding towards a deeper understanding of the seismic challenges that are aimed to be addressed.

02

Approach

Methods

In the course of my project, I employed a multi-faceted research approach that integrated literature research, interviews with relevant user groups, cause-effect analysis, and the Inside Out Design method. Each of these methods served distinct and valuable purposes in the development and design process. These methods allowed to identify pain points in peoples experiences, as well as draw out relevant requirements which allowed for the development of concepts.

I started with conducting extensive literature Research, to gain a comprehensive understanding of the existing knowledge, best practices, and prior solutions related to my project. This method allowed me to build a solid foundation, drawing from the wealth of knowledge in relevant fields. By reviewing academic studies, reports, and articles, I ensured that my project was informed by the latest insights in the subject matter.
The direct engagement with relevant user groups was crucial in gathering first hand insights and feedback. By conducting interviews, I was able to empathize with the unique needs, preferences, and pain points of the end-users. This approach not only provided a qualitative perspective but also established a human-centered design framework, ensuring that the final solution is tailored to the real-life experiences and challenges of the intended users.
Cause-effect analysis helped me dissect complex problems and understand the interplay of variables within the context of my project. By identifying root causes and potential consequences, I was able to make informed decisions and develop targeted solutions. This method acted as a diagnostic tool, enabling a more precise understanding of the problem's underlying dynamics.
After choosing a concept, I used inside out design in order to put function of the product first, and design the aesthetics from the function, which in a way already helped me determine other design aspects, like the shape and materials needed to create a lasting product.

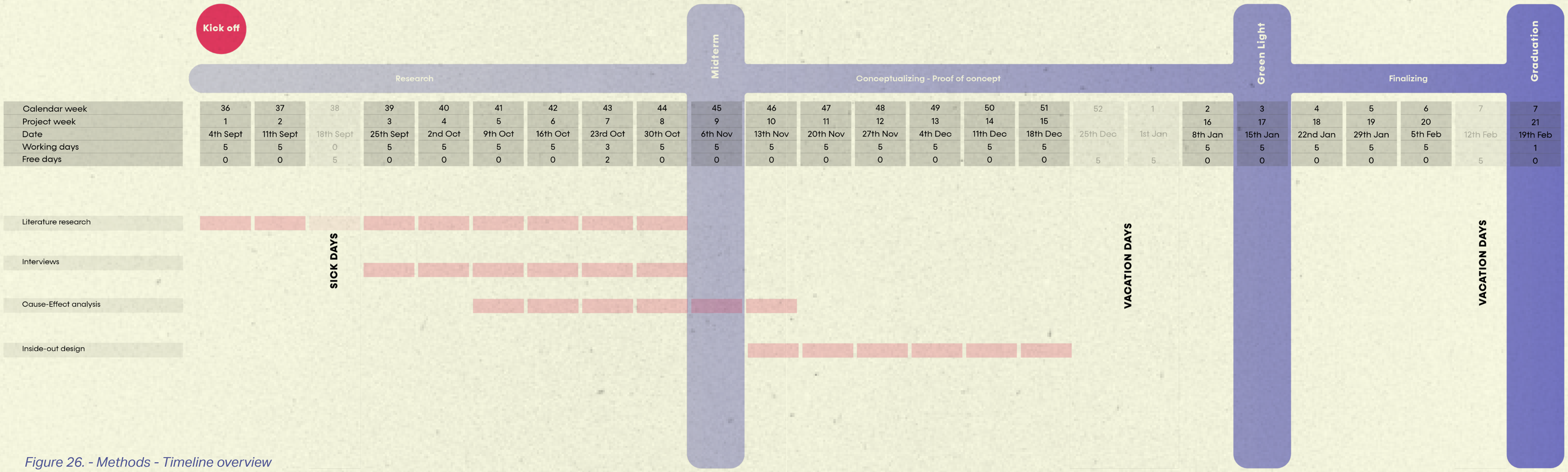


Figure 26. - Methods - Timeline overview

Interviews

People from Zagreb

The interviews conducted with a diverse set of participants offered invaluable insights into how people with varying types of housing experienced and coped with the seismic events, shedding light on the nuances of their individual circumstances and responses. These interviews encompassed a spectrum of living conditions, including two residents in concrete reinforced buildings on the sixth floor, two on the second floor, and two individuals living in the historical 19th-century buildings within the city center. Additionally, the perspective of two 7-year-old children was included, offering a unique and unfiltered viewpoint.

Through these interviews, an understanding of earthquake preparedness, resilience, and responses emerged. Residents in concrete reinforced buildings on higher floors discussed their experiences with swaying structures and the need for secure furniture. Those on lower floors emphasized concerns about rapid evacuation and accessibility. In contrast, inhabitants of the 19th-century buildings in the city center shared their stories of enduring structural vulnerabilities and the emotional attachment to their historic homes.

The inclusion of young participants brought a unique viewpoint to the research, highlighting the need for age-appropriate earthquake education and awareness. Their experiences and perceptions added a layer of understanding to the overall findings.

These interviews not only provided a comprehensive view of the challenges and adaptive strategies associated with various housing types but also underscored the importance of tailoring earthquake preparedness and mitigation efforts to suit the diverse needs of the community. The insights gained from these interviews will serve as a cornerstone for further research and design exploration, ultimately contributing to the development of more effective and sensitive solutions for seismic resilience in Zagreb's unique urban context.

The interviews were done in person with individuals, and in order to best capture the answers I used a recorder as well as writing down the answers. This flexible approach of capturing the responses allowed me to have a more fluid conversation with the participants and note any extra information that they wanted to reveal about their experiences.

Figure 27. - Interviewees, overview of groups

How much do you know about earthquakes?

- I know the bare minimum about earthquakes
- I know a little bit about earthquakes now, not too much, more about the Croatian area
- I know roughly about earthquakes, why they occur, what they are, etc., basic things, I know about the consequences
- I know enough about earthquakes, how they manifest, and what is the likeliness for them in Croatia, and at which areas, definitely learned more after I've experienced it

How much did you know about earthquakes before you experienced one?

- I didn't know anything about earthquakes before
- Before the earthquake I knew what I saw on the news, didn't think about it, it was always somewhere further away, the last I heard about the earthquake in Italy, a lot of damage and injuries, in our area, I had no knowledge about earthquakes before, that's all
- Before the earthquake I didn't have much knowledge, it always felt like something that happened in other places, not in my country
- I knew big earthquakes could have catastrophic consequences

What kind of building/house are you living in?

- I live in the center, old buildings, wooden beams, stone and shade in between, second floor
- Type of building - modern construction, reinforced concrete, on the third (last) floor
- Type of building - modern construction, reinforced concrete, on the sixth floor, a bigger building, it has a wide base

Are you aware of weaknesses of your home?

- Cracks in the walls, they needed to be renovated; reinforced with another row of beams on the floor and ceiling; the gable walls of the upper floor were renovated with lightweight material; weak points - foundations, old materials, thick noise that cracks and falls; renovated everything, they want to strengthen the building; possible wall cracking in a strong earthquake
- The biggest problem is the chimneys and side walls, the chimneys are too heavy and big, not attached properly, they fall either inside the building or on the road, there are holes in the roof
- I don't know exactly, I haven't seen the earthquake study, I know that a fault line passes in front of the house
- not sure, I am assuming it could be the buildings hallway (the staircase)
- I don't know

How did the 2020. earthquake affect you?

- Very badly psychologically affected by the earthquake, fear, restlessness, it is difficult to return to normal life; a lot of moving, a feeling of helplessness
- Quite shaken mentally, never experienced anything like that before; very mentally disturbed, it took a long time for him to relax
- Constantly waiting for a new blow, when a truck or bus passes by and a vibration is felt, everyone waits and watches to see if there will be an earthquake; fear of the building collapsing, fear for the family
- A lot of stress, mostly fear for my children and family, stress if we all weren't in the same place, not knowing how to contact them...Very mentally disturbed, it took a long time for him to relax; waiting for a new earthquake
- Some stress, although I think it didn't impact me as much as it did my family, mostly I cared that everyone was safe; the earthquake didn't impact me long term
- A lot of stress, mostly fear for my family, I cannot move as fast as them, and I fear of being a burden or holding them back and putting them in danger, I fear for my grandchild

How did you feel during the earthquake?

- Great fear, shock, the greatest fear for the child, a feeling of helplessness, fear of letting the child go to the bathroom alone, fear of letting the child sleep alone in the room
- Fear and panic, helplessness, rush of adrenaline to gather everyone together

- *Shock and confusion, especially as it happened while we were still sleeping, then fear and instinct to gather everyone and leave as soon as possible*
- *Really scared, I was with my mom, and there was a lot of noise*

How did you feel after the earthquake?

- *Adrenaline, protection, get out of there, not caring about the property*
- *Panic, fear, the house scattered, broken windows, broken pictures, the instinct to survive, get out of the building as soon as possible*
- *Panic, fear, the house had cracks, everyone was very scared, wanting to get out*
- *It was scary, wanted to leave, didn't know what was happening*

Did you, or anyone in your household, get injured?

- *No, in the end thankfully everyone was okay, but a lot of stress*
- *Yes, one member of the family stepped on some glass from broken decoration*

How did you feel living in your home after the earthquake?

- *Insecure, scared, inability to sleep, powerless to solve problems - at night they slept with spoons and pots next to their beds, lamps*
- *Insecure, fear of repetition or a stronger earthquake, the question of what if, how the house will handle it*
- *Constant fear for the family*
- *The earthquake did bring a lot of stress, but I felt secure in our home because I had trust in the building*
- *I don't care so much for me but more for my daughter and grandchild*
- *I was scared, I don't like to be alone in rooms, I also feel scared for my mom, and I feel sad because she gets sad*

Did you practice any protection methods during the earthquake?

- *Went under the doorway*
- *Stood next to the load bearing wall*
- *No*

Did your life (in any way, physical or mental/emotional) change after experiencing the earthquake?

- *Life after has changed, different thinking, greater caution, everything I buy I see that it is adapted for an earthquake, where I go I see what kind of real estate is, life in fear, big change*
- *Experiencing an earthquake, awareness, learning about an earthquake*
- *More stress and thinking about everything that we put in the home*
- *More stress for loved ones*

How did the aftershocks affect you?

- *No sleep, horrible, fear all over again*
- *Fear for loved ones, conctantly waiting for a bigger impact*
- *Additional stress, panic, fear*
- *They are really scary, and always make me feel sick (nauseous)*

How did you adapt your home for seismic acitvity?

- *Renovation of the building - the entire building invested, in a loan of €250,000 - on the staircase, attic, basement, roof; the ceiling had to be restored, a network of chains holding the bricks (ceiling) was placed horizontally, injection technique; only I did the strengthening of the floors*
- *Securing pictures to the wall, as well as fixing furniture to the wall*
- *Basic renovation*
- *I didn't adapt the home, there wasn't any significant damage*
- *I moved heavy objects to lower heights*

Conclusion

The findings from the interviews conducted with a diverse group of participants in Zagreb following the earthquake were consistent in highlighting the significant and lasting impact of the seismic event on their lives. The overarching theme that emerged was a pervasive sense of stress and anxiety experienced by all participants, both immediately after the earthquake and in the ensuing months. The uncertainty stemming from the continuous aftershocks and the looming threat of a potentially stronger earthquake weighed heavily on their minds.

> **"For weeks we slept with cooking pots and spoons next to our beds, fearing the worst..."**
> **– Female, 26, living in an old building in the city centre**

Notably, the highest levels of stress were expressed by individuals residing in the old buildings within the city center. They grappled with the acute awareness that their homes were structurally unsafe, which led many to make the difficult decision to temporarily or permanently vacate their dwellings. This upheaval in their lives further compounded the emotional strain.

A prevalent source of stress was the feeling of helplessness, as participants expressed their inability to adequately protect their loved ones, particularly parents with young children. The earthquake served as a harsh teacher, illuminating the gaps in their knowledge about seismic risks and the lack of preparedness, prompting a desire to learn more about earthquake safety.

Residents of old buildings in particular faced a financial burden. The seismic vulnerabilities of their homes necessitated costly interventions to secure them. Often, the entire building community had to take on substantial loans to finance essential renovations. These interventions included measures like removing or securing chimneys, reinforcing staircases, and fortifying weight-bearing walls, highlighting the considerable financial toll exacted by the earthquake.

In sum, the interviews unveiled feelings of stress, uncertainty, and resilience within Zagreb's earthquake-affected population. These findings will be used for further research and guide the design efforts aimed at mitigating the human suffering associated with seismic events in this historic and seismically active city.

Discussion

The interviews aimed to explore the factors contributing to issues and suffering during and after earthquakes. Participants were questioned about their general earthquake knowledge, living conditions, and their emotions during and after the 2020 earthquake. The responses often highlighted feelings of anxiety, helplessness, fear, and particular concern for loved ones. Participants expressed their distress in feeling unable to assist those in need, such as their children, or not having information about the safety of family and friends. These emotional responses were frequently linked to residing in older or structurally unreliable buildings, resulting in uncertainty about the buildings' resilience to stronger seismic events.

Some participants reported experiencing post-traumatic stress disorder (PTSD) symptoms and heightened stress triggered by vibrations, even from sources like buses or trams. Notably, participants residing in buildings known to be seismically safe reported lower stress and fear levels compared to those in older, more vulnerable structures.

However, it's essential to acknowledge potential limitations in the interview process. My personal earthquake experience and potential biases could have influenced the framing of questions and interpretation of responses. While this familiarity might have facilitated more targeted inquiries, it could also have led to overlooking certain aspects that a less-biased interviewer might have considered. This dual perspective could be seen as both an advantage and a limitation.

To address potential researcher bias, future research might benefit from having a separate interviewer who can maintain objectivity.

Another aspect to consider is the sample size and representativeness of the interviewees. The limited number of participants may not fully capture the diversity of earthquake-affected populations in Zagreb. Future research recommendations include conducting interviews with a broader and more diverse selection of participants to obtain a more comprehensive understanding of earthquake-related experiences and perspectives.

Analysis

- Scenarios
- Pain points

This analysis delves deeper into the experiences of individuals affected by earthquakes. The exploration will be guided by creating different scenarios, crafted from insightful interviews with target groups in Zagreb.

The presented scenarios will paint vivid and insightful pictures of earthquake-related situations, illuminating the complex and versatile interactions and challenges that arise during such events.

Ultimately, the objective is to identify the pain points that emerge from this analysis. These pain points will help define requirements that will be used to guide the future research to develop solutions that address the real-world needs of those affected by earthquakes.

03

Scenarios

Representing challenges

To better understand the potential challenges and vulnerabilities faced by residents of Zagreb during seismic events, I created graphic scenarios depicting three different intensities of earthquakes: 5.5, 6.0, and 6.5 (*the strongest earthquake that can happen in Zagreb, Dr. Marijan Herak, 2013.*) on the Richter scale. These scenarios served as powerful tools for highlighting the specific problems that might unfold in each seismic event, laying the groundwork for further analysis and concept design.

In the scenario representing an intensity of 5.5, the focus was on demonstrating the initial impacts and immediate responses required. It illustrated the potential for structural damage, particularly in older buildings, and the need for swift evacuation protocols. The challenges presented included ensuring the safety of residents and addressing issues like fallen debris and disrupted utilities.

The 6.0 intensity scenario delved into a more powerful earthquake, emphasizing the amplification of structural damage and a heightened level of stress among the affected population. This scenario highlighted the importance of preparedness and emphasized the potential for building collapses, demanding effective emergency response and rescue operations.

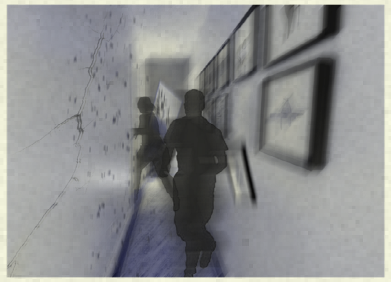
The most intense scenario at 6.5 underlined the severe consequences of a major seismic event. It portrayed extensive structural damage, potential loss of life, and the profound psychological impact on residents. This scenario illuminated the urgency of both short-term relief efforts and long-term seismic resilience measures.

By creating these graphic scenarios, I aimed to provide a visual representation of the challenges and vulnerabilities that arise at different seismic intensities, thereby laying the foundation for tailored concept designs to address these issues. These scenarios offer a comprehensive understanding of the evolving challenges during earthquakes, helping to inform the development of effective solutions and strategies to minimize human suffering in seismically active Zagreb.

5 a.m. - family peacefully sleeping in their apartment of an old building on the 2nd floor

5 a.m. - the shaking starts, abruptly waking the family up

5:01 a.m. - the shaking intensifies, fear kicks in, smaller furniture starts oveturning, debris is falling



5:01 a.m. - shaking is stronger and stronger, parents need to get to their child in the other room; cracks are visible, debris is falling, furniture and pictures are falling, glass is cracking

5:01 a.m. - on the way to the childs room mother steps on the glass from the fallen frames

5:02 a.m. - the child is awake and scared, doesnt know what's happening, parents come to get the child

5:02 a.m. - shaking continues, cracks are forming, debris is falling, beams are detaching, broken glass is on the floor; family stands below a doorway near a weight-bearing wall

5:03 a.m. - shaking stops, the family is in shock, quickly inspecting the condition of their apartment and assessing the quickest route to leave

5:05 a.m. - family is carefully leaving their apartment, assessing the condition of the staircase, and trying to step around the debris

5:07 a.m. - father is trying to call the rest of the family, but the call is not going through; feeling of helplesness and anxiety deepens

5:09 a.m. - family is desperate and stressed as they don't know if the rest of their family and friends are alive and well

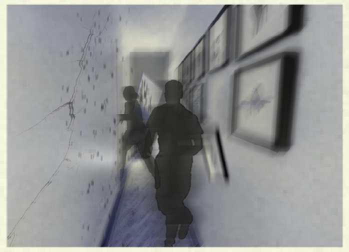
5:10 a.m. - family has left the building and is standing farther away from it, in case of aftershocks; they are in shock about what they went through, as well as seeing the condition of their building from the outside

Figure 28. - 5.5 earthquake intensity scenario

5 a.m. - family peacefully sleeping in their apartment of an old building on the 2nd floor

5 a.m. - the shaking starts, abruptly waking the family up

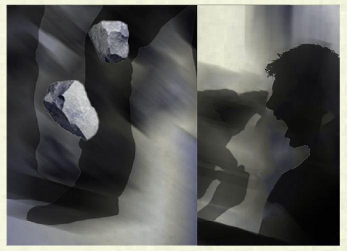
5:01 a.m. - the shaking intensifies, fear kicks in, smaller furniture starts oveturning, debris is falling



5:01 a.m. - shaking is stronger and stronger, parents need to get to their child in the other room; cracks are visible, debris is falling, furniture and pictures are falling, glass is cracking

5:01 a.m. - child is scared and alone, cannot leave the room as the doors are blocked by fallen materials

5:02 a.m. - parents cannot reach the child due to fallen materials and strong shaking



5:02 a.m. - shaking continues, cracks are forming, debris is falling, beams are detaching, broken glass is on the floor; during this shaking the father gets injured by falling material

5:03 a.m. - shaking stops, the family is slowly getting over the fallen furniture and materials and assesing the best way to leave the property

5:05 a.m. - family is carefully leaving their apartment, assessing the condition of the staircase, and trying to step around the debris

6:00 a.m. - the father is getting urgent help for his leg injury, the family knows they were lucky nobody got hurt in a greater way

6:30 a.m. - fmily is trying to call the rest of the family, but the calls are not going through; feeling of helplesness and anxiety deepens

6:40 a.m. - family is desperate and stressed as they don't know if the rest of their family and friends are alive and well

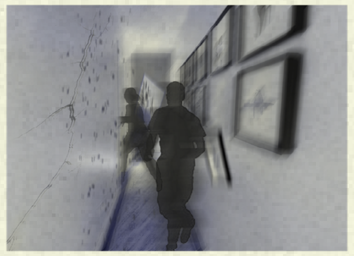
7:10 a.m. - family is reunited in front of the building and is standing farther away from it, in case of aftershocks; they are in shock about what they went through, as well as seeing the condition of their building from the outside

Figure 29. - 6.0 earthquake intensity scenario

5 a.m. - family peacefully sleeping in their apartment of an old building on the 2nd floor

5 a.m. - the shaking starts, abruptly waking the family up

5:01 a.m. - the shaking intensifies, fear kicks in, smaller furniture starts oveturning, debris is falling

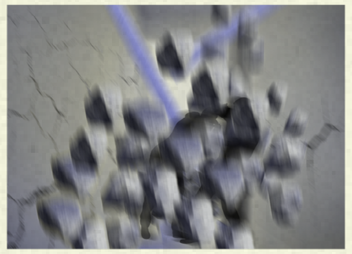


5:01 a.m. - shaking is stronger and stronger, parents need to get to their child in the other room; cracks are visible, debris is falling, furniture and pictures are falling, glass is cracking

5:01 a.m. - the child is awake and in fear, confused and unsure of what is happening; he tries to get out of bed and leave the room but cannot do it due to walls collapsing and too strong shaking

5:02 a.m. - parents cannot get to their child, the shaking is too strong and building is starting to collapse

5:02 a.m. - shaking continues, stronger and stronger, the family is getting injured, collapse is inevitable



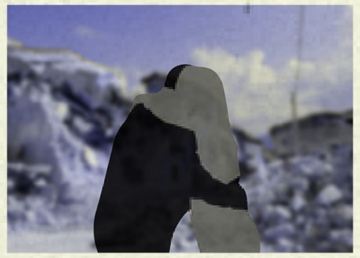
5:03 a.m. - shaking doesn't stop, walls and ceilings collapsed and are injuring and crushing the family

5:05 a.m. - building is in ruins, family members cannot be seen or heard; child is stuck under ruins, mother is not concious, and the father is bleeding to death

7:10 a.m. - rescue team and neighbours are trying to find the survivours and help get them out of the ruins; this step could last anywhere from hours to days

5:10 p.m. - after hours of searching, the child is found under the ruins, it is mostly unharmed

5:20 p.m. - the child is rescued and being transported to get emergency examination



6:30 p.m. - after they have been saved, the child and the mother reunite, greiving the loss of the father, who uncon-cious bled out under the ruins

Figure 30. - 6.5 earthquake intensity scenario

Pain points

Scenarios - conclusion

The scenarios presented are based on interviews with individuals from Zagreb who had experienced earthquakes, as well as expert insights on earthquake intensity and building damage potential. These scenarios serve as tools to simulate real-life earthquake situations, pointing out some of the challenges and difficulties that individuals face during seismic events.
The scenarios have pinpointed several critical issues that demand attention and resolution. These challenges have been synthesized into a set of Pain Points, representing the core areas requiring intervention and improvement. Here I've summarised the pinpoints, which will help define requirements for further design process.

Areas to address

In my pursuit of designing effective solutions to minimize human suffering during earthquakes, the research has revealed a range of present pain points that individuals in seismically active areas often grapple with. These pain points serve as factors to address during the conceptualization phase, as they point out the core challenges faced by communities and individuals. The pain points will serve to better define requirements, which are a much needed step before conceptualization.

Figure 31. - overview of pain points

Pain points

Helplessness Due to Lack of Knowledge: Many people feel helpless in the face of earthquakes due to a lack of awareness about earthquake safety measures and a dearth of knowledge about how to protect themselves and their loved ones.

Injuries from Falling Furniture and Structural Failures: Injuries often occur when furniture topples over or walls and roofs collapse during seismic events, posing a significant risk to personal safety.

Risk of Death and Crushing Injuries: The risk of death or serious injuries from being crushed, trapped under debris, or suffering structural collapses looms large during earthquakes.

Lack of Evacuation Plans and Safety Measures: Communities often lack well-defined evacuation plans and the correct safety measures to guide residents during seismic events.

Affordability of Solutions: Many individuals and families face barriers to accessing affordable solutions to fortify their homes against earthquakes, compounding their vulnerability.

Scarcity of Solutions on Micro and Macro Levels: The absence of practical solutions that cater to both individual households and communities perpetuates the burden of stress and insecurity during and after earthquakes.

Long-lasting Anxiety and Stress: Even long after a significant earthquake event, the lingering anxiety and stress experienced by individuals can have a profound and lasting impact on their well-being.

Feeling Unsafe in One's Own Home: The unsettling feeling of insecurity within one's own home due to the looming threat of earthquakes is a constant source of distress.

Figure 32. - A son and a mother hours after the 2020. earthquake in Zagreb, photo by Damjan Tadic

As the phase of conceptualization starts, these pain points will be a base for creating requirements, informing the design and development of solutions that aim to alleviate the profound suffering experienced by individuals living in seismically active areas. My ultimate goal is to create problem solving, affordable, and accessible measures that empower communities and individuals to navigate seismic events with greater safety and peace of mind.

Concept exploration

04

- Requirements
- Conceptualization
- Evaluation

In order to start conceptualizing, a structured approach is needed, aimed at defining precise requirements derived from the insights gathered in previous chapters. These requirements will serve as the guidelines to devise relevant solutions for the diverse challenges that arise during earthquakes.

The approach will be to focus on the creation and evaluation of a range of concepts tailored to address various earthquake-related issues. These concepts will be evaluated through The Harris profile, through which it's aimed to identify the concept that aligns most closely with the defined requirements and holds the potential to make a substantial impact.

The selected concept will serve as the core of the future design process. As the design process moves forward, focus will shift towards refining and expanding upon this chosen solution, paving the way for a tangible and effective response to the unique challenges presented by seismic events.

Requirements

The previously identified pain points served as a base in defining the requirements for further designing. These requirements will help steer the conceptualization process, as well as evaluate the concept choices. In the graphic bellow, a list of requirements is shown. All of the bellow mentioned requirements have been evaluated (*for full evaluation of requirements, see Appendix*) in order to get ranked by their importance, and in such a way a hierarchy of demands and wishes was created.

Figure 33. - Project requirements

Research question

How can a **cost-effective** and **aesthetically acceptable** solution be designed to **minimize the human suffering** experienced by individuals living in 19th century buildings in seismically active Zagreb?

In order to better understand the listed requirements, it is usefull to revisit the Research Question and focus on the most importans aspects mentioned in it. The requirements are formed based on the information gained from interviews, which resulted in scenarios, from which Pain Points were made. All of these combined, together with research question, serve as a ground for defining these requirements.

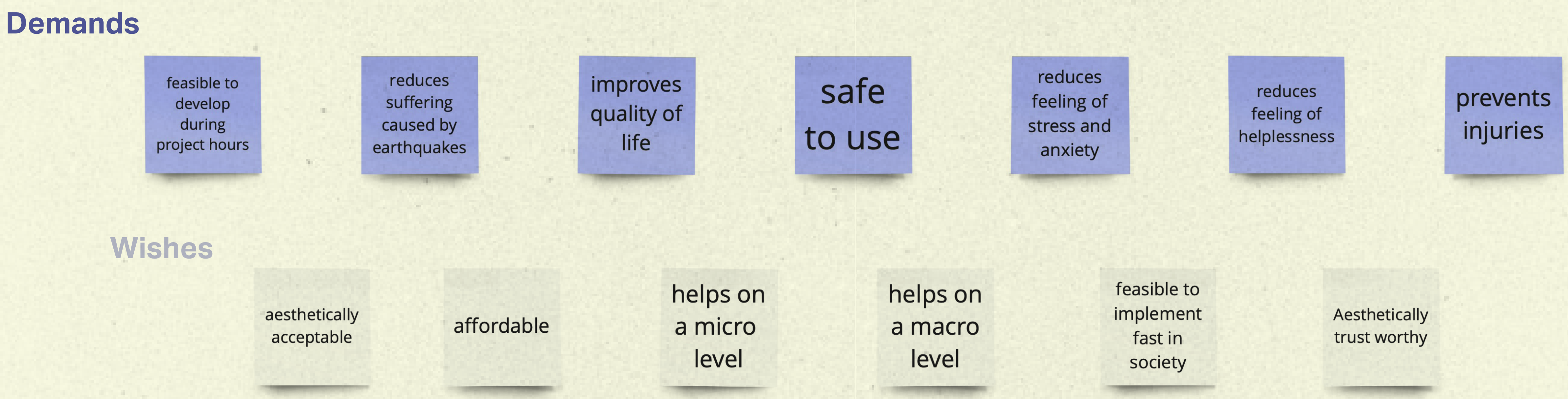


Figure 34. - Project requirements and their relevance from left to right, top to bottom, divided into demands and wishes

Conceptualization

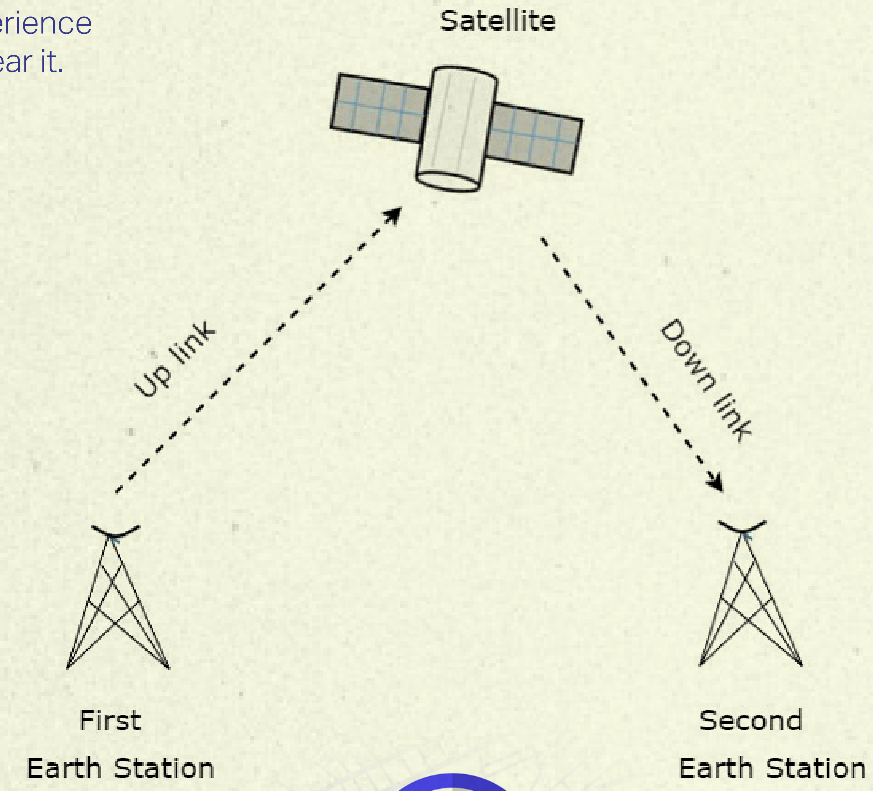
Concept 1 - Embrace

The 'Embrace' concept, a solution designed to address the profound sense of helplessness experienced by individuals during and after earthquakes, a scenario all too familiar to those living in seismically active regions. One of the most distressing aspects of such events is the uncertainty surrounding the safety and well-being of loved ones when communication lines are disrupted.

'Embrace' offers a wearable lifeline, taking the form of a bracelet that can be comfortably worn at all times. It's a simple yet incredibly powerful tool, allowing individuals to establish immediate contact with their loved ones, even in the most chaotic of circumstances. With a few swift gestures, users can transmit crucial information: their location, status (whether they are well, injured, or trapped), and even their heartbeat – a subtle yet vital indicator of their overall condition.

This innovative product not only provides much-needed reassurance during the chaos of an earthquake but also serves as an invaluable resource for search and rescue efforts. 'Embrace' can aid in locating individuals who may be trapped or injured, accelerating the response time of first responders and potentially saving lives.

The 'Embrace' concept exemplifies the fusion of technology and empathy, offering a solution that not only reduces stress during seismic events but also contributes to the safety and well-being of individuals and their communities. By providing a direct line of communication and valuable health data, this wearable offers a sense of control and connection during times of crisis, ultimately transforming the experience of earthquakes for those who wear it.



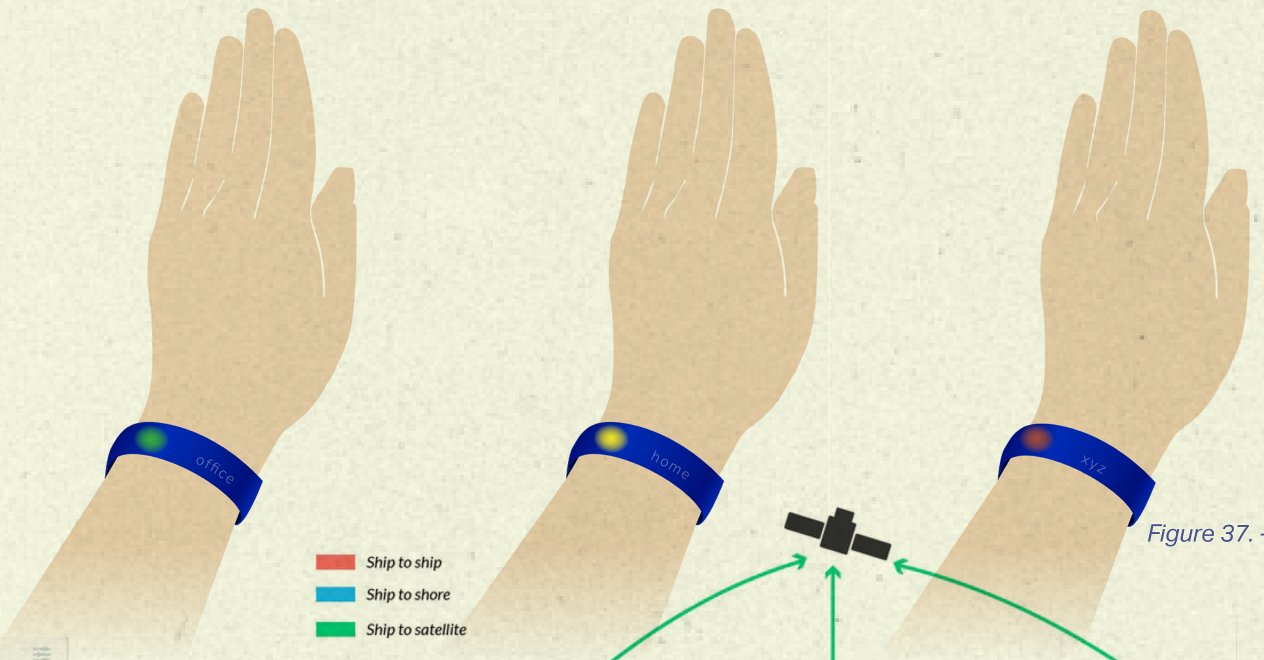


Figure 37. - Embrace sketch

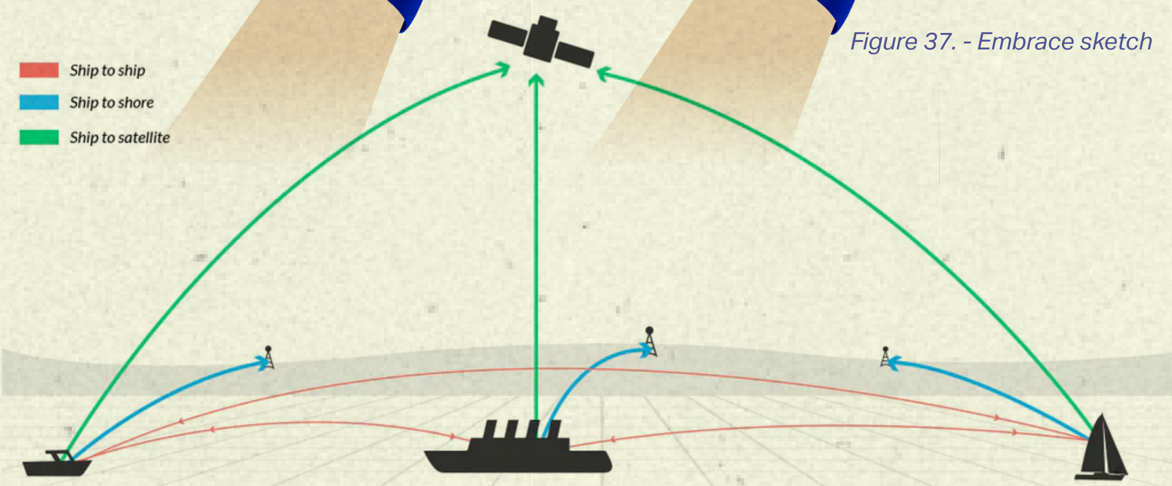


Figure 36. - AIS For Bluewater Sailing Yachts

Figure 35. - Smart watch functionalities - heart rate sensor, temperature sensor, movement sensor...

Concept 2 - QuakePlan

The second concept, 'QuakePlan,' is an app designed to empower individuals with a proactive approach to earthquake preparedness. This innovative tool offers a comprehensive and personalized solution, making it easier for users to safeguard their homes and loved ones in the event of a seismic event.

At the heart of 'QuakePlan' is its home-scanning feature. Users can scan their homes, taking into account the layout, existing furniture, and its placement throughout the space. The app uses this data to generate a personalized home plan tailored to the user's specific circumstances. This plan goes beyond generic advice by providing actionable, customized recommendations that enhance earthquake preparedness.

One of the standout features of 'QuakePlan' is its ability to create personalized evacuation plans. By analyzing the scanned data, the app can suggest optimal escape routes and point out potential obstacles that could hinder safe egress during an earthquake. For example, it may recommend moving a coffee table to ensure unobstructed exit paths or advise against placing artworks with glass coverings in passageways to prevent injury during tremors.

Additionally, 'QuakePlan' has the potential to serve as a post-earthquake assessment tool. Users can employ the app to estimate the damage to their homes, providing valuable insights not only for personal use but also to ease the workload of building engineers tasked with assessing numerous properties after a seismic event.

In essence, 'QuakePlan' empowers individuals to take proactive measures to protect their homes and loved ones. By offering personalized guidance and practical solutions, this app transforms earthquake preparedness into a tangible and accessible process, enhancing safety and resilience in the face of seismic events.

Figure 38. - Interior design app

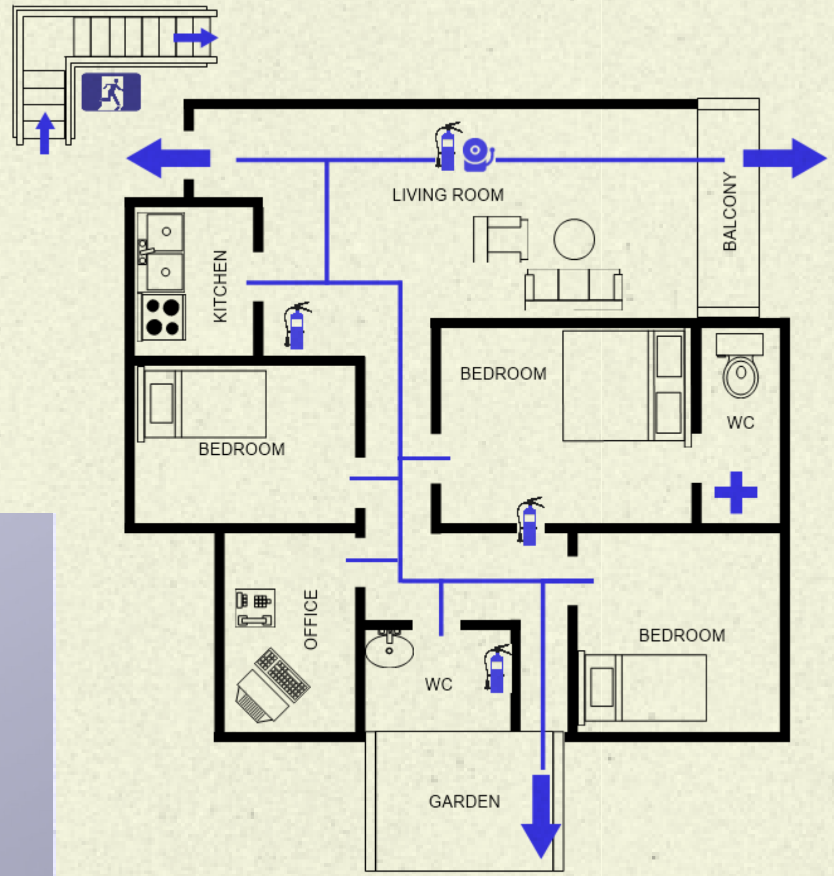


Figure 39. - Evacuation plan

Figure 40. - Scanning of the home through the app

Concept 3 - The Seismic Shield furniture line

The third concept focuses on furniture design that places seismic safety at its core: the SeismicShield Furniture Line. In regions prone to earthquakes, ensuring the safety and well-being of residents is of main importance, and this innovative furniture line is engineered to serve as more than just décor—it's a lifeline during seismic events.

The SeismicShield Furniture Line should incorporate a range of adaptations that make it primarily earthquake-resistant. One design intervention is the design of a wider and more stable base, ensuring that items like tables and cabinets won't tip over during tremors, reducing the risk of injury. But what sets this furniture line apart is its transformative potential to provide rapid protection in the face of building collapse.

Imagine a dining table that can be quickly converted into a sturdy shelter, complete with impact-resistant materials, offering a safe haven in the event of structural failure. Or a wardrobe that can serve as a protective cocoon, providing a secure space for individuals to seek refuge during an earthquake. Even a chair with a slide-out protection lid, instantly accessible when needed most. The SeismicShield Furniture Line empowers users to harness everyday objects as swift and reliable tools for personal safety.

This concept not only redefines the role of furniture but also exemplifies the fusion of design and seismic resilience. It's an embodiment of the philosophy that functional and aesthetically pleasing pieces can also be lifesaving assets during times of crisis. With the SeismicShield Furniture Line, homeowners in seismically active areas can enjoy the peace of mind that their furniture isn't just an addition to their decor—it's a protector of their well-being.

Figure 41. - modular furniture

Figure 42. - tungsten plates for reinforcement

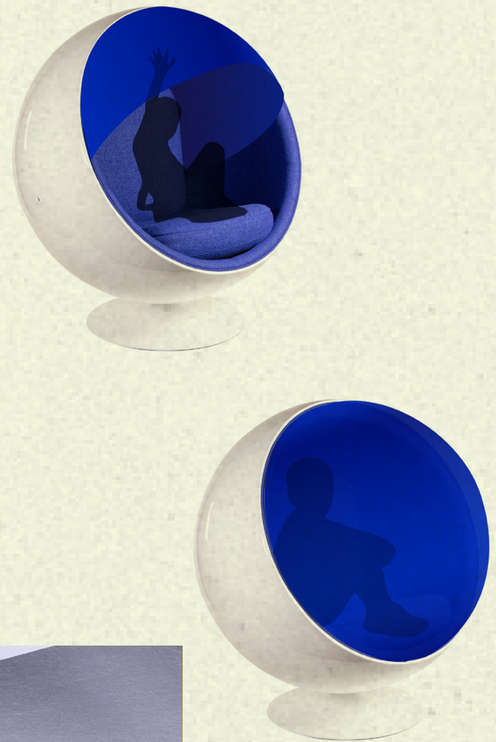


Figure 43. - Seismic shield sketch 1

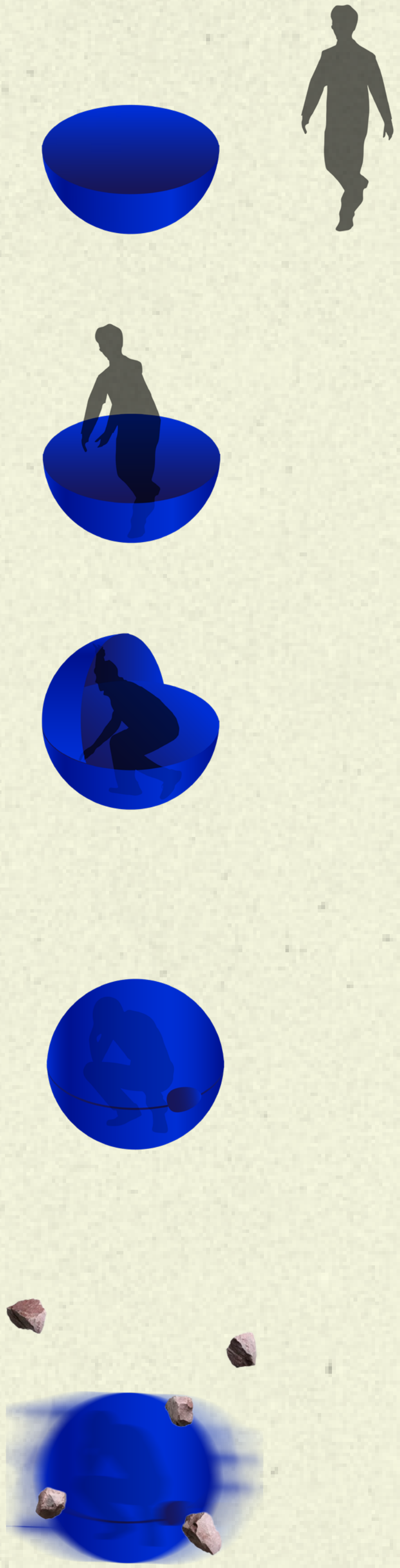
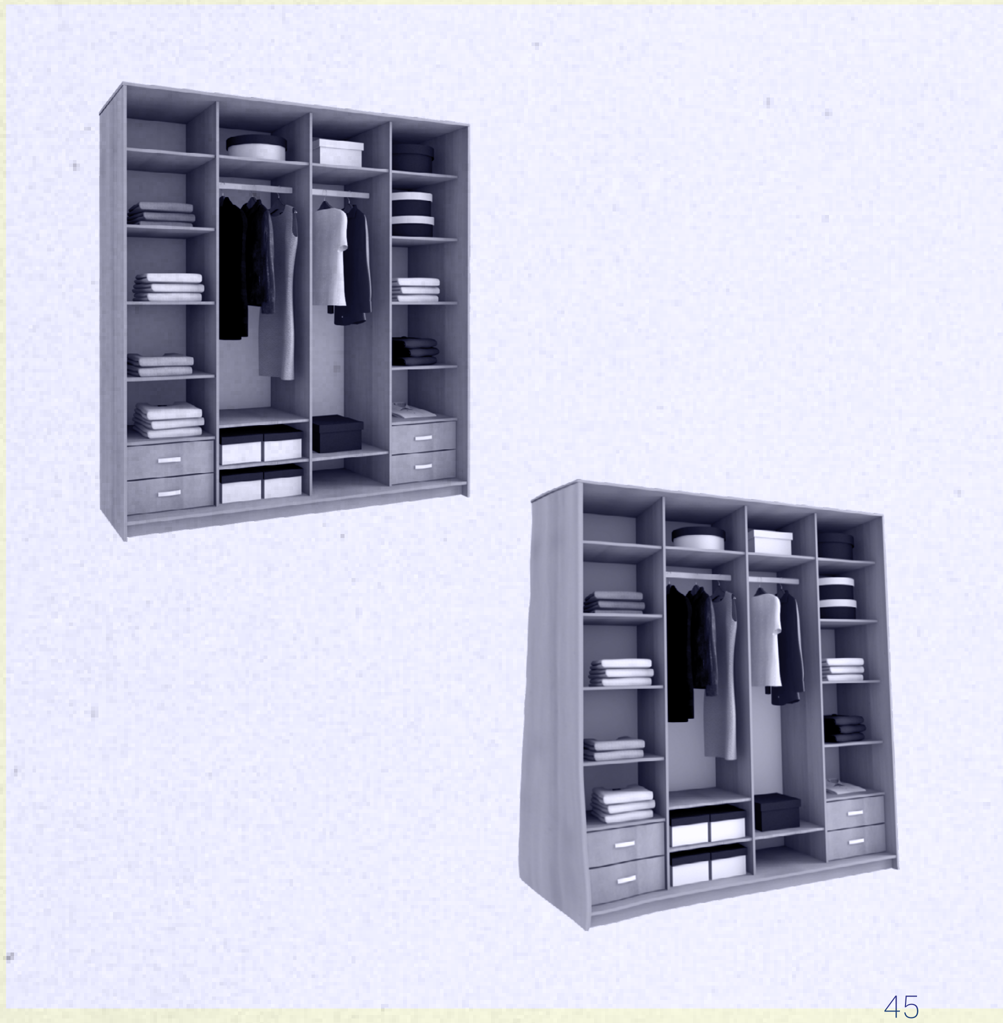


Figure 44. - Seismic shield sketch 2

Figure 45. - wardrobe redesign with wider base



Concept 4 - QuakeNet

The fourth, the Modular Construction Product, addresses the overall reinforcement of a home. In seismically active regions, the need for enhanced structural protection is critical. This rough concept envisions a range of modular products designed for installation by individuals or with expert assistance, aimed at fortifying homes to prevent property collapse and, by extension, mitigate the risk of fatalities and severe injuries during earthquakes.

The core idea behind this concept is to provide an accessible and adaptable solution that empowers homeowners to reinforce the structural integrity of their properties. These modular components could encompass various protective features, such as additional bracing, reinforcement of load-bearing elements, or even flexible components that absorb seismic forces.

While this concept is promising, it is important to acknowledge that it is at an early stage of development and necessitates extensive research and refinement. It requires rigorous testing, structural engineering considerations, and practical feasibility assessments to ensure its effectiveness in earthquake mitigation.

As of now, the Modular Construction Product concept represents a compelling vision for enhancing seismic resilience in homes. However, it is essential to recognize that its full realization demands additional time, resources, and research efforts to reach a stage of viability for design and implementation in seismically active areas.

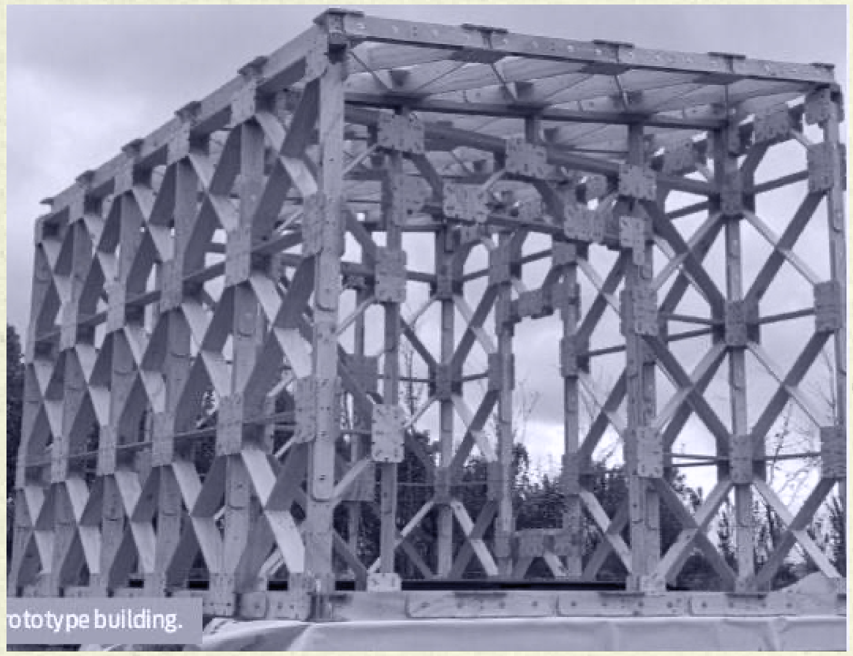


Figure 46. - X construction

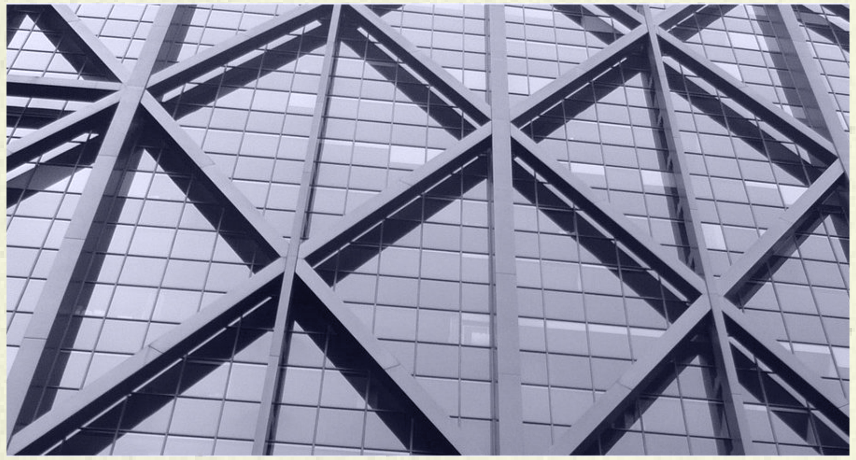


Figure 47. - X construction for strenghtening of the building

Figure 48. - QuakeNet concept sketch

Evaluation

In the evaluation process of the four distinct concepts—'Embrace,' 'QuakePlan,' 'Seismic Shield,' and 'QuakeNet'—I relied on the Harris Profile method for a comprehensive assessment. This method enabled me to gauge how well each concept aligned with the established requirements, ultimately identifying the concept with the most potential for effectively addressing earthquake-related challenges.

The first step involved ranking the requirements based on their importance and relevance, assigning weightage to prioritize them accordingly. This allowed for a clear understanding of which criteria were most significant in addressing the core issues related to earthquake preparedness and safety. It was then evaluated how each of the four concepts met these prioritized requirements. The assessment considered the strengths and weaknesses of each concept in relation to the specified criteria.

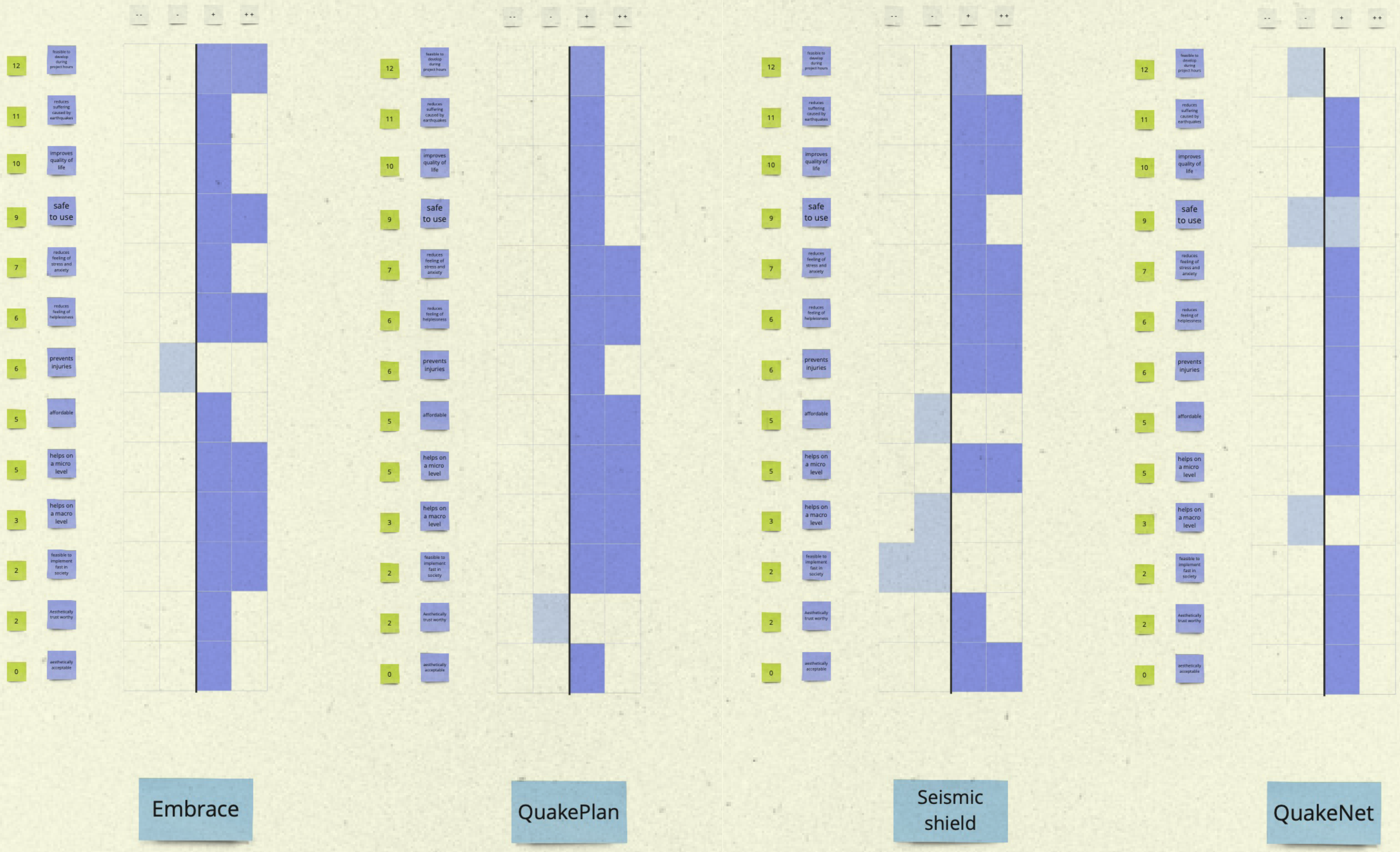


Figure 49. - Concepts evaluation through Harris Profile

After evaluating all four concepts using the Harris profile, Embrace and Quake-Plan emerged as the most compatible with the relevant requirements. The final decision to proceed with Embrace was influenced by a combination of personal preference and the desire to develop specific skills throughout the project, as well as the concept scoring high through the evaluation with Harris profiles. Embrace offered challenges aligned, with the field of Industrial Design Engineering and addressed the key issues identified in the project.

Therefore, I chose to continue the design process with the concept of Embrace, in hopes to tackle the issue of inadequate communication options during and after earthquakes, all while honing my engineering skills.

Design exploration

- Key factors
- Types of communication
- Communication scheme
- Components - inside out design
- Shape exploration

In this chapter, I stated the key factors that the design of Embrace has to address, furthermore an exploration of various communication technologies will be presented, each evaluated impartially to discern their respective advantages and drawbacks. The chosen communication type and its intricately designed communication scheme will be important topics in this examination.

Within this chapter, a detailed definition of the essential components required for 'Embrace' can be found, laying the foundation for an inside-out design methodology. Subsequently, the exploration will extend to the design of shape, where sketching will be employed to find a harmonious balance between aesthetics and functionality.

05

Key factors

What makes Embrace

As I start with design exploration, several key factors demand consideration. The main function of the bracelet lies in its communication capabilities. Long-range communication is imperative, enabling users to transmit data over considerable distances, even in remote or disaster-stricken areas.

Low bandwidth communication suffices for the purpose, as it enables essential data exchange without significant data volume. Cost-effectiveness is a crucial factor, ensuring affordability for a broad user base. Lastly, the communication option must exhibit low risk of damage or interruption during earthquakes, guaranteeing reliable functionality when it matters most.

The selection of shape and materials for the bracelet is as well to be considered. Materials that are durable, resistant to environmental stressors, as well as skin friendly should be prioritised.

Ergonomic considerations are important to the bracelet's usability and comfort. Addressing sizing options to cater to a diverse user base, needs to be considered. Additionally, the bracelet should offer adjustability to accommodate various wrist sizes.

The choice of edges is another aspect to consider; the option of stainless steel rims or bendable wire dressed in silicone provides flexibility and user preference. Filleted edges enhance wearer comfort, ensuring that the bracelet can be worn without causing discomfort.

Color selection plays a role in the bracelet's aesthetics and visibility. It is essential to choose colours that resonate with users and enable seamless integration during everyday activities. Color customisation options may also be considered to cater to individual preferences.

Types of communication

Embrace aims to adress the issue of conventional means of communication failing due to damages to cellular towers and widespread power outages. This device enables people in earthquake-affected areas to exchange vital information about their well-being and whereabouts, even when traditional cell phone communication proves impossible. In times of crisis, Embrace offers a means of reconnecting loved ones and providing a sense of reassurance in the face of adversity.

In the quest to determine the most suitable communication technology for this wearable device, relevant research was conducted to weigh the quality of various communication methods specifically for the situation of earthquakes. The selection process considered the unique circumstances surrounding earthquake scenarios, such as potential cellular tower damages, power outages, the necessity for long-range transmission, and the likelihood of not everyone having immediate access to a smartphone.

	Range	Bandwith	Cost	Earthquake influence
Cellular communication	Medium/long range	High bandwith	Low cost affordable solution	High - power outages, overwhelmed network, damaged towers
Bluetooth	Short range	Low bandwith	Low cost affordable solution	Low
WiFi	Short/medium range	High bandwith	Low cost affordable solution	High
Radiosignals	Long range	Low bandwith	Low cost affordable solution	Low
Satellite communication	Long range	Low & high bandwith	High cost - less affordable	Low

Figure 50. - Communications advantages and disadvantages table

Radiosignals

Satellite communication

In the context of earthquake scenarios, where maintaining communication is of utmost importance, the research led to the conclusion that a combination of technologies would be the most effective approach. Leveraging LoRa technology for long-range, low-power communication within a localized area, while connecting through base devices with satellite communication capabilities, emerged as a robust solution. This hybrid approach ensures that individuals can exchange vital information even when cellular networks are disrupted, power is scarce, or smartphones are not immediately accessible, addressing the specific challenges posed by earthquakes and disaster scenarios effectively.

LoRa

LoRa, short for Long Range, is a wireless communication technology designed specifically to address the unique challenges of long-range, low-power communication in Internet of Things (IoT) applications (*Semtech, 2012*). It offers several distinctive features and advantages that make it a suitable choice for a wide range of IoT use cases.

One of the key features of LoRa technology is its exceptional long-range connectivity. It allows devices to communicate over distances that can extend up to several kilometers in urban environments and even further in rural areas. This long-range capability is particularly valuable for applications that require connectivity over expansive geographic areas.

Another significant advantage of LoRa is its low power consumption. LoRa devices are highly energy-efficient, consuming minimal power during data transmission. This efficiency is critical for battery-operated devices or those deployed in remote locations, as it extends the lifespan of batteries and reduces the need for frequent maintenance. Additionally, LoRa signals exhibit robust signal penetration capabilities, allowing them to traverse obstacles like walls and buildings. This makes it suitable for both indoor and outdoor applications, including smart buildings and smart agriculture.

LoRa networks are highly scalable and can support a vast number of devices simultaneously, making them well-suited for large-scale IoT deployments where thousands or even millions of devices need to connect and communicate.

Security is another key aspect of LoRa technology. It incorporates encryption and security features to protect data during transmission, ensuring the confidentiality and integrity of the information exchanged between devices.

From a cost perspective, LoRa infrastructure is cost-effective to deploy and maintain. LoRa gateways, which serve as access points for devices, can cover large areas, reducing the overall infrastructure cost.

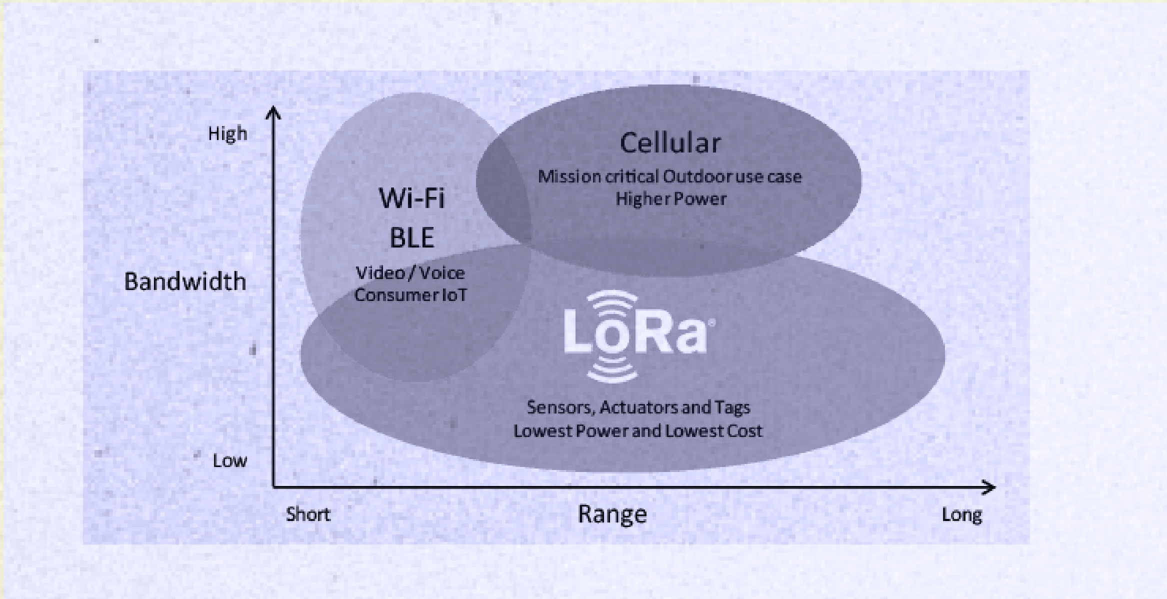


Figure 51. - LoRa - bandwith / range

Communication scheme

How & why

The communication scheme of the bracelet leverages LoRa (Long-Range) technology to facilitate efficient and long-distance data exchange. LoRa technology is specifically tailored for long-range, low-power communication, making it an ideal choice for this IoT-based wearable device.
The key features of LoRa technology include its ability to operate in unlicensed radio frequency bands, its low power consumption, and its capacity to penetrate obstacles. These attributes collectively make it well-suited for applications demanding extended wireless coverage and minimal energy consumption.

Each bracelet in the system utilizes LoRa technology to communicate with a base device. Notably, these bracelets have a communication range of up to 10 kilometers, ensuring they can establish connections even over considerable distances. To optimize coverage, base devices are strategically placed at intervals of approximately 10 kilometers. As bracelets come within the range of a base device, they automatically establish a connection.

The handy aspect of this communication scheme lies in the use of these base devices for satellite communication. Instead of equipping each bracelet with satellite communication technology, which would significantly increase energy consumption and device size, this approach streamlines the process. Base devices, located within 10-kilometer intervals, communicate

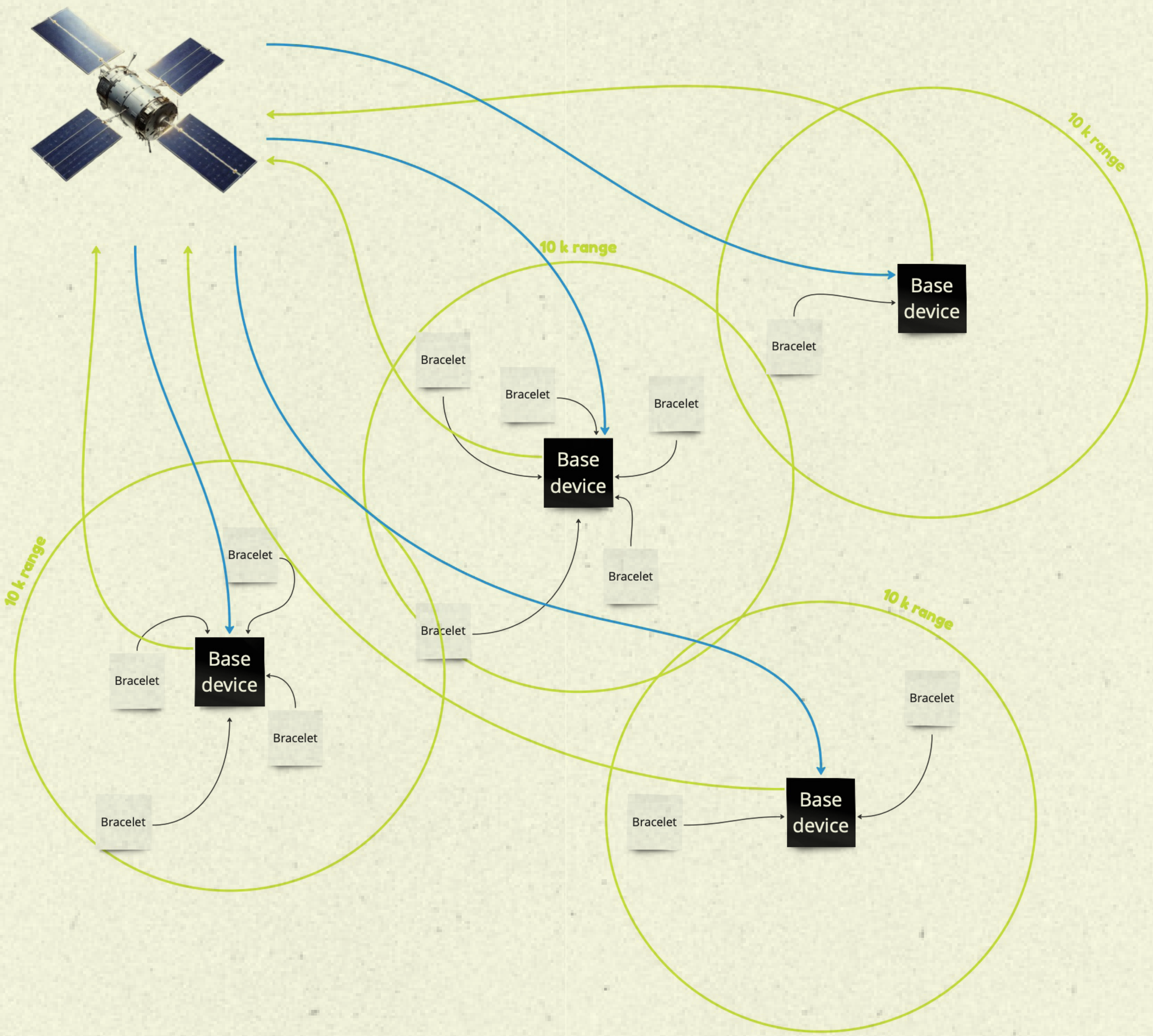


Figure 52. - Communications scheme for Embrace

with each other through satellites. This interconnected network of base devices effectively extends the range and capabilities of each bracelet.

Here's how it works: when a bracelet needs to exchange information with another bracelet, the data is first transmitted to the nearest base device within its range. This base device, equipped with satellite communication capabilities, relays the information to other base devices as needed, using satellite links. In turn, these base devices transmit the data to the targeted bracelet(s). This system eliminates the need for individual bracelets to possess satellite communication hardware, reducing both their energy requirements and physical size.

In summary, the communication scheme capitalizes on LoRa technology's long-range capabilities to establish connections between bracelets and strategically placed base devices. These base devices then harness satellite communication to relay information between bracelets, eliminating the need for satellite hardware in the bracelets themselves. This approach ensures efficient and reliable communication while minimizing energy consumption and device size, making the bracelet an ideal solution for various applications, including emergency and disaster scenarios.

Components

Inside out design

The beginning of the design exploration for Embrace started by carefully defining the essential components that would shape the functionality of the bracelet. The primary objective was to ensure that the device not only facilitated communication but also offered a range of vital features catering to the unique challenges presented by earthquake scenarios.

Microcprocessor: The microprocessor serves as the brain of the device, orchestrating various functions, processing data, and managing communication.

LoRa Transceiver Module: At the heart of our communication system lies the LoRa transceiver module, which enables long-range, low-power communication, ensuring that individuals can stay connected even in remote or disaster-affected areas.

GPS Module: Accurate location tracking is paramount in emergency situations. The GPS module provides real-time location data, aiding in rescue efforts and helping individuals pinpoint their positions.

Rechargeable Battery: To ensure prolonged operation without access to electricity, the device is equipped with a rechargeable battery that offers extended power endurance.

Vibration Motor: The vibration motor provides discreet alerts and notifications to users, ensuring that critical messages are conveyed without drawing unnecessary attention.

The system of communication through the bracelet is designed to be both comprehensive and resilient. As previously mentioned, the bracelet is capable of connecting to strategically placed base devices, each with satellite communication capabilities, to relay messages and data over longer distances. This interconnected network of base devices effectively extends the range and capabilities of the bracelet, ensuring efficient and reliable communication even in remote or disaster-affected areas.

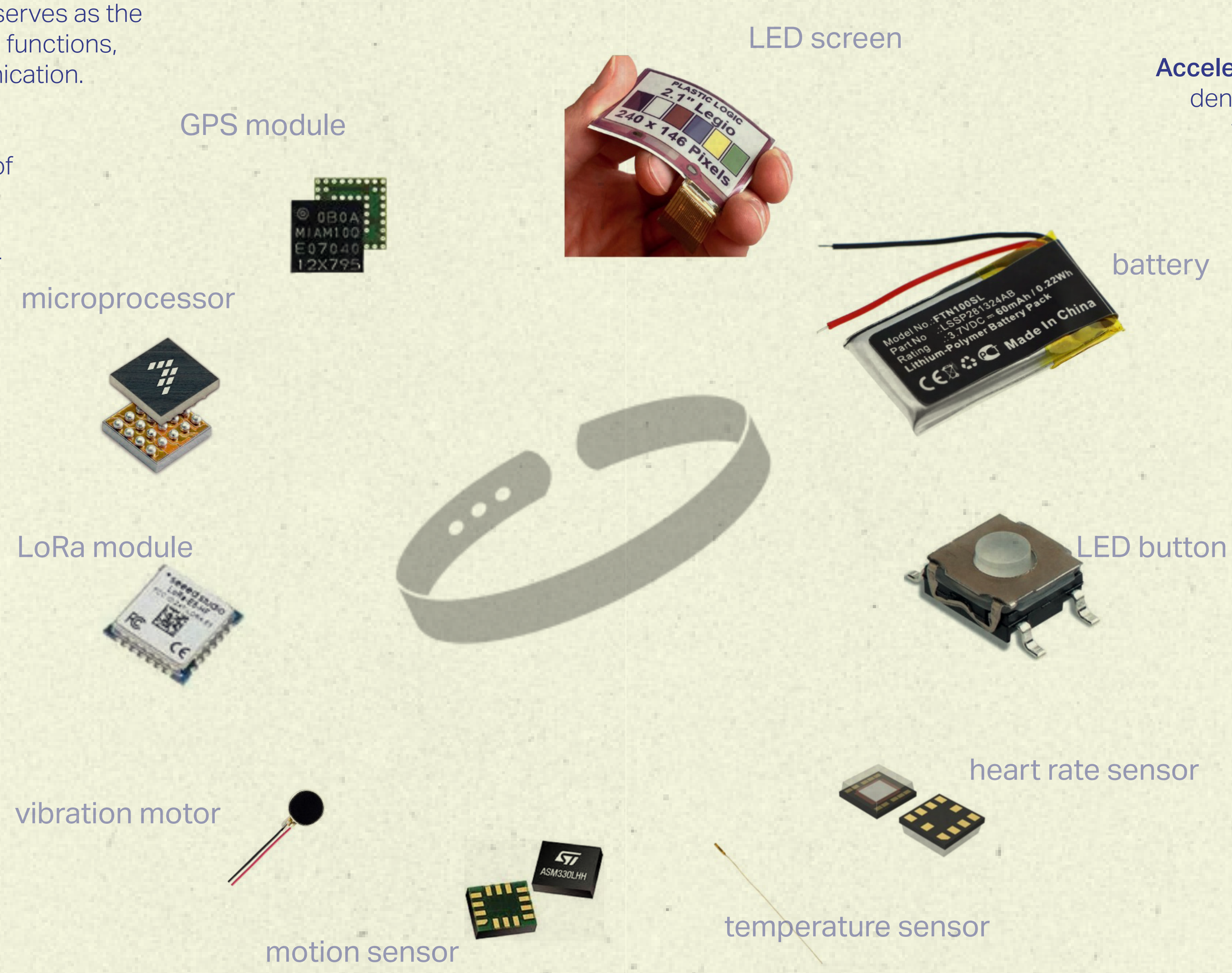


Figure 53. - Embrace components overview

Accelerometer: The accelerometer detects sudden movements and impacts, a crucial feature for earthquake detection and safety alerts.

Temperature Sensor: Monitoring temperature variations is vital in assessing potential hazards and providing relevant information to users.

Heart Rate Sensor: This sensor offers health monitoring capabilities, enabling users to track their well-being during and after earthquake events.

LED Display: The LED display offers a visual interface, allowing users to receive information and updates directly from the device.

Feedback Button: A dedicated button empowers users to send feedback or request assistance, enhancing their ability to communicate their needs effectively.

Components interaction

In its default state, the 'Embrace' device remains in sleep mode to conserve energy until an external signal prompts its activation. This energy-efficient approach ensures that the device remains operational for extended periods without frequent recharging.

Every two minutes, for a brief one-second interval, specific components within the device briefly awaken from sleep mode. These components include the microcontroller, LoRa transceiver module, and GPS module. Their purpose during this short interval is to check for incoming signals or notifications from the Base Device.

The Base Device serves as a central control unit that can send signals to 'Embrace' bracelets in the event of an earthquake or other emergencies. If the Base Device detects seismic activity or receives relevant information, it triggers a wake-up signal to 'Embrace' bracelets within its communication range.

Upon receiving the wake-up signal, all components within the 'Embrace' device become active. The microcontroller processes the incoming data and coordinates the device's response. The LoRa transceiver module facilitates communication with the Base Device, enabling the exchange of critical information.

Simultaneously, the GPS module provides accurate location data, ensuring that the device can pinpoint the wearer's position. This location information is vital for both the wearer's safety and for coordinating relief efforts during a seismic event.

The rechargeable battery powers the device during its active state, ensuring that it remains operational even when external power sources are disrupted, such as during an earthquake.

Additional sensors within the device, such as accelerometers, temperature sensors, and heart rate sensors, contribute to the device's functionality. These sensors can provide valuable data related to the wearer's well-being, environmental conditions, and physical activity.

In summary, the 'Embrace' device operates efficiently by conserving energy in sleep mode and periodically checking for wake-up signals from the Base Device. In the event of an earthquake or other emergencies, all components activate to facilitate communication, location tracking, and data collection to enhance the wearer's safety and well-being.

Shape exploration

Fleshing it out

The design process of Embrace went beyond the selection of essential components. It included exploration of shape and form, driven by a desire to create a wearable that seamlessly integrates technology into daily life. This shape exploration was guided by several key principles:

1. Component Integration: At the core of the design challenge was the need to accommodate a range of critical components, from sensors and transceivers to batteries and displays. The initial sketches considered the space required to house these components efficiently, ensuring optimal functionality without compromising on aesthetics.

2. Ergonomics and Comfort: Recognizing that wearability is paramount for a device meant for everyday use, the shape exploration prioritized ergonomics and comfort. The bracelet's contours were crafted to ensure a comfortable fit on the wearer's wrist, allowing for unhindered movement and ease of use.

3. Minimalistic Aesthetic: To set the bracelet apart from conventional wristwatches and to align with a modern, minimalist design, the shape exploration tried to steer clear of traditional watch-like forms. Instead, it aimed to create a sleek and unobtrusive profile that seamlessly blends with the wearer's attire and personal style.

Before starting the shape exploration through sketches and further development, I decided to create a Moodboard in order to better identify which aesthetic traits Embrace needs to have so it would appear as a minimalistic and non obtrusive wearable. I've gathered images and details of product that embody minimalistic design through their shape, colour choices, design of edges, and color and material combinations. This Moodboard will serve to better align the design of Embrace, with core traits it needs to have.

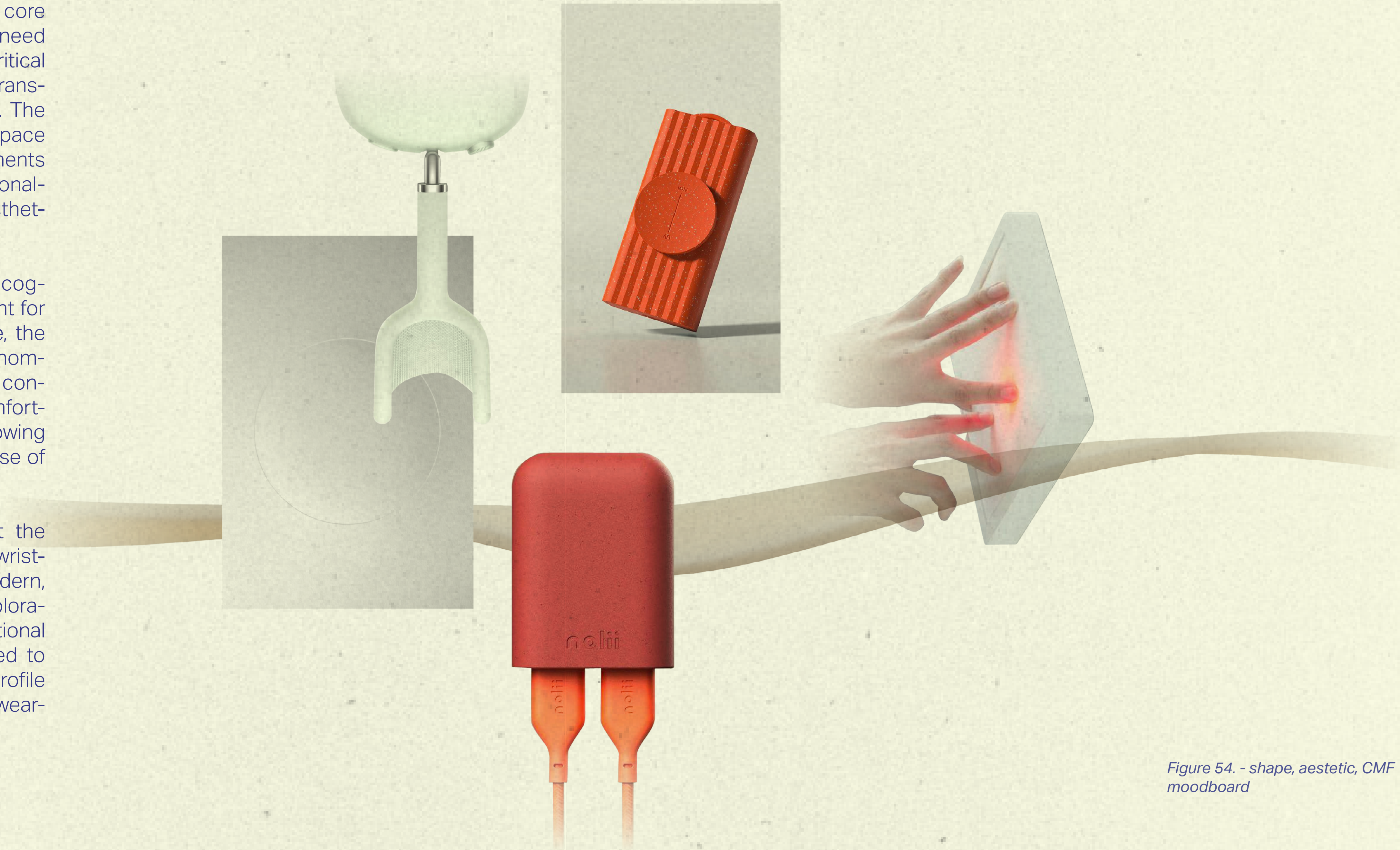


Figure 54. - shape, aestetic, CMF moodboard

Sketching

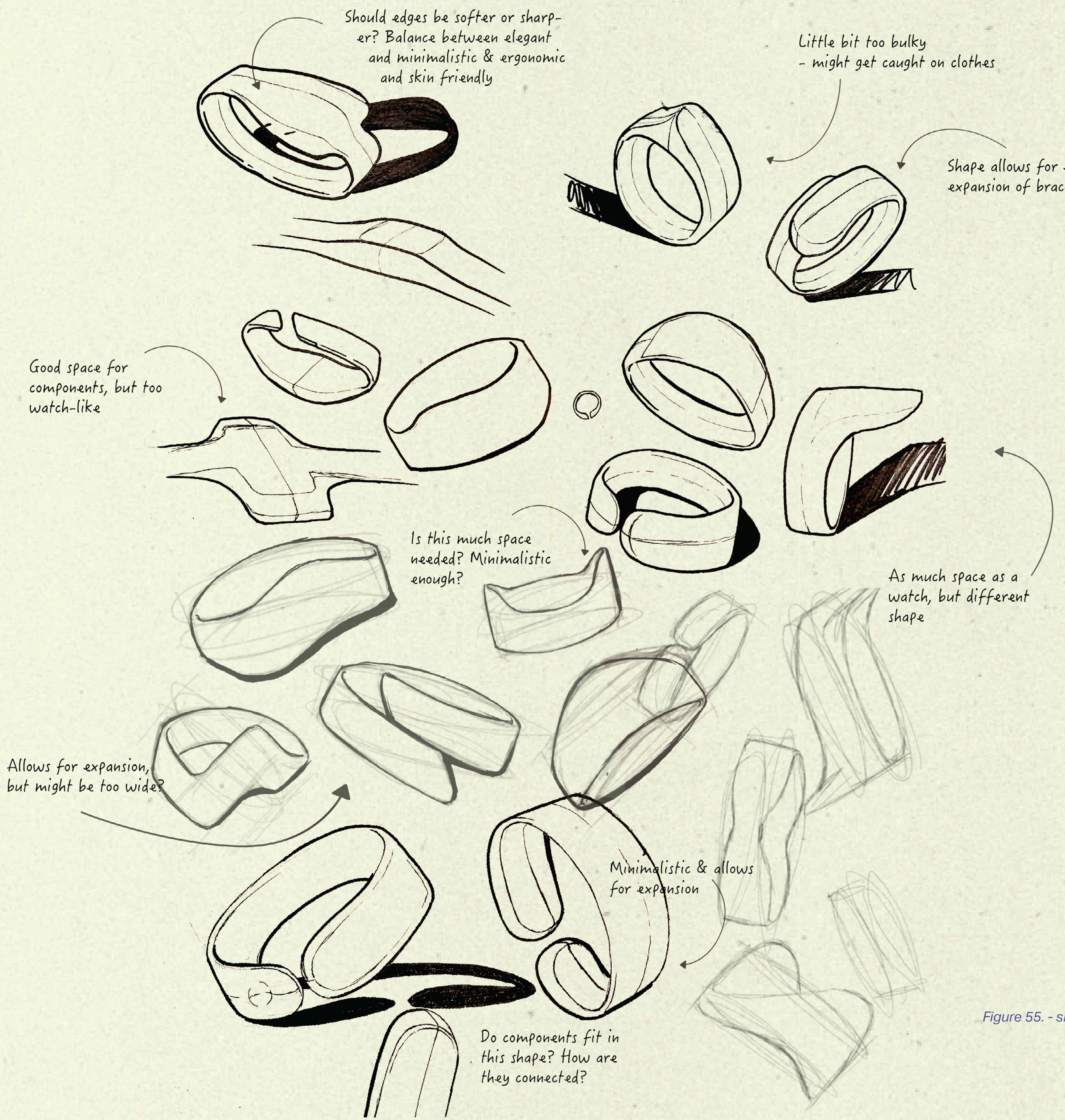


Figure 55. - sketch shape exploration

The result of this shape exploration is a range of sketches and design concepts that considered components integration, ergonomics, and aesthetic values. The concept sought to achieve a delicate balance between form and function, envisioning a wearable device that harmoniously integrated technology into the wearer's daily routine.

Throughout the sketches different forms were explored, all the while keeping in mind the sace that needs to be there for the components. Some shapes ended up being avoided either because of their likeness to a watch, too little space for components left, or too much space (being too bulky).

This exploration resulted in focusing on three shapes from which the final one should be chosen. These shapes (see following page) were chosen based on all of the values previously mentioned.

Narrowed choices

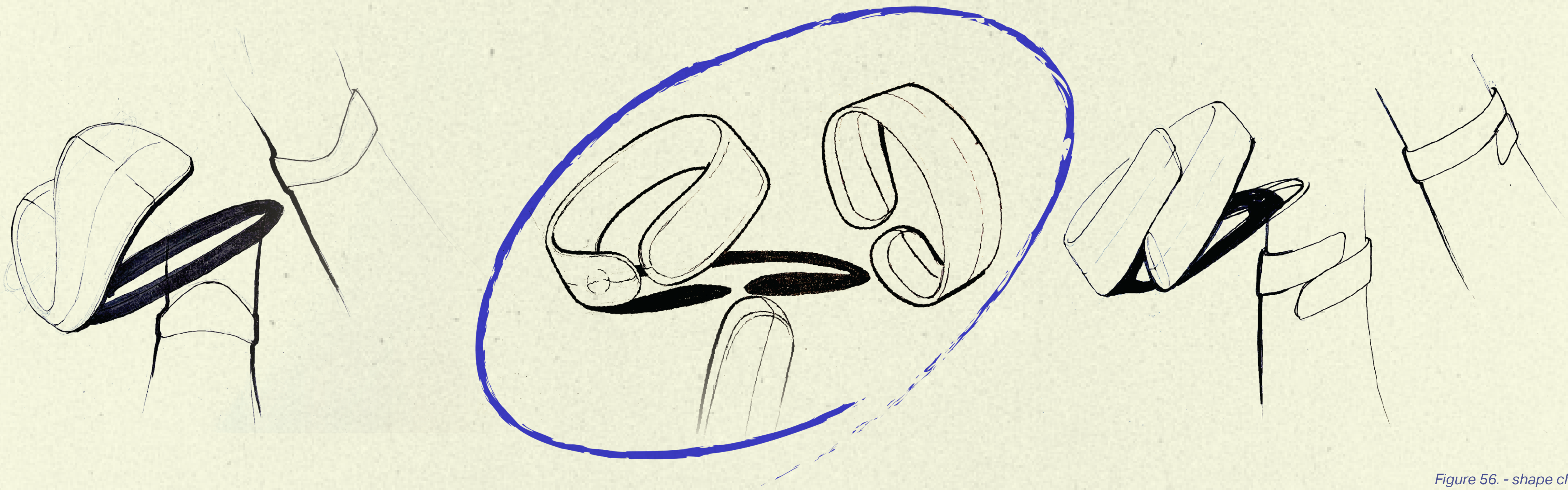


Figure 56. - shape choices

When it came to defining the visual identity of 'Embrace', various sketch directions were explored, each striving to encapsulate a distinctive and minimalistic aesthetic. These sketches represented different approaches, all with their unique potential.

Among the three sketch directions considered, the second option stood out as the better choice. This direction exuded a sense of minimalism that resonated with the core design philosophy of 'Embrace.' It struck a delicate balance by providing ample space to house the essential components while offering opportunities for bracelet expansion. This expandability was an important factor in ensuring that 'Embrace' could comfortably accommodate wrists of varying sizes, making it a versatile and inclusive wearable.

Ultimately, the second sketch direction is promising with its minimalist aesthetic but also shape that manages to house components, and the need for 'Embrace' to be a comfortable and adaptable solution for users of different ages. It was a choice that combined form and function, aligning with the vision of the smart bracelet.
In further chapters, details (such as sizes, materials, and components distribution) of this chosen shape will be looked into, and better explained as to why this shape was chosen.

Design embodiment

- Details
- Product use
- Product in context
- Production
- Model
- Business plan

06

This chapter delves deeper into the Embrace, exploring the details that bring this device to life. It is looked into the selection of materials, aiming for the synergy of comfort, durability, and functionality that underpins the bracelet's design. Ergonomics will take center stage as we see how the bracelet adapts to users of different ages and sizes, ensuring an optimal fit in every scenario.

But the bracelet is more than just a collection of materials and components; it's primary purpose lies in its function. New scenarios will be shown, where the product's capabilities are outlined, demonstrating its vital role in enhancing safety and communication during earthquakes.

Furthermore, the production plan that transforms the concept into a tangible reality will be looked at. A look into initial prototypes (models) will be shown, as well as an overview of needed steps inside of the Business plan. In the embodiment of Embrace, it's explained how details have been considered to empower users and ensure their safety in the face of adversity.

Details

Shape

The selected design for the Embrace bracelet emphasizes a minimalist approach, aiming for a sleek and unobtrusive appearance. Its distinct feature consists of a narrow opening strategically situated on one side of the bracelet, serving the dual purpose of enhancing aesthetics while ensuring optimal sizing flexibility. This design choice was made to accommodate a broader range of wrist sizes comfortably, aligning with the functional requirements of the device.

The bracelet's design further integrates a pragmatic arrangement of internal components within its form. One side of the bracelet is dedicated to user interaction and feedback provision, featuring a tactile button for user input. In contrast, the opposite side houses essential components such as the LED screen and the battery. This arrangement is intended to enable the display of notifications and maintain the device's power source, promoting efficient information exchange between the wearer and the device.

During the initial definition of the bracelet's shape, several key considerations were addressed to ensure functionality and comfort. Sizing parameters needed to be defined to accommodate a wide spectrum of wrist sizes, ranging from smaller to larger dimensions.

Adjustability was also an important factor, recognizing that wearers often fall between standard sizes. Additionally, the choice of material was guided by specific traits such as durability, comfort, and suitability for prolonged wear, further contributing to the overall design's success.

Figure 57. - components inside of outer shell

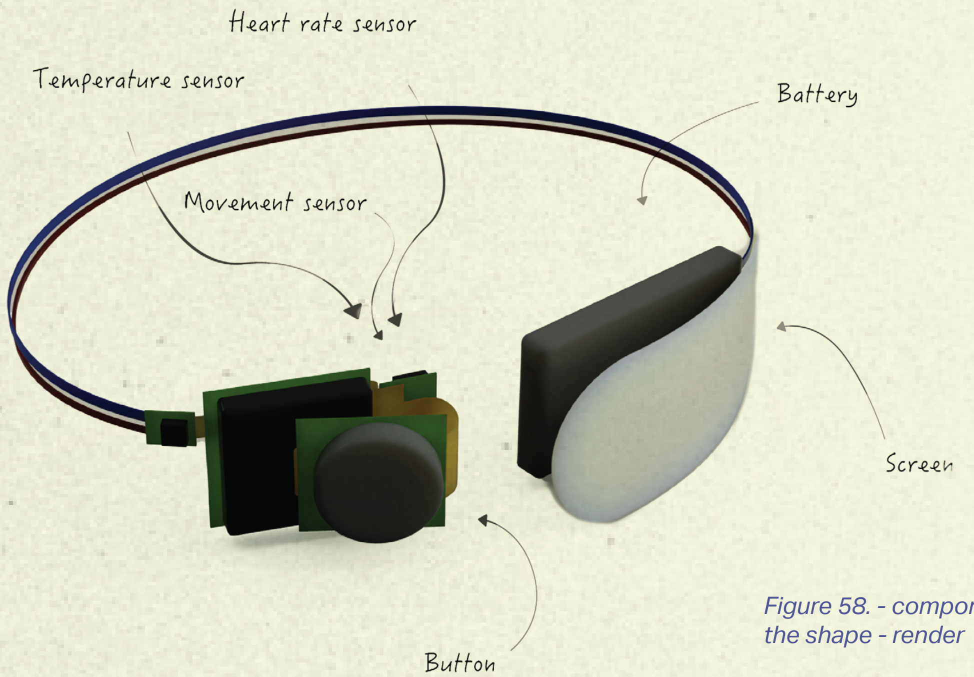
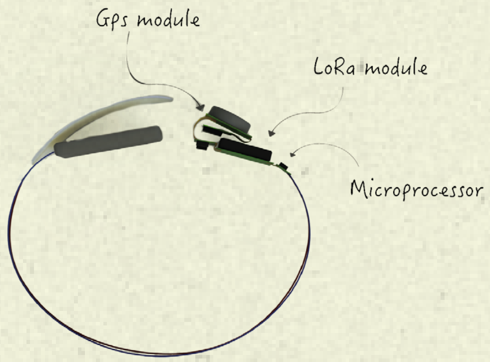
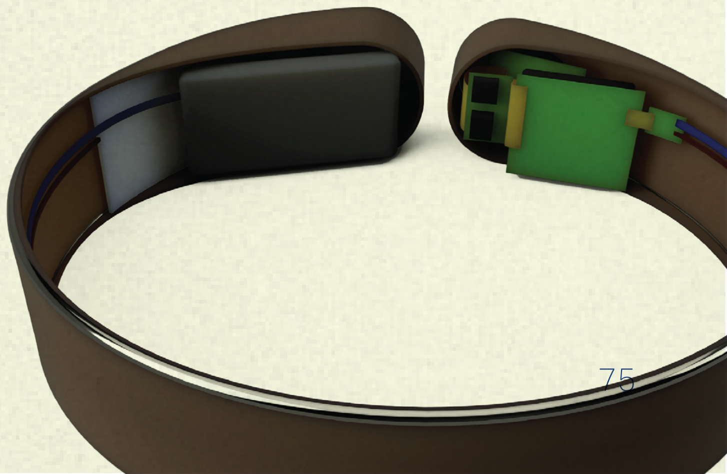


Figure 58. - components overview in the shape - render





Ergonomics

Embrace is designed in four different sizes, each catering to different age groups and varying wrist circumferences. The sizing strategy is based on percentile measurements (*for percentiles, see Appendix*), encompassing a range from the 5th to the 95th percentile, with particular attention given to the 50th percentile, representing the median wrist size.

For children as young as 6 years old, Embrace offers a dedicated size to provide an adequate fit (11,5 cm circumference). Adolescents also have a specific size designed to accommodate their unique wrist circumferences (13,5 cm circumference).

Embrace provides two adult sizes (15,5 cm and 17,5 cm circumference), with a primary focus on the 50th percentile, aligning with the median wrist size.

However, all of these sizes are augmented by adjustability, allowing for a more flexible fit and accommodating a broader range of wrist sizes beyond the median. The sizing approach is founded on empirical data, ensuring that the bracelet can be worn by individuals of varying body types.

Embrace shape features rounded fillets applied to all edges. This design approach aims to prioritize user comfort and user-friendliness while eliminating any sharp or uncomfortable edges. The incorporation of these fillets enhances the overall wearability and ergonomic quality of the bracelet, aiming for a smooth and pleasant experience for the wearer.

Figure 59. - sizes overview

Adjustability

A key feature that enhances the bracelet's adaptability is the inclusion of an adjustable gap. This strategically designed gap allows wearers to easily resize the bracelet, ensuring a snug and comfortable fit tailored to their individual preferences.

The bracelet's primary construction material is a blend of soft and hard silicone.

Integral to the bracelet's design are its edges, which are an essential part of the structure. Users have the option to select visible stainless steel rims, available in both gold and silver finishes. These rims not only enhance the bracelet's structural integrity but also provide expandability and the ability to return to its primary shape and size.

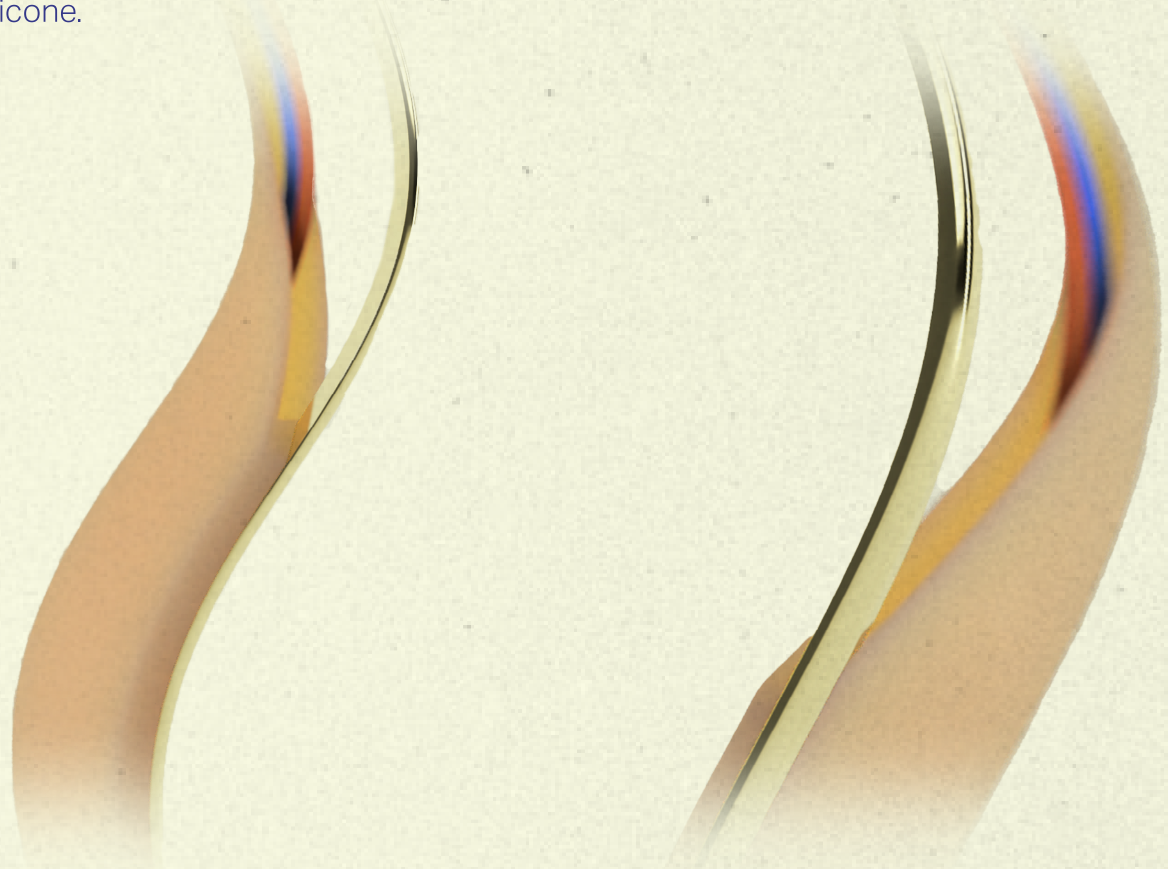


Figure 60. - edges cross section

Silicone is chosen for its wearer-friendly properties, including waterproofing, resistance to temperature extremes, and exceptional comfort. This choice ensures that the bracelet provides a pleasant and skin-friendly experience for its users.

Alternatively, hidden edges made from bendable wire dressed in silicone offer seamless integration while preserving flexibility. To further enhance wearer comfort, all edges of the bracelet are thoughtfully fileted. This attention to detail eliminates sharp angles and rough edges, Aiming for a comfortable and irritation-free fit.

Figure 61. - adjustability of Embrace - bend and expanded bracelet

Figure 62. - Embrace render - skin tones

Materials

The bracelet's primary material is silicone, comprising a combination of soft and hard silicone components. This choice was driven by the need for adjustability, ensuring that the bracelet accommodates various wrist sizes comfortably and securely.

Silicone offers several practical advantages for the bracelet:

Biocompatibility: Silicone is biocompatible, making it suitable for prolonged skin contact without causing irritation or discomfort.

Durability: Silicone is resistant to moisture, temperature extremes, and environmental stressors, enhancing the bracelet's durability and functionality in challenging conditions.

Adjustability: The use of both soft and hard silicone elements allows for flexibility and adaptability, ensuring a comfortable fit for a diverse user base.

Color Options: The bracelets are available in skin tones, providing users with a discreet and unobtrusive option.

The material selection aligns with the bracelet's aim to provide a practical, user-friendly, and reliable solution for seismic events.

Figure 63. - Embrace render - skin tones 2

Skin tones blending in seamlessly

Rims to match the wearers jewelry

Figure 64. - Embrace render - edges

Product use

Setting up Embrace

Setting up your 'Embrace' bracelet is a straightforward process facilitated through a user-friendly app designed for your convenience. Here's a step-by-step guide on how to get started:
Unboxing and Charging: When you receive your 'Embrace' bracelet, begin by unboxing it and plugging it into the charger provided. As soon as it's connected to the charger, the bracelet will power on.

1. Pairing with the App: Once your 'Embrace' bracelet is powered on, you can easily pair it with the dedicated 'Embrace' app. During the initial setup, you'll be prompted to enter the unique code that came with your bracelet. This code serves as the key to connect your bracelet to the app.

2. Personalize Your Code: After successful pairing, you have the option to personalize your code within the app. This customization feature allows you to rename your code, making it more recognizable and memorable for you.

3. Adding Contacts: With your 'Embrace' bracelet connected to the app, you can start building your contacts list. Simply input the unique codes of other 'Embrace' wearers whom you'd like to connect with. You can organize your contacts by priority, ensuring that the most important ones are readily accessible in times of need. Priority settings help determine the order in which contacts will be displayed in the event of an earthquake.

4. Explore 'Embrace' Features: The 'Embrace' app provides a comprehensive explanation of how the bracelet works, offering insights into its capabilities and functionality. This information ensures that you fully understand how to use 'Embrace' to its fullest potential.

5. Connect with a Community: The app also features a chat functionality where you can engage with other 'Embrace' users. This community forum allows you to ask questions, share experiences, and exchange valuable insights related to earthquake preparedness and safety.

Setting up your 'Embrace' bracelet through the app not only ensures a seamless connection but also empowers you with the tools and knowledge needed to stay safe and connected during seismic events. It's a user-centric experience designed to enhance your peace of mind and safety.

Figure 65. - Embrace set up and app use

Product use

Bracelet options

The functionality Embrace extends beyond its minimalist design, with a purposeful integration of features aimed at ensuring the safety and well-being of its wearer. As an earthquake occurs, the bracelet is woken up from sleep mode by the signals from the Base Device (which recieves signals from the Seismic network), and starts gathering the wearer's feedback and showing the received contacts information.
Positioned discreetly on one side of the bracelet is a button, strategically designed to provide a simple yet effective means of communication in times of distress.
This multifunctional button offers three distinct modes, each represented by a different colored light:

Green Light: This signifies that the wearer is in a safe environment, unharmed and not trapped. It serves as a beacon of reassurance, indicating that the individual is out of immediate danger.

Orange Light: An orange light signals that the wearer is okay but may be trapped or stuck in a particular location. It serves as a crucial alert to notify contacts that assistance may be required.

Red Light: The red light is a critical signal that the wearer is both injured and trapped. It signifies a more urgent need for assistance and medical attention.

Upon activation, each mode holds the corresponding light for 10 seconds, allowing the user to select the appropriate response in their specific situation. This intuitive interface empowers the wearer to convey vital information with just a simple press of the button.

In parallel, the bracelet automatically gathers and transmits essential data to the wearer's designated contacts. This information includes real-time location data, ensuring that the individual's whereabouts are known even in the most challenging circumstances. Additionally, the bracelet relays the wearer's heartbeat rate, body temperature, and movement data, providing a comprehensive overview of their well-being.

On the other side of the bracelet lies a discreet LED screen, where feedback from contacts is displayed. This screen is designed to automatically scroll through the information provided by contacts, ensuring that the wearer can read and respond to messages in a clear and organized manner.

Figure 66. - Embrace use of button

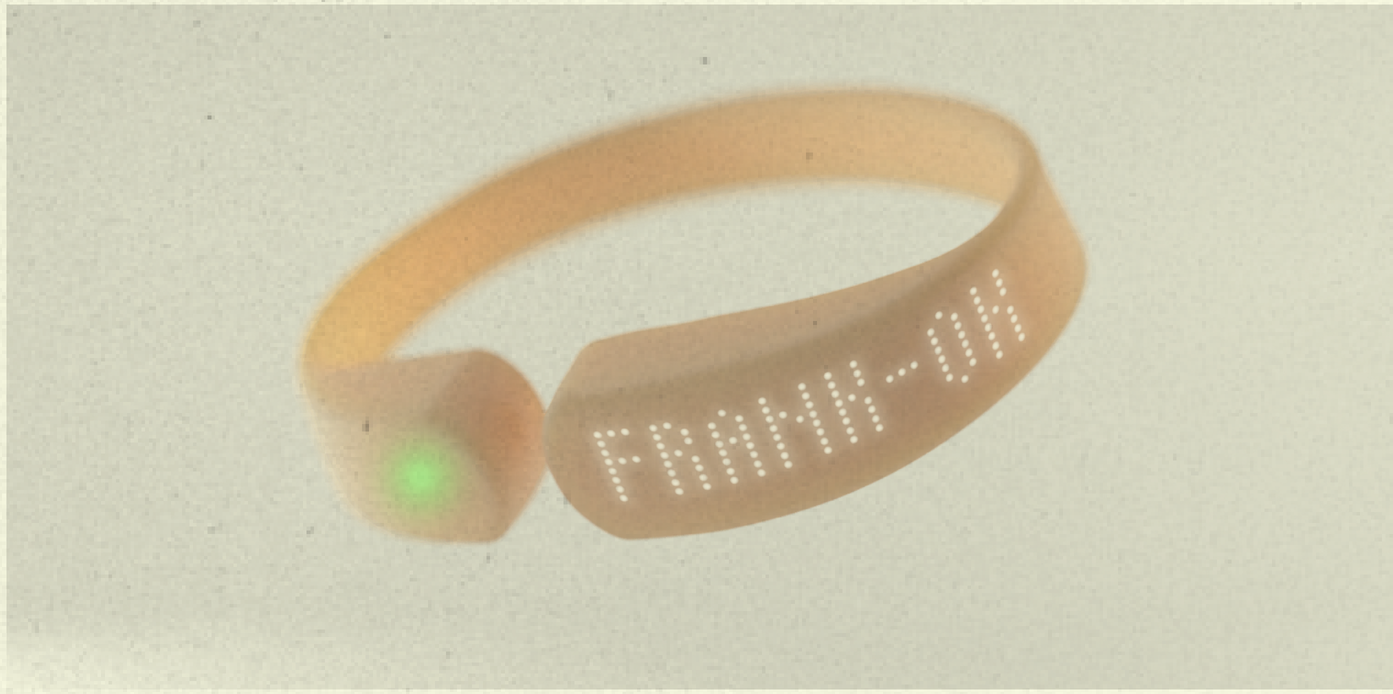


Figure 67. - Embrace reception of feedback

Charging of Embrace

'Embrace' is designed with energy efficiency in mind, ensuring that the bracelet remains functional and reliable with minimal power consumption. Key components within the bracelet, including the LoRa module, microprocessor, and GPS module, employ a sleep cycle. These components wake up for a brief one-second period every two minutes to check for signals from the seismic network. If no signals are detected, they return to a low-power sleep mode.

	Kinetis Microprocessor	LoRa Module	GPS Module	Heart Rate sensor	Thermal Sensor	Accelerometer	LED	Vibration Motor
Sleep mode	5 µA	2 µA	3 µA					
Connect Mode	35 µA	50 µA	25 µA					
Active Mode	385 µW			275 µA	370 µA	11 µA	5 440 µA	42 µA

6 months waking up every 2 minutes and active mode for 6 hours:

802 J

Battery capacity (80%) = 640 J

3 months waking up every 2 minutes and active mode for 6 hours:

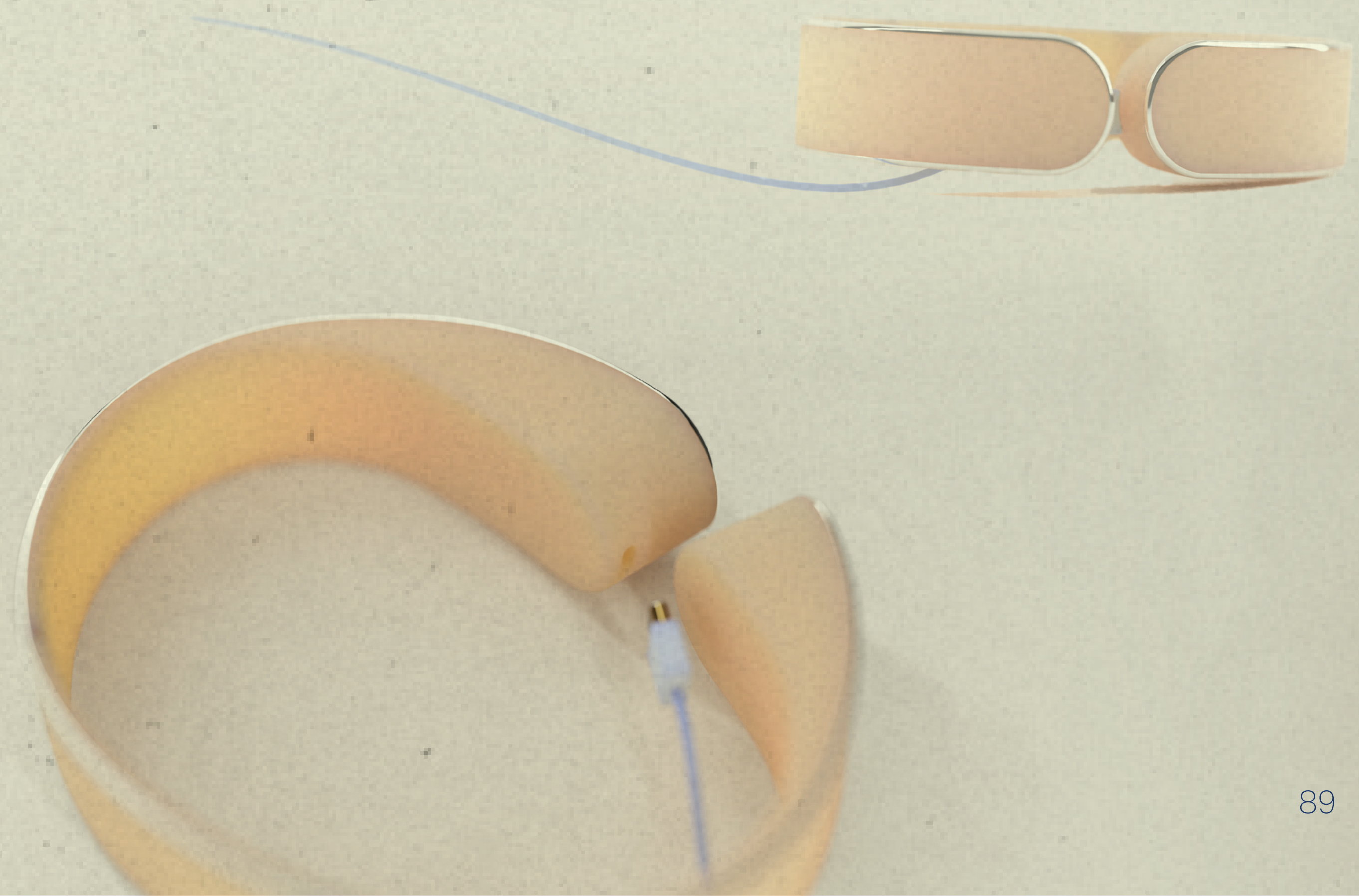
646 J

Battery capacity (80%) = 640 J

Figure 68. - Battery life calculation

This energy-efficient approach allows 'Embrace' to operate on a single charge for approximately three months, providing long-lasting functionality and peace of mind. It also reserves enough battery life to keep the bracelet in Active mode for six hours during this period, ensuring you remain connected when it matters most.
To keep the user informed about the bracelet's battery status, the 'Embrace' app provides a visual representation of the battery percentage. Additionally, the bracelet features a vibration motor that delivers a gentle 'buzz' when it's time to recharge, ensuring that the wearer is never caught off guard and can continue relying on 'Embrace' for safety and communication needs.

Figure 69. - Embrace charging



Product in context

Scenarios

Building upon the insights from previous scenarios, new scenarios have been developed to showcase the practical application of 'Embrace' during seismic events. These scenarios aim to illustrate how the bracelet can be effectively utilized to address key challenges and pain points identified earlier. The integration of 'Embrace' into these scenarios demonstrates its potential to reduce suffering and enhance safety during earthquakes.

The scenarios incorporate various aspects of 'Embrace,' including its communication capabilities, user feedback mechanisms, and real-time data sharing. By depicting realistic situations and user interactions with the bracelet, these scenarios provide a clear understanding of how 'Embrace' can empower individuals and facilitate communication during seismic events.

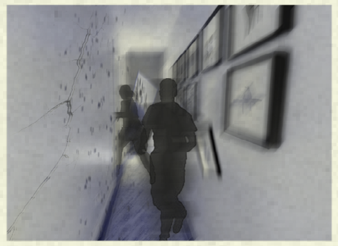
These scenarios serve as a tool for evaluating the effectiveness of 'Embrace' in mitigating the challenges posed by earthquakes and highlight its role in enhancing resilience and well-being during such events.

Figure 70. - 6.0 earthquake intensity scenario with Embrace

5 a.m. - family peacefully sleeping in their apartment of an old building on the 2nd floor

5 a.m. - the shaking starts, abruptly waking the family up

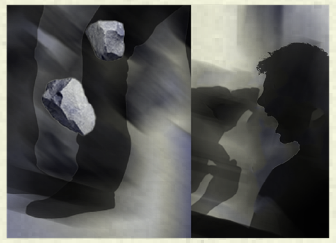
5:01 a.m. - the shaking intensifies, fear kicks in, smaller furniture starts oveturning, debris is falling



5:01 a.m. - shaking is stronger and stronger, parents need to get to their child in the other room; cracks are visible, debris is falling, furniture and pictures are falling, glass is cracking

5:01 a.m. - child is scared and alone, cannot leave the room as the doors are blocked by fallen materials

5:02 a.m. - parents cannot reach the child due to fallen materials and strong shaking



5:02 a.m. - shaking continues, cracks are forming, debris is falling, beams are detaching, broken glass is on the floor; during this shaking the father gets injured by falling material

5:03 a.m. - shaking stops, the family is slowly getting over the fallen furniture and materials and assesing the best way to leave the property

5:05 a.m. - family is carefully leaving their apartment, assessing the condition of the staircase, and trying to step around the debris

6:00 a.m. - the father is getting urgent help for his leg injury, the family knows they were lucky nobody got hurt in a greater way

6:30 a.m. - fmily is trying to call the rest of the family, but the calls are not going through; feeling of helplesness and anxiety deepens

6:40 a.m. - family cannot use their cell phones, but remembers they have Embrace. They quickly report their state and look for the state of their friends and family

6:50 a.m. - family reads through the state of their contacts (mostly family), and finds that most of them are safe and uninjured, while some are uninjured, but stuck at their location

6:55 a.m. - family feels instant relief knowing their loved ones are alive and well, they discuss how to help the friends that cannot leave their locations

7:10 a.m. - family is reunited in front of the building and is standing farther away from it, in case of aftershocks; they are in shock about what they went through, as well as seeing the condition of their building from the outside

5 p.m. - a man decided to go to the city for a stroll and a cup of coffee

5 p.m. - suddenly he starts feeling mild odd shaking/vibration, he begins to be alert and suspects an earthquake is starting - he knows he is in the old city centre, therefore is in danger of falling structures

5:01 p.m. - the shaking starts intensifying and the city centre is chaotic. Brick and stone is falling everywhere, it is difficult to move due to the shaking. The man is trying to protect his head and vital organs

5:03 p.m. - the shaking finally stops; the man is in shock, and the first thing he wants to do is call his family and friends to make sure everyone is alright, the only problem is - the calls are not getting through, and there is no internet connection

5:03 p.m. - the man remembers he has his Embrace, and quickly checks the state of his contacts

5:03 p.m. - he then reports his state (he is uninjured and safe), as he knows his family will worry about him, especially knowing he is in the city centre

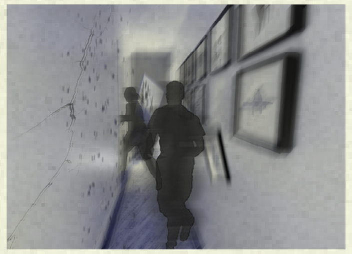
5:05 p.m. - he is in shock, but is grateful to know his family is alright; he is thinking of a way to get home

Figure 71. - 6.0 earthquake intensity scenario with Embrace

5 a.m. - family peacefully sleeping in their apartment of an old building on the 2nd floor

5 a.m. - the shaking starts, abruptly waking the family up

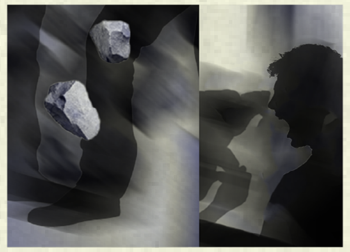
5:01 a.m. - the shaking intensifies, fear kicks in, smaller furniture starts oveturning, debris is falling



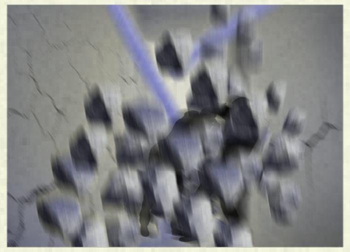
5:01 a.m. - shaking is stronger and stronger, parents need to get to their child in the other room; cracks are visible, debris is falling, furniture and pictures are falling, glass is cracking

5:01 a.m. - the child is awake and in fear, confused and unsure of what is happening; he tries to get out of bed and leave the room but cannot do it due to walls collapsing and too strong shaking

5:02 a.m. - parents cannot get to their child, the shaking is too strong and building is starting to collapse



5:02 a.m. - shaking continues, stronger and stronger, the family is getting injured, collapse is inevitable



5:03 a.m. - shaking doesn't stop, walls and ceilings collapsed and are injuring and crushing the family

5:05 a.m. - building is in ruins, family members cannot be seen or heard; child is stuck under ruins, mother is not concious, and the father is bleeding to death

7:10 a.m. - rescue team and neighbours are trying to find the survivours and help get them out of the ruins; this step could last anywhere from hours to days

10:10 a.m. - the child used their Embrace device, and after only a few hours of searching, the child is found under the ruins, it is mostly unharmed; Embrace allowed for a faster reaction and less search time

10:20 a.m. - the child is rescued and being transported to get emergency examination

11:30 p.m. - after they have been saved, the child and the mother reunite, greiving the loss of the father, who uncon-cious bled out under the ruins

Figure 72. - 6.5 earthquake intensity scenario with Embrace

Conclusion

The scenarios depicted with the intervention of Embrace provide valuable insights into its potential impact during earthquake events. Three scenarios were explored, each reflecting different earthquake intensities and settings.

In the first scenario, with an intensity of 6.0 on the Richter scale, a family residing in a historic city center house experienced significant damage. With conventional phone lines down, they turned to Embrace for communication. This scenario demonstrated Embrace's capability to alleviate anxiety and provide a means of contact, contributing to a sense of relief in such situations.

The second scenario, also with a 6.0 intensity earthquake, portrayed an individual strolling in the city center when the earthquake struck. Similar to the first scenario, Embrace offered a reliable communication channel for reaching out to family members. This scenario reinforced the device's potential to address communication challenges amid urban seismic events.

The third scenario, involving a more severe 7.0 intensity earthquake, depicted a family trapped in a city center house that eventually collapsed. Despite the dire circumstances, a child managed to use Embrace to send feedback about being trapped and injured, along with their location. This prompt communication significantly expedited the family's rescue compared to the previous scenario without Embrace.

In conclusion, these scenarios underscore the potential of Embrace as a valuable tool for mitigating suffering during earthquake events particularly in situations where conventional communication channels are disrupted or unavailable.

While they offer promising insights, further real-world testing and validation would be necessary to fully assess the device's impact and ensure its practicality and effectiveness in various earthquake-affected situations.

Production

Process

1. Custom Flexible PCB Fabrication: The production journey commences with the fabrication of a custom flexible printed circuit board (PCB). This PCB serves as the foundation upon which the various electronic components will be mounted. The flexibility of this PCB is essential to ensure that the bracelet can conform to the wearer's wrist while maintaining its functionality.

2. Component Mounting: With the flexible PCB in place, electronic components are expertly mounted onto it. These components include the microcontroller, an array of sensors (such as accelerometers, temperature sensors, and heart rate sensors), the LoRa transceiver module, GPS module, rechargeable battery, and other critical elements that enable the bracelet to fulfill its life-saving functions.

3. Connectivity: The remaining components, such as the LED screen and feedback button, are meticulously connected to the flexible PCB. These user interface elements play a vital role in ensuring seamless interaction between the wearer and the device.

4. Encapsulation: To safeguard the delicate electronics from the elements, including moisture, dust, and mechanical stress, a protective encapsulation process is employed. The components are carefully arranged and encapsulated within a robust housing that shields them from external environmental factors and mechanical shocks.

5. Silicone Injection: After encapsulation, a silicone injection process is employed to create a durable, water-resistant seal around the encapsulated electronics. This step ensures that the bracelet can withstand exposure to moisture and adverse conditions without compromising its functionality.

6. Testing and Quality Assurance: The finished bracelet then undergoes rigorous testing. This testing phase assesses not only the functionality of the device but also the material and structural durability. Various conditions and stress tests are conducted to ensure that the bracelet performs reliably in diverse real-world scenarios.

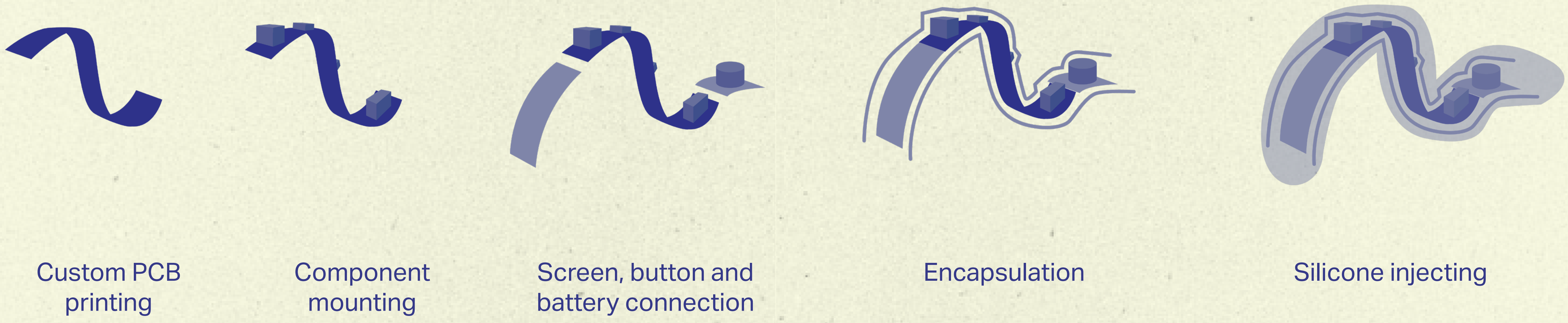


Figure 73. - Production graphic

Model

Process

The process of creating a model for Embrace involved several steps to achieve the initial bracelet prototype. It began with the design of a mould in Fusion 360, which would be used to inject silicone and create the bracelet using the desired material. Once the mould design was finalized, I had it 3D printed.

After 3D-printing mould, I relized that there were some imperfections that needed to be addressed. These imperfections were sanded to improve the quality of the mould, hoping for a better final result for the prototype.
The next step was the selection of the silicone material. PT Flex 85 liquid rubber was chosen, this silicone material comes in two parts, A and B, which need to be mixed in a 50-50 ratio to activate it.

Before injecting the silicone, it was necessary to prepare the mould. I applied a release agent to the mould surface to facilitate the easy extraction of the bracelet once it had hardened.
With the silicone mixture prepared and the mould ready, the injection process began. However, this process had its challenges. The silicone mixture had a relatively short hardening time, and its thickness made it difficult to inject into narrow areas within the mould. After multiple attempts, I've managed to create a one-piece bracelet.
The initial model served as a material and shape confirmation, but had some imperfections, notably air bubles trapped inside due to difficulties in removing them during the mixing process. As a result, further model variations were explored to achieve the desired flexibility and structure for the Embrace bracelet. These variations included one with 3D-printed sides and a bendable silicone back, as well as another with a fully 3D-printed bracelet.

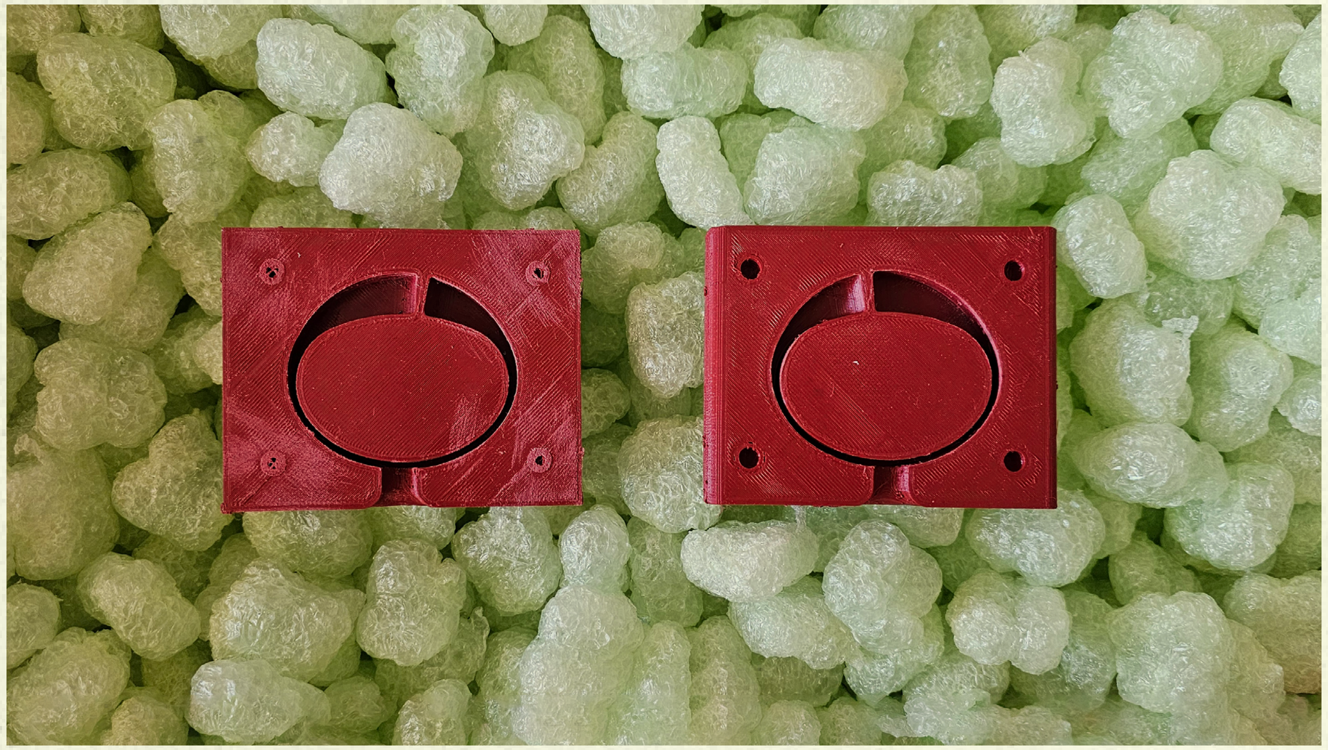


Figure 74. - 3D printed mould

Figure 75. - PT Flex 85 liquid rubber, part A & B

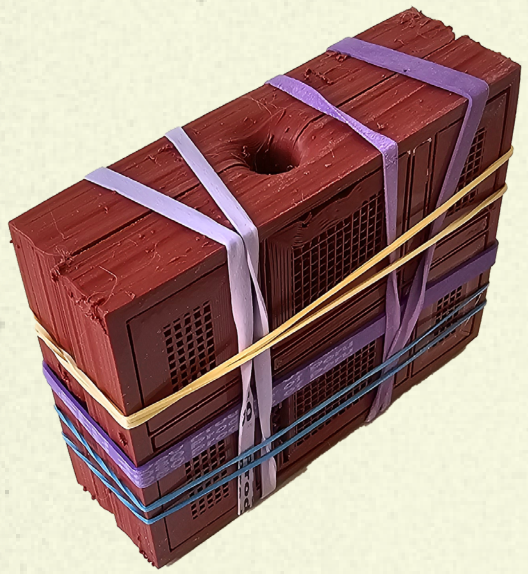


Figure 76. - assembled mould

Figure 77. - silicone bracelet, taken out of the mould

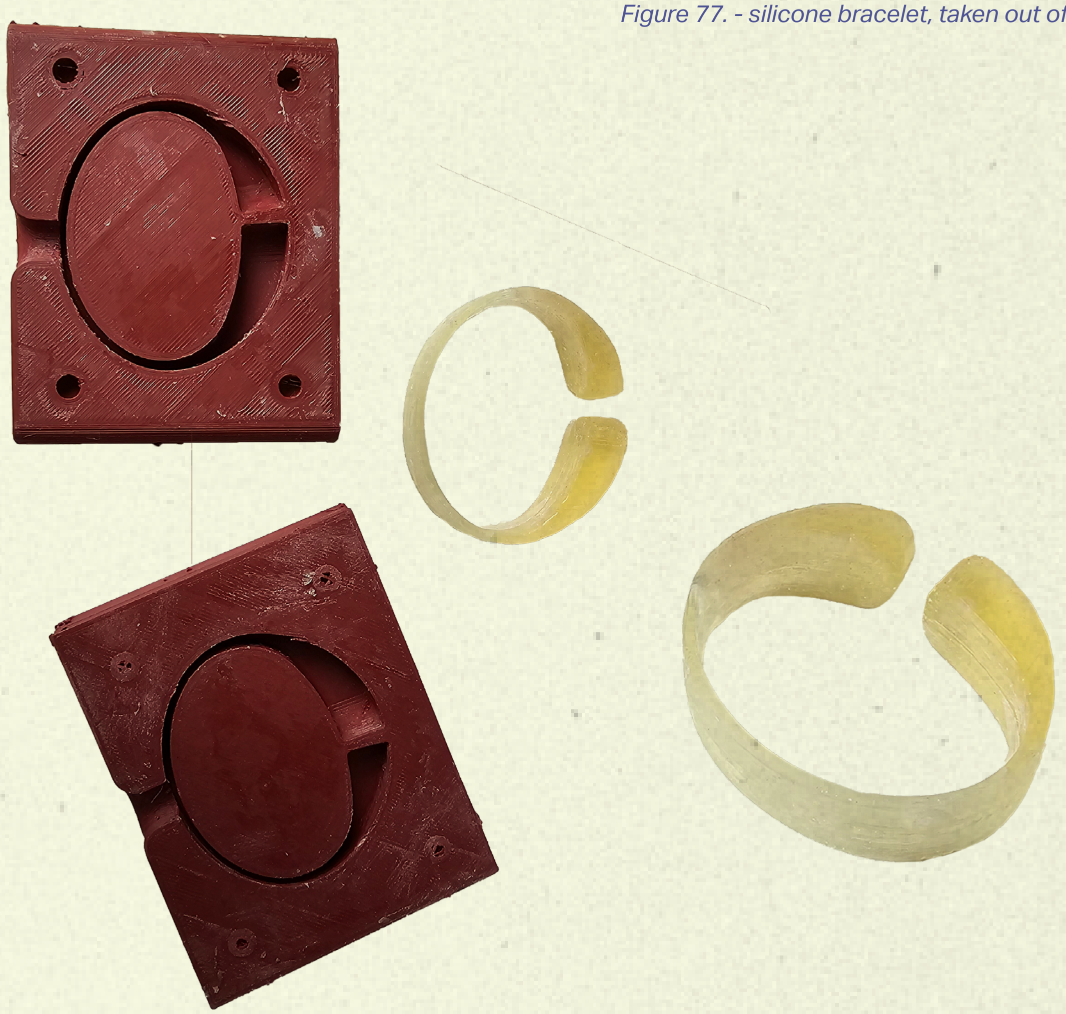
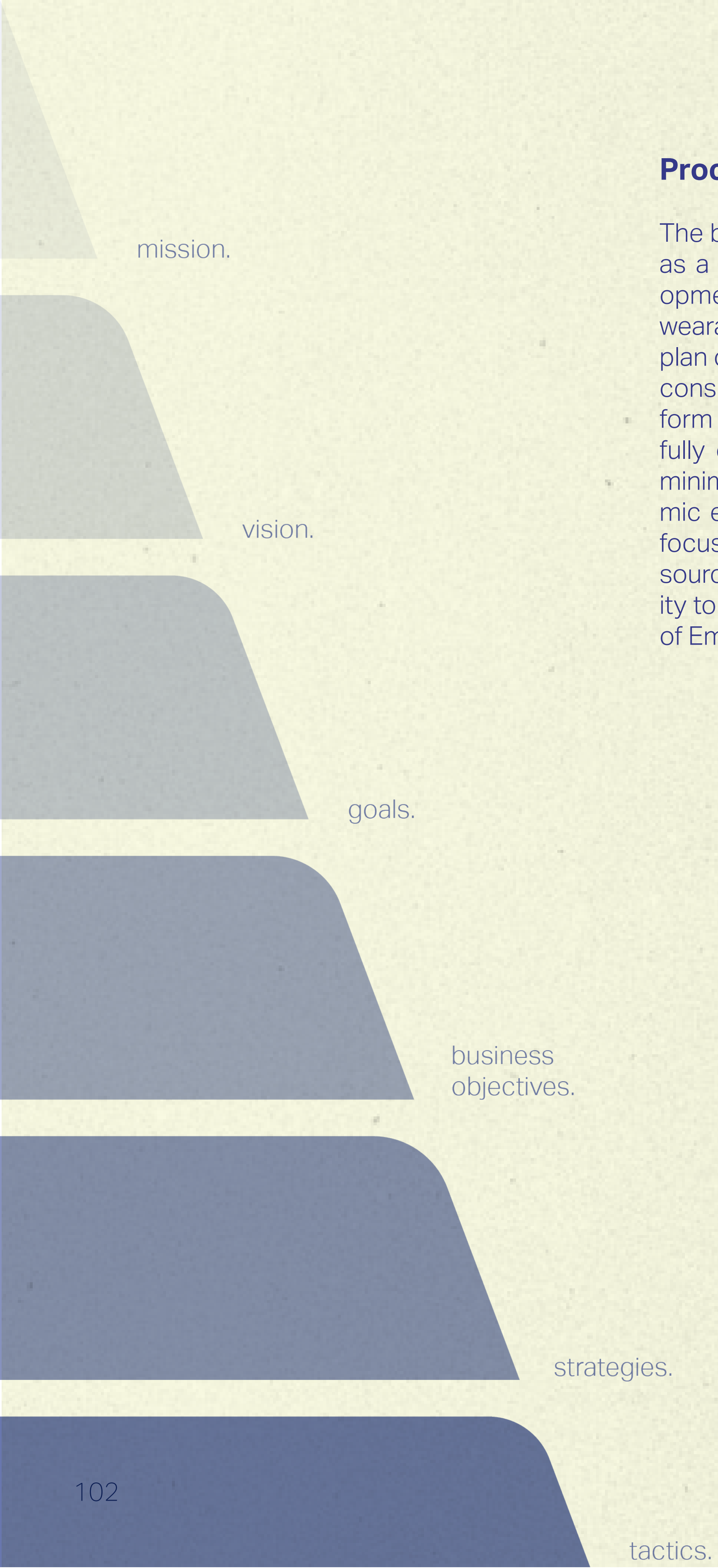


Figure 79. - 3D printed bracelet sides connected with bendable silicone back

Figure 78. - 3D printed bracelet

Figure 80. - 3D printed bracelet on hand

Business plan



Process

The business plan for Embrace serves as a blueprint for the potential development and launch of the Embrace wearable communication device. This plan outlines key strategies, steps, and considerations necessary to transform Embrace from a concept into a fully operational solution designed to minimize human suffering during seismic events. The objective of this plan focuses on practical execution, resource allocation, and business viability to ensure the successful realization of Embrace's mission.

Embrace - Earthquake Communication Bracelet

I. Executive Summary

Embrace is an earthquake communication bracelet designed to provide immediate assistance and enhance safety during seismic events. This business plan outlines the strategy for the development and distribution of Embrace, including a subsidy model and a service system. The business plan begins with a description of what societal need is central to the Embrace's design. It then elaborates on how the Embrace meets this need by explaining the bracelets function and use. After answering the central questions about the product itself, a specific description of the market for Embrace will be given as well as which target demographic is most likely to be receptive to the product.

After determining what the product is and who should buy it, consideration is given to the business model. The business model explains how subsidies can be used to make purchasing an Embrace financially attractive to the target audience and how more income can be generated from the Embrace with the "Service System" after the sale. Subsequently, the marketing of the Embrace is addressed.

After explaining the revenue model and how to market the product, the resulting financial projections are discussed. Finally, the challenges Embrace may have to overcome with regard to legislation, market adoption and sustainability are discussed.

II. Business Description

2.1 Vision and Mission

- Vision: To reduce human suffering caused by earthquakes, particularly among vulnerable populations.
- Mission: To develop, produce, and distribute affordable and effective Earthquake Communication Bracelets - Embrace

2.2 Product Description

Embrace is a wearable communication device that allows users to exchange vital information during earthquakes. It features long-range communication technology, a user-friendly interface, and an array of sensors for tracking the wearer's condition. During every day life, when no earthquakes are occurring, Embrace is in sleep mode and is worn either as a seamless skin tone bracelet, or as an aesthetic addition through adding golden/silver rims. It activates when an earthquake occurs, and allows for reception and transmission of information.

III. Market Analysis

3.1 Target Market

- Communities in earthquake-prone regions
- Insurance companies interested in disaster preparedness
- Governments and NGOs focused on disaster relief efforts

IV. Business Model

4.1 Subsidy Model

- Establish partnerships with insurance companies to offer Embrace as part of earthquake insurance packages.
- Subsidize the cost of Embrace through government initiatives and corporate social responsibility programs.

4.2 Service System

- Implement a "Return and Recycle" program where users can return Embrace when they no longer need it or when leaving earthquake-prone areas.
- Recycled devices can be refurbished and redistributed to new users or donated to communities in need.

V. Marketing Strategy

5.1 Branding

- Position Embrace as a reliable and accessible earthquake relief solution.
- Emphasize its affordability and ease of use.

5.2 Distribution

- Collaborate with insurance providers to integrate Embrace into their offerings.
- Establish partnerships with disaster relief organizations for mass distribution in vulnerable regions.

VI. Financial Projections

6.1 Revenue Streams

- Sales to individuals and organizations
- Subsidy and insurance partnerships
- Service system fees for device return and recycling

6.2 Expenses

- Research and development
- Manufacturing and production
- Marketing and distribution

6.3 Projected Profit

- Profit margins will depend on subsidy and insurance agreements.
- Projected profitability within the first three years.

VII. Risk Management

7.1 Regulatory and Compliance Risks

- Ensure compliance with international safety standards.
- Navigate regulatory challenges in different markets.

7.2 Market Adoption Risks

- Address potential resistance to adopting new technology.
- Invest in marketing and education efforts to promote Embrace.

VIII. Sustainability and Social Impact

8.1 Environmental Impact

- Use environmentally friendly materials and recycling practices.
- Promote sustainability in manufacturing and operations.

8.2 Social Impact

- Focus on providing disaster relief to vulnerable populations.
- Collaborate with NGOs and governments to enhance community resilience.

IX. Conclusion

The business plan for Embrace outlines a potential strategy for the development and distribution of this earthquake communication bracelet. With a subsidy model, service system, and a strong focus on affordability and accessibility, Embrace aims to make an impact in reducing human suffering caused by earthquakes while promoting sustainability and social responsibility.

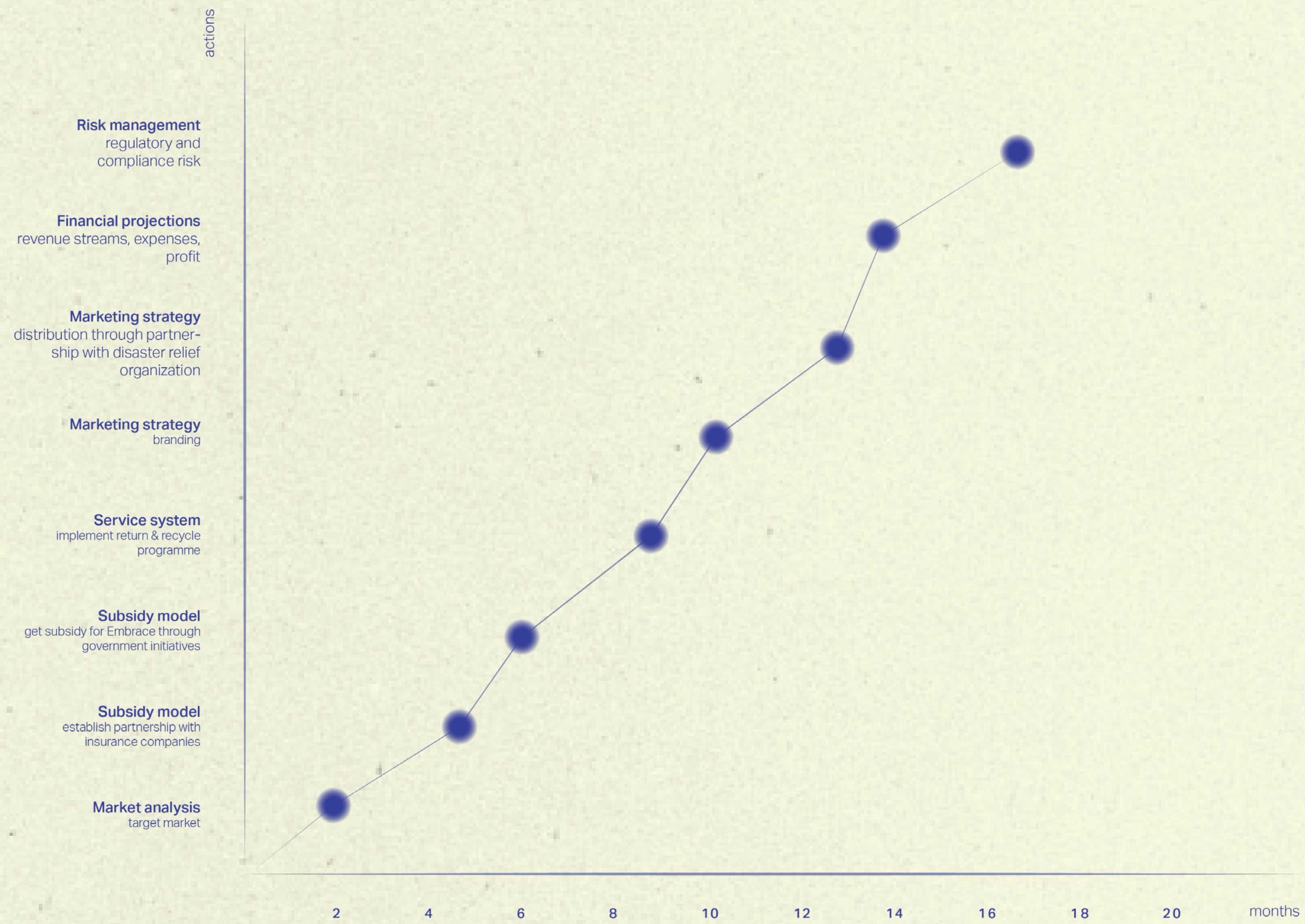
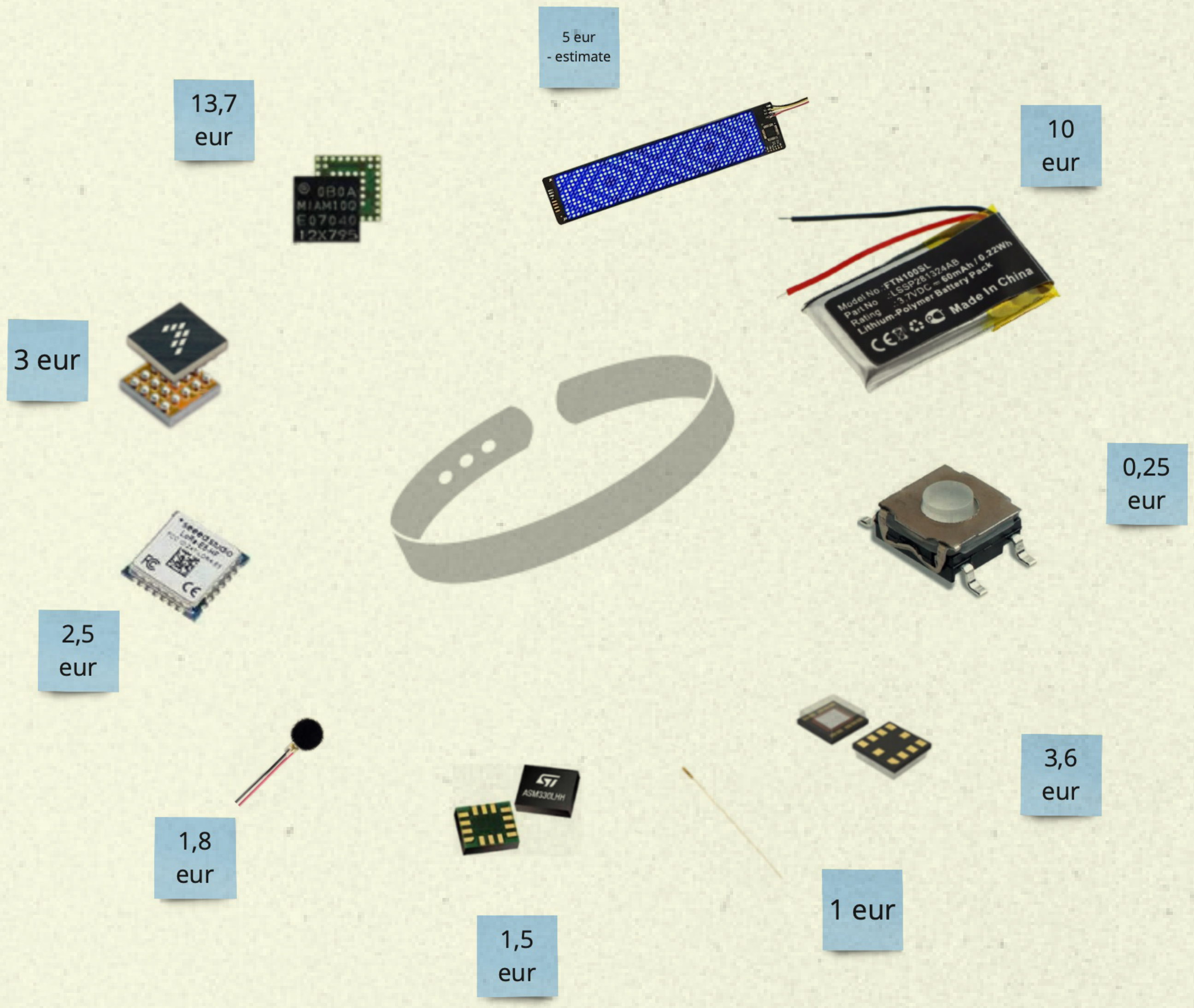


Figure 81. - business plan timeline

Price estimation

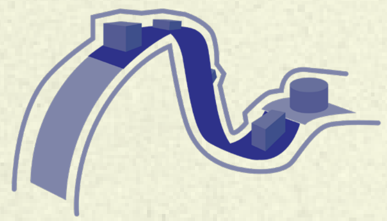
Components

43 euros - estimate



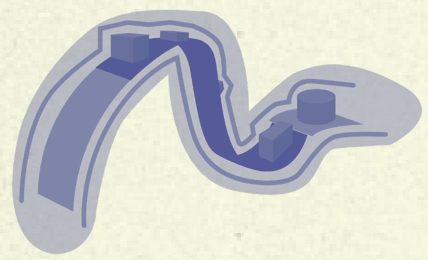
Encapsulation

1 euro - estimate



Outer materials

5 euros - estimate



Estimate of 49 euros per bracelet

Evaluation

- User acceptance testing
- Summary
- Reflection

In this section, the culmination of the design process is presented, showing the results of the questionnaire designed to gauge user acceptance of 'Embrace.' This invaluable feedback, collected through questioning different user groups, will show how this wearable resonates with potential users.

But this chapter goes beyond mere data presentation. It will show my personal reflection of the project, summarizing the objective evaluation of the project, with my subjective thoughts on the whole process. The encountered challenges, and the envisioned solutions. It offers an opportunity to step back and appreciate the effort that brought 'Embrace' to fruition, while also providing valuable insights for the road ahead.

07

User acceptance testing

Questionnaire

To gauge user reactions and test that the bracelet effectively met their needs and expectations, user acceptance testing was conducted. This involved engaging different user groups and gathering valuable feedback through a questionnaire. The biggest difference between the two chosen groups of participants is that one group has experienced a strong earthquake, and lives in earthquake prone areas, while the other group hasn't and doesn't live in an area affected by earthquakes.

The questionnaire served as a structured tool for assessing user acceptance. It included detailed explanations of how Embrace works, shedding light on its purpose and the features it encompasses. To provide users with a visual reference, renders of the bracelet were incorporated, highlighting its functions. The questionnaire was designed to elicit valuable insights on various aspects of Embrace, including its aesthetics, comfort, and usability. Users were encouraged to provide feedback on their initial impressions, the intuitiveness of the bracelet's features, and its overall appeal, and the most important part was feedback on whether they think this product is important during situations such as earthquakes and would they be willing to wear it.

Figure 82. - acceptance testing groups

Group 1

participants living in Croatia

Group 2

participants from various countries

Group 1: has experienced stronger erthquake
lives in earthquake prone area

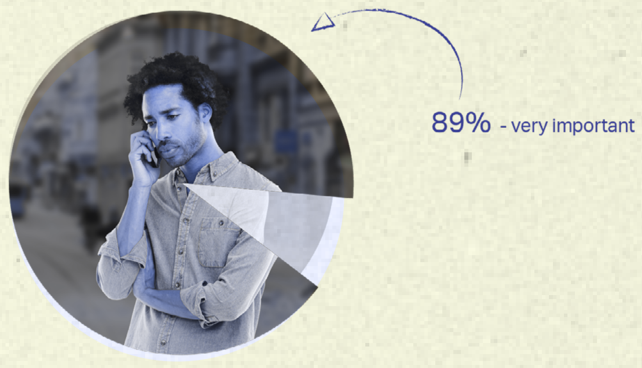
18 participants

Group 2: 65% hasn't experienced stronger erthquake
doesn't live in earthquake prone area

14 participants

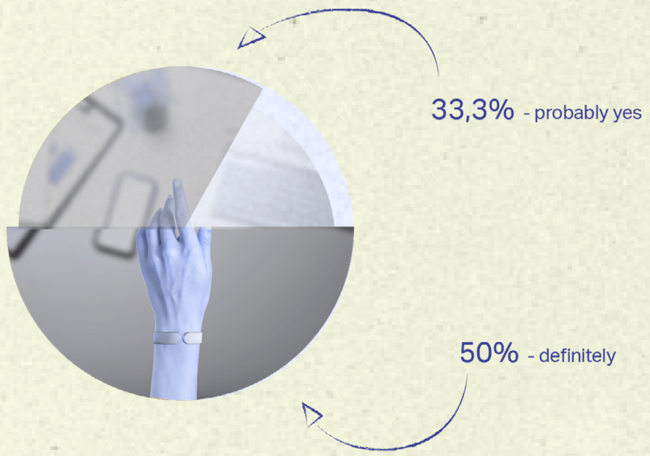
importance.

How important do you think a communication device like this could be during an earthquake emergency?



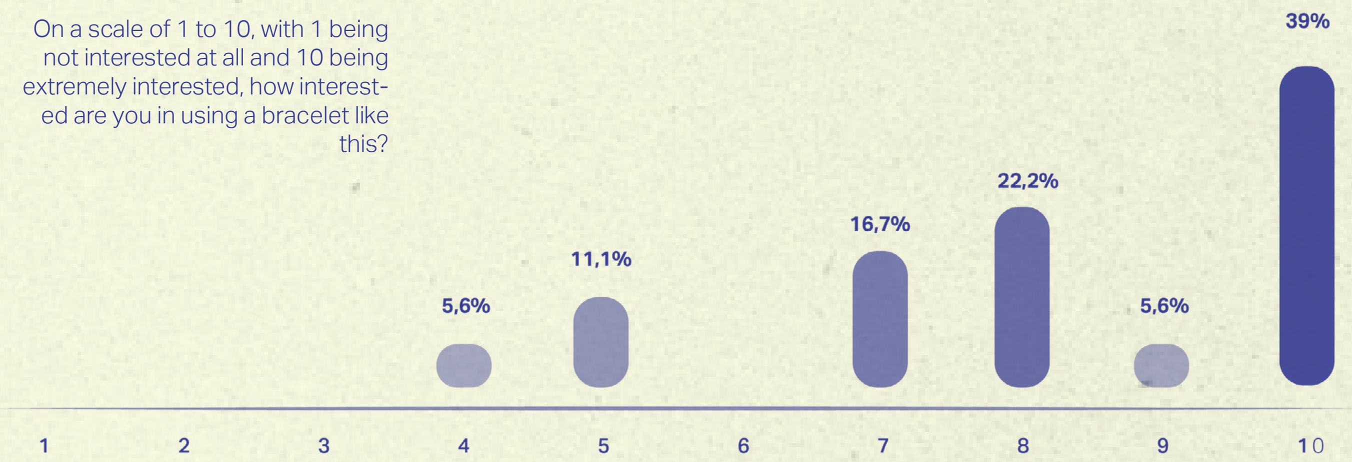
use.

Would you be willing to wear this bracelet during your daily activities, knowing it could help in earthquake emergencies?



interest.

On a scale of 1 to 10, with 1 being not interested at all and 10 being extremely interested, how interest-ed are you in using a bracelet like this?



impression.

What are your initial impressions of the bracelet's design and appearance?

“Elegant, seamless, and innovative.”

“Modern and functional, definitely needed.”

“If you didnt know the function, it could pass for jewelry.”

factors.

What factors would influence your decision to wear or not wear the bracelet regularly?

“Elegance and if its wearable with work clothes.”

“The frequency of earthquakes where I live.”

“Comfort and ease of use.”

“The worry for my loved ones.”

features.

Are there any additional features or functions you would like to see in a device like this?

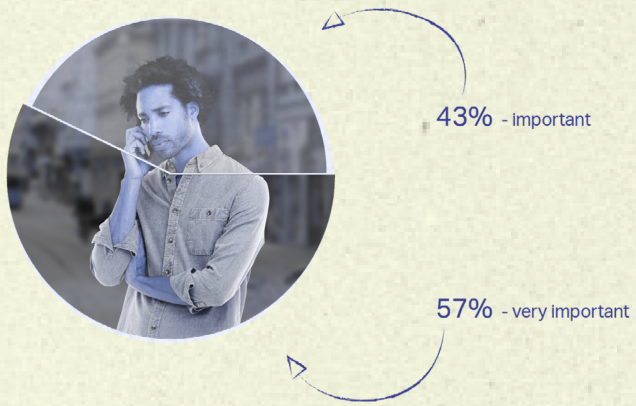
“Ability to contact emergency services.”

“Time and date.”

“No.”

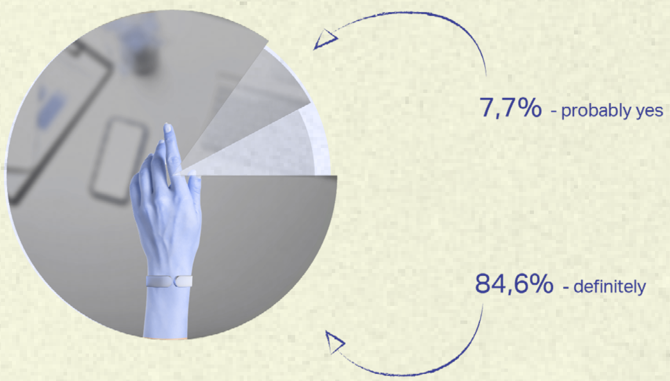
importance.

How important do you think a communication device like this could be during an earthquake emergency?



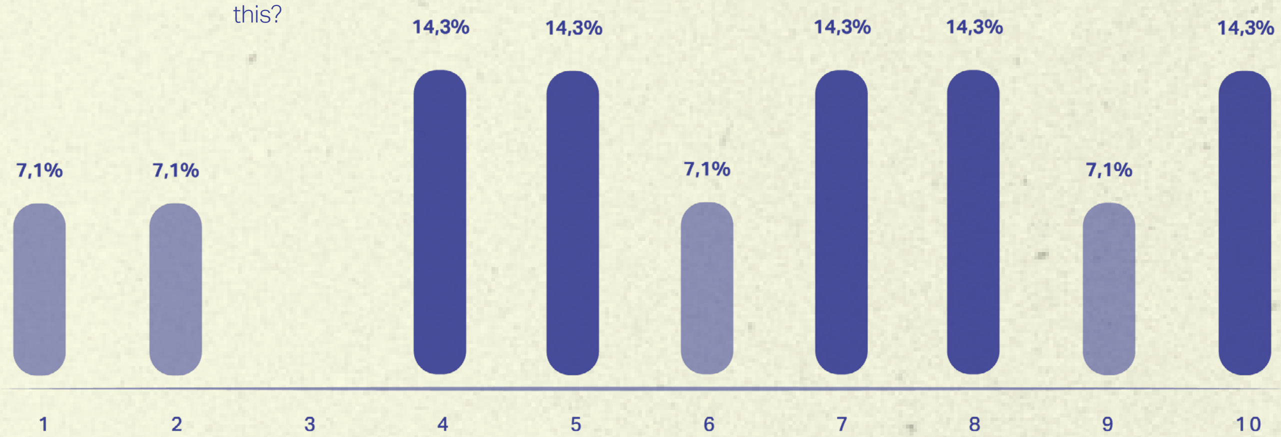
use.

Would you be willing to wear this bracelet during your daily activities, knowing it could help in earthquake emergencies?



interest.

On a scale of 1 to 10, with 1 being not interested at all and 10 being extremely interested, how interested are you in using a bracelet like this?



impression.

What are your initial impressions of the bracelet's design and appearance?

"The bracelets seem to have a neutral impact on your look, with the possibility to accentuate it's appearance with the rims if so desired by the user. The bracelet seems like it would be comfortable to wear."

"Very stylish for something meant for emergencies, in a good way. Because you do not want people to refrain from wearing because they are ugly."

"I like the skin tone variations and the fact that it is not very noticeable. I would definitely wear it."

factors.

What factors would influence your decision to wear or not wear the bracelet regularly?

"The overall looks and idea of the bracelet. If I would live in an area where earthquakes happen often, I would wear it."

"If it measures additional data such as a fitness tracker it would be even better. I have never lived in an earthquake sensitive area so maybe be that is why I would like additional features.."

"... i would prefer this functionalities added to the smart watch I use every day, seamlessly, not specifically to a device just for this."

"Also; I would buy it for €50 but not for €200 because of the "bad things (dangerous situations from earthquakes) only happen to other people" train of thought.."

features.

Are there any additional features or functions you would like to see in a device like this?

"I think this functions could be added to an existing smart watch."

"Perhaps link it to other natural disasters such as storms, wildfires en flooding too"

"A way to personalize it to differentiate it from the other members of my family or household that would be wearing the exact same band."

Conclusion

> **“Very stylish for something meant for emergencies, in a good way. Because you do not want people to refrain from wearing because they are ugly.”**
>
> *- Participant X, Group 2*

The user acceptance testing conducted for Embrace offers valuable insights into its potential adoption and perception among different user groups. While the Croatian group, with prior earthquake experiences, expressed a strong sense of importance and willingness to wear the bracelet, the various participants group, including those without earthquake experiences, also displayed significant interest and willingness.

These findings indicate that the purpose and potential of Embrace can be recognized by a wide range of users, irrespective of their earthquake exposure. The positive initial impressions of its design, described as stylish, comfortable, and neutral in appearance, bode well for its acceptance as a daily wearable device.

Factors influencing the decision to wear the bracelet included aesthetic considerations, earthquake frequency in the user's area, additional features, and price sensitivity. The preference for integrating functionalities into existing smartwatches suggests an opportunity for product diversification and customization.

In conclusion, the user acceptance testing demonstrates strong potential for Embrace as a communication device during earthquake emergencies. Its elegant design and user-friendly features, combined with positive user attitudes, position it as a promising solution to reduce human suffering caused by earthquakes. Further development efforts should focus on addressing user feedback and preferences to enhance Embrace's appeal and usability.

Discussion

The insights gotten from the testing point to the potential adoption of the device and its perceived value among different user groups. However, it is essential to consider the implications of these findings, acknowledge potential limitations, and outline recommendations for future user acceptance testing.

Implications:

Positive Reception: The strong interest and willingness to wear Embrace, even among participants without earthquake experiences, indicate that the device has broad appeal. Its design, which was praised for its style and comfort, contributes to its positive reception.

Cross-Functional Integration: Participants expressed a preference for integrating Embrace's functionalities into existing smartwatches. This suggests an opportunity for cross-functional collaboration with established wearable technology brands to offer integrated solutions.

Additional Features: Some participants mentioned the desire for additional features, such as tracking other natural disasters like storms, wildfires, and flooding. This feedback highlights potential directions for product expansion and differentiation.

Price Sensitivity: Price sensitivity was a recurring theme, with participants indicating that they would be more inclined to purchase Embrace at a lower price point. This insight should inform pricing strategies to maximize accessibility.

Limitations:

Limited Sample Size: The sample size for the user acceptance testing, particularly among participants with earthquake experiences, was relatively small. This limitation may impact the representativeness of the findings and generalizability to larger populations.

Biased researcher: The questions were conducted by a researcher who had personally designed the bracelet. This bias could have influenced the framing of questions and interpretation of responses, potentially introducing a confirmation bias.

Geographic Scope: The testing focused on participants from only a few geographic locations - Croatia, Netherlands, Mexico. Different regions may have unique perspectives and requirements related to earthquake preparedness.

In conclusion, the user acceptance testing offers promising insights into Embrace's potential as an earthquake communication device. However, recognizing the limitations and conducting further comprehensive testing with diverse participants would be essential for refining the product and maximizing its impact on reducing human suffering during earthquake emergencies.

Summary

Throughout the course of this project, the central focus was to address the research question: "How can a cost-effective solution be designed to minimize suffering of individuals living in seismically active Zagreb?" This endeavor involved a methodical and approach, evolving through several phases.

The project commenced with comprehensive initial research, delving into the seismic activity in Zagreb, the prevalent building types, and the lived experiences of those affected by earthquakes. This foundational knowledge laid the groundwork for the subsequent stages.

Interviews with Zagreb residents who had firsthand experiences with earthquakes provided invaluable insights into the emotional and practical challenges faced during seismic events. Coupled with scenario analysis, these interviews unveiled pain points and areas in need of intervention.

The defining of specific requirements followed, driven by the results from interviews and scenario analysis. These requirements allowed for a choice of design direction, Embrace - a communication focused bracelet for earthquake emergencies.

The design phase encompassed exploration, from the choice of communication technology to the bracelet's shape, material, and ergonomics. This design exploration was essential in creating a wearable communication device that met the identified requirements.

The embodiment of the design brought forth Embrace, a cost-effective wearable communication device designed to mitigate human suffering during seismic events. Embrace addresses the emotional and practical challenges faced by individuals living in earthquake-prone regions by providing a means of communication and reassurance during crises.

Notably, Embrace is designed with a minimalistic bracelet shape that prioritizes user interaction and feedback. It incorporates a button for user input and an LED screen for notifications, ensuring effective information exchange during seismic events.

User acceptance testing involving two distinct participant groups further validated Embrace's potential impact. The feedback received from those with and without earthquake experience highlighted the device's appeal, design, and significance in disaster resilience.

In conclusion, Embrace emerges as a tangible solution born from a systematic approach, supported by research, user insights, and a steadfast drive to improving the lives of individuals residing in seismically active regions, such as Zagreb.

Reflection

Personal insights

When starting this project, I was met with a degree of uncertainty regarding its eventual trajectory. The research exploration initially delved deeply into earthquake-related subjects, encompassing seismic knowledge, building types, and their responses to earthquakes. This phase was important in gaining insights into structural vulnerabilities and the challenges faced by individuals during seismic events. While this initial focus served to identify weak points in homes and enhance my understanding of earthquake-induced issues, it became apparent that the project would ultimately take a different direction, addressing earthquake-induced suffering through means other than interior interventions.

Reflecting on the project research, I recognize the value of extending the research scope to encompass a broader range of emergency solutions, especially since the project later focused on the development of Embrace, a wearable communication device tailored to alleviate earthquake-related suffering, which was a very different approach than focusing on an interior design, or a structural solution.

Regarding project planning and time management, I am content with my approach. Conducting interviews early in the research phase proved advantageous, offering critical insights into the experiences and needs of earthquake-affected individuals. However, I also believe that additional interviews or questionnaires at various stages, including the design phase, might have enabled a more iterative and user-centered development process.
One area where I would have liked to dedicate more time but found to be somewhat outside the project's scope since the project started without a concept, was the testing of Embrace's functionality, especially its real-world performance. However, this limitation was inherent to the project's evolution, transitioning from general earthquake research to comprehensive concept development. I found the guidance and feedback provided by my Chair and Mentor very useful, as it helped me form and answer the needed questions, especially in moments where I was doubting my direction or how to decide on next steps. Their insights and suggestions were invaluable, ensuring alignment with the project's goals and objectives. Our cooperation proceeded smoothly, characterised by open communication, regular updates, as well as easy reachability whenever I needed additional information or feedback.

In conclusion, this project has been a journey of growth and exploration, encompassing extensive research, concept development, and the creation of Embrace, a device aimed at minimizing earthquake-induced suffering in Zagreb. While certain areas could have been further refined or explored, I am happy with the progress made and the outcomes achieved during this project.

Future research

- Testing & recommendations

In the final chapter of this report, the focus shifts towards recommendations for future research and testing regarding Embrace. These recommendations stem from the insights gained throughout the development and evaluation process of the project.

By identifying areas that warrant further exploration and refinement, this chapter aims to provide valuable guidance for future endeavors related to Embrace.

08

Testing & recommendations

Next steps

Future research and design development for the Embrace project offer several directions to refine the device's functionality, usability, and versatility. These recommendations are based on a the research done throughout this project, and the results gotten from the finished design.

User Acceptance Testing Expansion: Building on the initial user acceptance testing, further research should involve a more extensive and diverse participant pool. This expansion will provide a more robust assessment of Embrace's appeal across various demographics and geographic regions.

Real-World Performance Testing: To evaluate the practical effectiveness of Embrace in challenging scenarios, real-world performance testing should be conducted. This includes assessing the device's ability to maintain LoRa communication through barriers like thick concrete, which is crucial for cases involving collapsed buildings and trapped individuals.

Shape Optimization: Further testing and exploration of the bracelet's shape and form factor could be useful. Iterative design improvements should be guided by user feedback and preferences.

Material Research: Conduct research to determine the optimal softness and hardness of the silicone material used in the bracelet's construction. Material properties like durability, comfort, and suitability for long-term wear should be assessed thoroughly.

Integrated Functionality: Investigation of feasibility of integrating Embrace's earthquake communication functionalities into existing smartwatches or wearable devices. This approach can offer users seamless access to essential emergency features without the need for an additional device.

Expanded Emergency Interventions: Expanding the scope of Embrace's emergency intervention capabilities beyond earthquakes. Considering additional variations designed to address various natural disasters such as flooding, storms, wildfires, and other weather-related emergencies could address wider group of users.

Cost-Effective Solutions: Exploring cost-effective manufacturing processes and sourcing options to ensure that Embrace remains accessible to a broader range of users, especially in earthquake-prone regions with varying socio-economic backgrounds.

Global Reach: Expand research to include international markets with different seismic risks and disaster preparedness needs. Understanding the unique requirements of diverse regions will help tailor Embrace's features to address a broader spectrum of challenges.

Comprehensive Feedback Loop: Maintain an open and ongoing feedback loop with users, emergency responders, and experts in disaster management. Continuously incorporate their insights into the design and functionality of Embrace.

Regulatory Compliance*:* Ensure that Embrace complies with relevant safety and regulatory standards, both nationally and internationally, to facilitate widespread adoption and distribution.

In conclusion, future research and design development for Embrace should prioritize extensive user testing, real-world performance evaluations, and iterative design improvements. By addressing the recommendations outlined above, the Embrace project can continue to evolve as a reliable and effective tool for reducing human suffering during a wide range of emergency situations, ultimately making a significant impact on global disaster resilience efforts.

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Appendix

- About earthquakes
- How do we measure earthquakes?
- Seismic waves
- Sub-questions
- Types of buildings
- Injuries due to earthquake
- Existing design solutions
- Interviews
- Cause-effect
- Requirements evaluation
- Scope & Product Vision
- Components overview
- Ergonomics - sizes
- Power consumption calculations
- Questionnaire results
- Project brief

About earthquakes

Earthquakes

An earthquake, referred to colloquially as a quake, tremor, or temblor, occurs when the Earth's surface experiences shaking due to the sudden release of energy within the Earth's lithosphere, leading to the generation of seismic waves.

Earthquakes exhibit a wide range of intensities, from imperceptible ones that go unnoticed, to powerful ones capable of launching objects and individuals into the air, causing significant damage to critical infrastructure, and leaving entire cities in ruins. The seismic behavior of a region encompasses the frequency, type, and magnitude of earthquakes that occur within a specified timeframe. Meanwhile, the seismicity at a specific geographical point on Earth represents the average rate of energy release through seismic events per unit volume. The term "tremor" is also employed to describe non-earthquake-related seismic vibrations.

On the Earth's surface, earthquakes manifest as ground shaking, displacement, or disruptions. In instances where a substantial earthquake's epicenter is situated beneath the ocean, it can displace the seafloor enough to generate a tsunami. Additionally, earthquakes have the potential to instigate landslides.
In a broader context, the term "earth

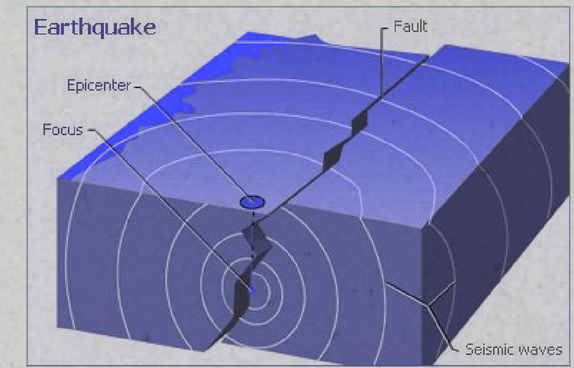


Figure 83. - Earthquake Vector Graphic

quake" encompasses any seismic event, regardless of its origin, be it natural or human-induced, that generates seismic waves.

While most earthquakes are the result of geological fault ruptures, they can also be triggered by phenomena such as volcanic activity, landslides, explosions in mines, and nuclear tests. The point at which an earthquake initially ruptures is known as the hypocenter or focus, with the epicenter being the point on the Earth's surface directly above the hypocenter.

Seizmic Waves

Seismic waves encompass a diverse range of wave types, each with its own set of distinctive characteristics. Primary waves, commonly referred to as P-waves, are the swiftest seismic waves, and they have the ability to traverse through both solid and liquid materials. This unique property makes them the first to arrive at a seismic recording station during an earthquake. Secondary waves, or S-waves, follow P-waves and, in contrast, they can only travel through solid substances. The motion of S-waves is responsible for more pronounced shaking and is often felt as a distinct jolt during an earthquake.

In addition to P and S-waves, surface waves play a significant role in earthquake dynamics. There are two primary types of surface waves: Love waves and Rayleigh waves. Love waves move in a horizontal, side-to-side motion and are responsible for causing a significant amount of ground shaking. On the other hand, Rayleigh waves move in both horizontal and vertical directions, creating a rolling motion that can result in substantial damage to buildings and structures. These surface waves, although slower than P and S-waves, often induce the most noticeable ground movement and are a critical factor in earthquake destruction.

Understanding the behavior of these various seismic wave types is fundamental to seismic research, earthquake monitoring, and ensuring preparedness for the potential impact of seismic events.

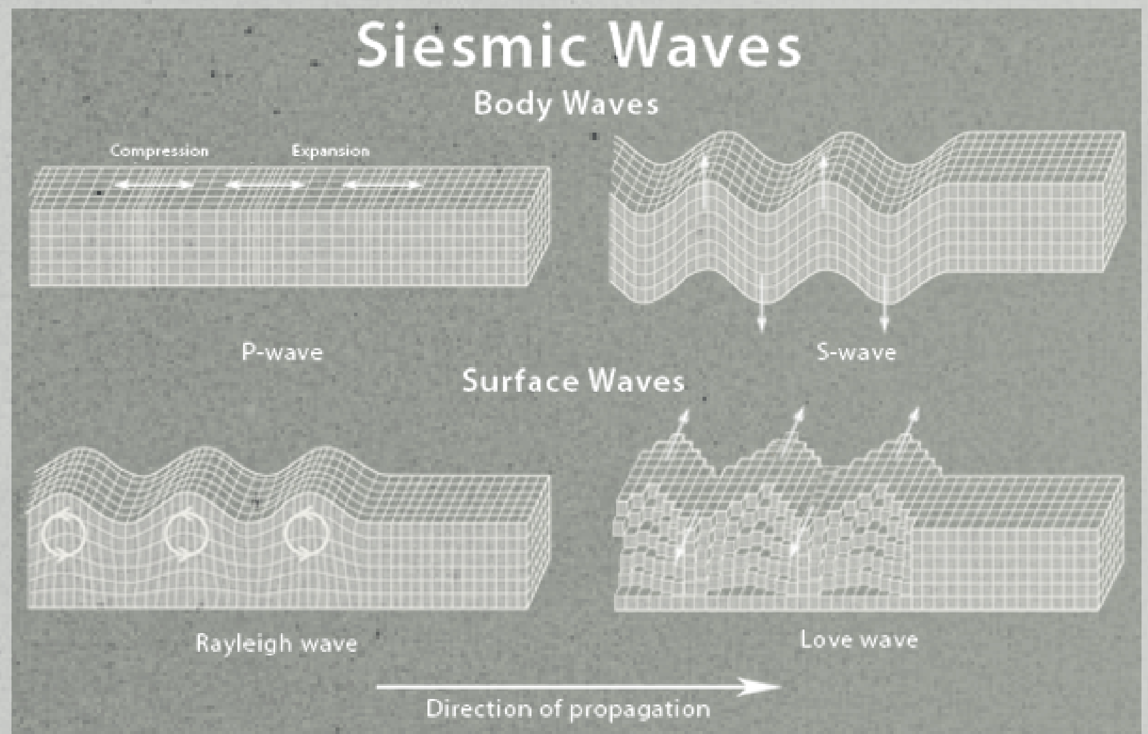


Figure 84. - Types of Seismic Waves

How do we measure earthquakes?

Measurement

Earthquakes are measured using a variety of scientific instruments and scales to quantify their intensity and magnitude. The primary tools for earthquake measurement include seismometers, seismographs, and various magnitude scales.

Seismometers are sensitive instruments that detect ground motion caused by seismic waves. When an earthquake occurs, these devices record the ground's movements, such as the shaking, rolling, and swaying, in multiple directions. This data is crucial for understanding the earthquake's characteristics.

Seismographs are instruments that graphically display the information recorded by seismometers. They produce seismograms, which are visual representations of the ground motion over time. Seismologists analyze these seismograms to determine the earthquake's location, depth, and the amplitude of seismic waves.

Two common scales are used to measure the magnitude of an earthquake. The Richter scale, developed by Charles F. Richter in 1935, quantifies an earthquake's magnitude based on the amplitude of seismic waves. The moment magnitude scale, or "Mw," has largely replaced the Richter scale as it provides a more accurate measurement for larger earthquakes. Moment magnitude considers several factors, including the fault length, slip, and rigidity of rocks involved.

The intensity of an earthquake, on the other hand, is measured using the Modified Mercalli Intensity (MMI) scale, which evaluates the effects of an earthquake on people, buildings, and the Earth's surface.

Magnitude	Intensity	Impact	The average rate of earthquakes
2.0 or less	Micro	Rarely felt	Over millions a year
2.0 to 2.9	Minor	Slightly felt	Over one million per year
3.0 to 3.9	More than minor	Often felt	Over a hundred thousand per year
4.0 to 4.9	Light	Felt by most people	Over ten thousand per year
5.0 to 5.9	Moderate	Can damage poor structures	Over a thousand per year
6.0 to 6.9	Strong	Causes damage to moderate well-build structures	Over a hundred per year
7.0 to 7.9	Major	Causes damage to most buildings	Ten to twenty per year
8.0 to 8.9	Great	Major damage to buildings	One per year
9.0 or more	Greatest	Can collapse all buildings	One every ten or more years

Figure 85. - Richter Scale

Strong intensity

When a powerful earthquake strikes, it sets in motion a chain of significant and far-reaching effects that impact the environment and society. The initial and most immediate result is the intense ground shaking, which can last for varying durations depending on the earthquake's magnitude. This shaking, in turn, leads to structural damage, compromising the integrity of buildings and bridges. Unreinforced masonry structures are especially vulnerable, and they may suffer partial or complete collapse. Even modern, well-engineered buildings can experience varying degrees of damage, emphasizing the extensive reach of the earthquake's impact.

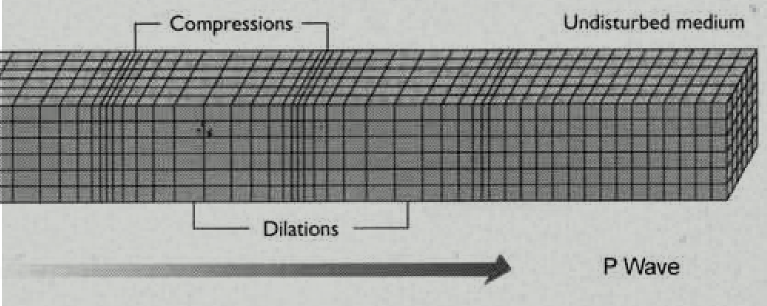
In hilly or mountainous regions, the earthquake-induced shaking can trigger landslides due to the abrupt release of stress on rock and soil. These landslides can obstruct roads, damage essential infrastructure, and pose substantial threats to local communities. Additionally, the seismic event is frequently followed by aftershocks, which are smaller but still impactful seismic events that can continue for days, weeks, or even months. These aftershocks further stress already weakened structures and complicate the efforts of rescue and recovery teams. In some cases, strong earthquakes can manifest as visible surface ruptures, where the ground is displaced along a fault line, with these ruptures often several meters wide. Should the earthquake's epicenter be situated beneath the ocean, it can displace the seafloor, giving rise to tsunamis. These massive, destructive waves inundate coastal areas, resulting in widespread damage and loss of life.

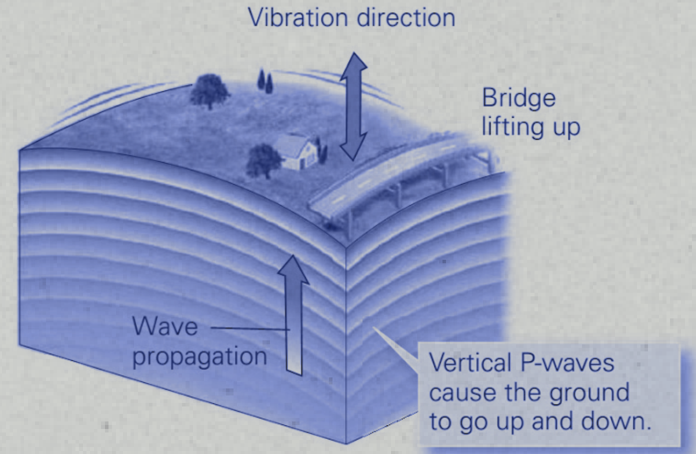
The consequences extend beyond the immediate physical impact. Strong earthquakes frequently disrupt essential services such as water, electricity, and transportation, further complicating rescue and recovery efforts and affecting the well-being of affected communities. This disruption of services can lead to humanitarian crises, with displaced populations, injuries, and loss of life necessitating urgent humanitarian interventions.

Moreover, strong earthquakes often result in significant economic repercussions. The cost of rebuilding infrastructure and addressing the extensive damages can strain local and national economies. Recovery efforts can extend over many years, involving the meticulous process of rebuilding homes, reconstructing damaged infrastructure, and the gradual restoration of normalcy.

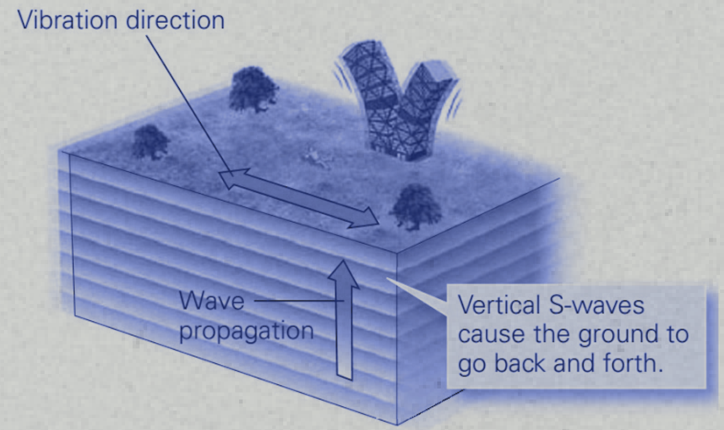
Seismic waves

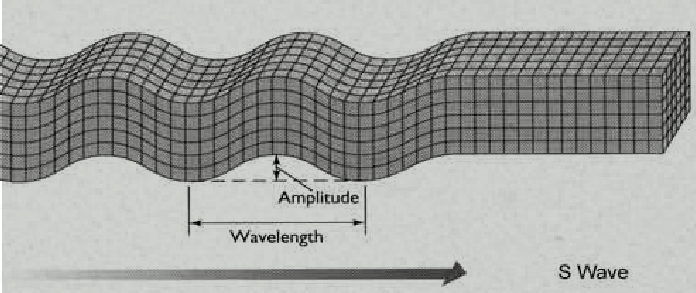
P waves, or Primary waves, are the fastest seismic waves and can travel through both solid and liquid materials. P waves are characterized by their compressional motion, where particles move in the same direction as the wave's propagation, causing alternating compression and expansion of the material. This compressional motion allows P waves to travel through the Earth's interior, and typically be the first to be detected in an earthquake event.



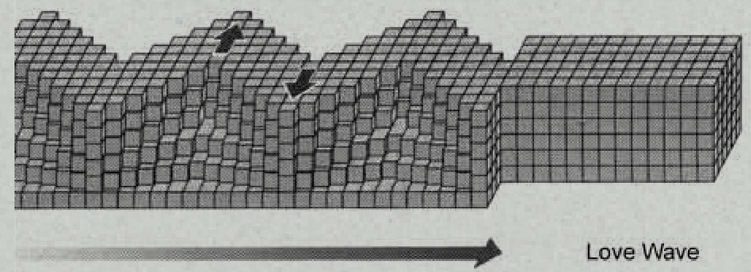


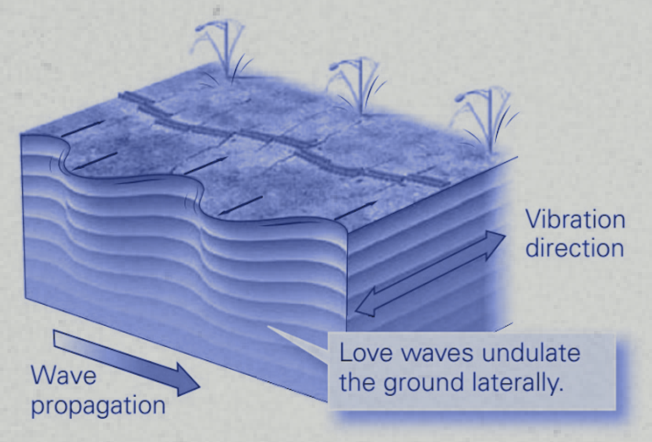
S waves, or Secondary waves, are one of the two main types of seismic waves produced during an earthquake. Unlike P waves, S waves can only travel through solid materials, making them slower than P waves. S waves are characterized by their shearing motion, where particles move perpendicular to the wave's direction of propagation, causing a side-to-side or shaking motion. These waves are responsible for the more pronounced shaking and are typically detected after the faster P waves.



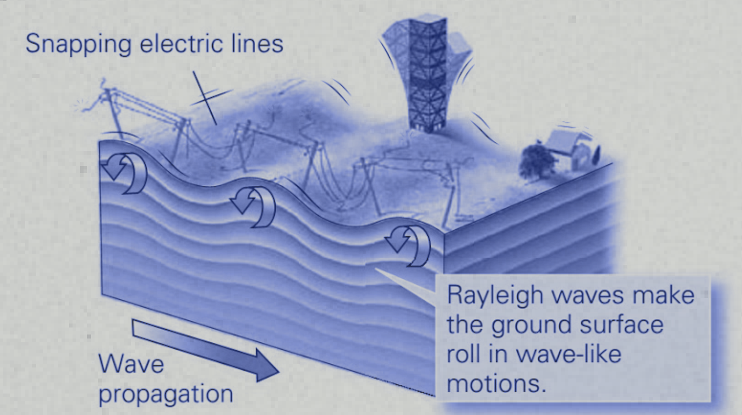


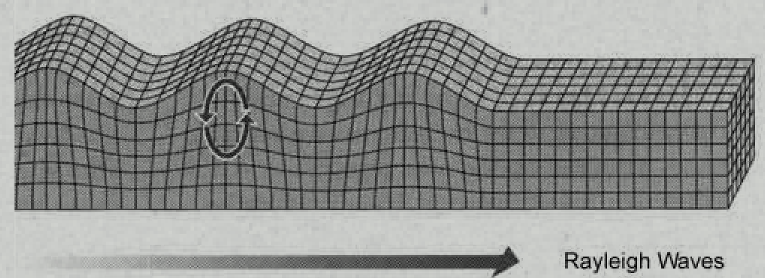
Love waves are a type of surface seismic wave, also known as *L-waves*. They are slower than P and S waves, and they travel along the Earth's surface. Love waves cause the ground to move in a side-to-side, or horizontal, motion, making them responsible for the strong shaking and swaying experienced during an earthquake. These waves are especially damaging to buildings and structures, as they create significant ground movement.





Rayleigh waves are a type of surface seismic wave produced during an earthquake. They are characterized by an elliptical, rolling motion, with particles moving in both vertical and horizontal directions. These waves travel along the Earth's surface and are slower than P and S waves. Rayleigh waves are responsible for causing the most significant ground movement and can induce strong shaking and damage to buildings and structures during an earthquake.





Sub-questions

The sub-questions within this research framework were important in pinpointing specific areas that needed exploration and analysis. One of the key areas addressed was the structural vulnerabilities inherent in 19th-century buildings in Zagreb. These structures, often characterized by their historical significance, were researched to understand their weaknesses and susceptibilities to seismic activity.
Another aspect discovered by the sub-questions was the human experience during earthquakes. These inquiries led to the examination of factors contributing to human suffering, encompassing emotional, physical, and psychological aspects. They prompted a deep dive into the feelings of anxiety, fear, and helplessness that individuals might encounter during such events. This understanding was important for developing effective solutions that address not only structural concerns but also the well-being of the people residing in these buildings.

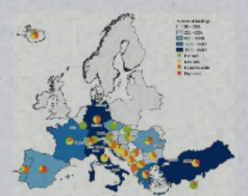
Furthermore, the I explored existing solutions and financial considerations. Looking into the cost-effectiveness of potential interventions, with a goal that any proposed solution would be both feasible and sustainable within the given constraints. The balance between functionality and aesthetics was also an important area of focus, as the solution should not only enhanced safety but also seamlessly integrated with the lives of people.

Overall, the sub-questions provided a structured and comprehensive framework for the research, ensuring that it remained focused on addressing the multifaceted challenges posed by seismic activity in 19th-century buildings in Zagreb. They guided the research towards achieving a holistic understanding of the problem, identifying practical considerations, and facilitating well-informed decision-making.

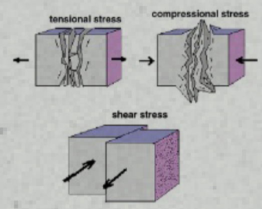
Sub-questions	Relevance	Methods	Expectations
What is the main cause of injury during an earthquake?	High	Literature research	Find out what mainly causes injuries - this might lead to first concepts
What is the main cause of death during an earthquake?	High	Literature research	Find out what mainly causes death - this might lead to first concepts Point out the areas that need addressing
Why does collapse happen?	Medium	Literature research Interviews	To find out main reasons for collapse - first step to designing a solution
What is the main cause for human suffering during and/or after earthquakes?	High	Interviews Literature research	Find out about what people perceive as most impactful on their emotional and physical state during and after an earthquake happens
Why are current solutions not affordable?	Medium	Interviews Literature research	It will give more insight into specific reasons for costly solutions - materials, work force, demand...
What makes a solution affordable?	High	Literature research Looking into existing projects	Create a list of features, requirements that make a solution affordable
How to make an affordable solution?	Medium	Literature research Consulting with experts	Find out about factors that influence the price of the solution, look into production & materials
What are some current solutions designed for protection during earthquakes?	Medium	Research	Find out what has been addressed through a design solution, and what still remains as an issue.
What aesthetic features should the solution take into consideration?	Medium	Research Interviews	Find out what features people give importance to regarding products used during emergencies/natural disasters
Are there any case studies or successful examples of projects or solutions in other earthquake-prone regions that can provide insights or inspiration?	Medium	Research	Inspiration

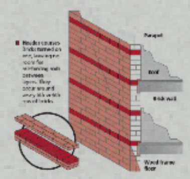
Types of buildings

Unburnt sun dried bricks laid in mud mortar

Types of Buildings	Properties	Usage	Behaviour during earthquake
Mud and Adobe Houses	• low level skill for construction and excellent insulation against heat and cold • The mixing of straw improves the tensile strength • Coating the outer wall with waterproof substance such as bitumen improves against weathering • The strength of mud walls can be improved significantly by split bamboo or timber reinforcement • Timber frame or horizontal timber runners at lintel level with vertical members at corners further improves its resistance to lateral forces which has been observed during the earthquakes.	• More than 100 million people in India live in these type of houses	• complete collapse • very weak in shear, tension and compression • Separation of walls at corner and junctions takes place easily under ground shaking • The cracks pass through the poor joints • After the walls fail either due to bending or shearing in combination with the compressive loads, the whole house crashes down • Extensive damage during earthquake especially if it occurs after a rainfall
Masonry Buildings	• Masonry buildings of brick and stone are superior with respect to durability, fire resistance, heat resistance and formative effects • They consist of various material and sizes (concrete blocks, rock blocks or lime stones; concrete brick-solid and hollow; Natural stone masonry)	• Because of its easy availability and economic reasons this type of construction are widely used	• Very heavy and attract large inertia forces • Unreinforced masonry walls are weak against tension (Horizontal forces) and shear, and therefore, perform rather poor during earthquakes • These buildings have large in plane rigidity and therefore have low time periods of vibration, which results in large seismic force • These buildings fall apart and collapse because of lack of structural integrity, which could be due to lack of 'through' stones, absence of bonding between cross walls, absence of diaphragm action of roofs and lack of box light action • All of them undergo severe damage resulting in complete collapse and pileup ina heap of stones • The inertia forces due to roof or floor is transmitted to the top of the walls and if the roofing material is improperly tied to the wall, it will be dislodged. The weak roof support connection is the cause of separation of roof from the support and leads to complete collapse
Reinforced Masonry Buildings			• withstood earthquakes well, without appreciable damage • For horizontal bending, a tough member capable of taking bending if found to perform better during earthquakes • If the corner sections or opening are reinforced with steel bars even greater strength is attained • Even dry packed stone masonry wall with continuous lintel band over openings and cross walls did not undergo any damage
Brick-Reinforced Concrete Frame Buildings	• consists of RC frame structures and brick lay in cement mortar as infill • This type of construction is suitable in seismic areas • Design of frame should be such that the plastic hinge is confined to beam only, because beam failure is less damaging than the common failure		• The failures are due to lack of good design of beams /columns, frame action and foundation • Poor quality of construction inadequate detailing or laying of reinforcement in various components particularly at joints and in columns /beams for ductility • Inadequate diaphragm action of roof and floors • Inadequate treatment of masonry walls • The damage is mostly due to failure of infill, or failure of columns or beams • Spalling of concrete in columns • Cracking or buckling due to excessive bending combined with dead load may damage the column • The buckling of columns are significant when the columns are slender and the spacing of stirrup in the column is large • Severe crack occurs near rigid joints of frame due to shearing action, which may lead to complete collapse • The differential settlement also causes excessive moments in the frame and may lead to failure
Wooden Buildings	• Most common type of construction in areas of high seismicity • It is also most suitable material for earthquake resistant construction due to its light weight and shear strength across the grains • Resistant is highest for diagonal braced wall • Buildings with diagonal bracing in both vertical and horizontal plane perform much better	• Northern Europe • USA • Canada • Japan • Australia • parts of South-East Asia	• The main reason of failure was its low rigidity joints, which acts as a hinge • Failure is also due to deterioration of wood with passage of time • Wood frames without walls have almost no resistance against horizontal forces • The traditional wood frame Ikra construction of Assam and houses of Nicobars founded on wooden piles separated from ground have performed very well during earthquakes • Wood houses are generally suitable up to two stories
Reinforced Concrete Buildings	• This type of construction consists of shear walls and frames of concrete		• The damage to reinforced concrete buildings may be divided broadly into vibratory failure and tilting or uneven settlement • When a reinforced concrete building is constructed on comparatively hard ground vibratory failure is seen, while on soft ground tilting, uneven settlement or sinking is observed • In case of vibratory failure the causes of damage may be considered to be different for each case, but basically, the seismic forces, which acted on a building during the earthquake, exceeded the loads considered in the design, and the buildings did not have adequate resistance and ductility to withstand them • The shear walls are found to be effective to provide adequate strength to the buildings • Severe damage to spandrel wall between the vertical openings is observed • The Precast and prestressed reinforced concrete buildings also suffered severe damage mostly because of poor behaviour of joints or supports
Steel Skeleton Building	• Buildings with steel skeleton construction differ greatly according to shapes of cross sections and method of connection • They may be broadly divided into two varieties, those employing braces as earthquake resistant elements and those which are rigid frame structures • The former is used in low building while the later is used in high-rise buildings	• Steel skeleton construction, particularly the structural type in which frames are comprised of beams and columns consisting of single member H-beams, is often used in high-rise buildings	• When braces are used as earthquake resistant elements, it is normal to design so that all horizontal forces will be borne by the braces • This type of building is generally light and influence of wind loads is dominant in most cases • However, there are many cases in which the braces have shown breaking or buckling in which joints have failed • The non-structural damage is common but none of these building severely damages as observed in 1906 San Francisco earthquake
Steel and Reinforced Concrete Composite Buildings	• Steel and Reinforced Concrete Composite Structures are composed of steel skeleton and reinforced concrete and have the dynamic characteristics of both • It is better with respect to fire resistance and safety against buckling as compared to steel skeleton	• Not really used for residential housing	• compared to reinforced concrete structures it has better ductility after yielding • As these features are the properties, which are effective for making a building earthquake resistant and are, found to perform better during earthquakes



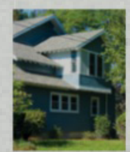




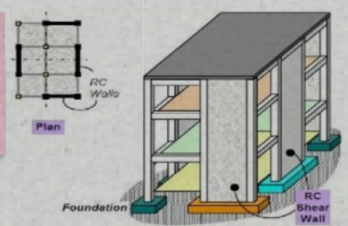

Shearing is **a force tending to cause deformation of a material by slippage along a plane or planes(areas) parallel to the imposed stress**. The resultant shear creates a large effect in nature, being closely related to the downslope movement of earth materials, and to earthquakes

The failure of bottom chord of roof truss may also cause complete collapse of truss as well as the whole building. If the roof/floor material is properly tied to the top walls causing it to shear of diagonally in the direction motion through the bedding joints. The cracks usually initiate at the corners of the openings. The failure of pier occurs due to combined action of flexure and shear. Near vertical cracks near corner wall joint occur indicating separations of walls. For motion perpendicular to the walls, the bending moment at the ends result in cracking and separation of the walls due to poor bonding. Generally gable end wall collapses. Due to large inertia forces acting on the walls, the Wythe of masonry is either bulge outward or inward. The falling away of half the wall thickness on the bulged side is common feature. The masonry with lower unit mass and greater bond strength shows better performance. The unreinforced masonry as a rule should be avoided as a construction material as far as possible in seismic area.




Shear wall definition: Shear walls (shear panels) **protect a home or building from becoming warped or distorted when attacked by horizontal (lateral) forces during an intense wind event, hurricane, or seismic event.** For many years, builders constructed shear walls with wood or steel framing.






Why do buildings collapse?

Contributing factors

While shaking caused by earthquakes is a big reason for damage and collapse of properties, there are multiple factors influencing the final outcome, besides the shaking itself.
These factors include liquefaction of soil, foundation failure, structural weaknesses in the building, and the failure of soft floors.

Liquefaction of Soil: Liquefaction occurs when water-saturated soil temporarily loses its strength and stiffness during an earthquake. This is particularly problematic in areas with loose, waterlogged soils. As seismic waves pass through, the soil can behave like a liquid, causing a loss of support for building foundations. Buildings may sink or tilt, leading to structural damage or collapse.

Foundation Failure: The foundation of a building is critical for distributing the structural loads and maintaining stability. During an earthquake, the ground shaking can cause excessive settlement, tilting, or shifting of the foundation. If the foundation fails to withstand these dynamic forces, it can result in structural damage or collapse of the building.

Structural Weakness: Many older buildings were constructed without the seismic design and reinforcement measures necessary to withstand strong earthquakes. Insufficiently reinforced masonry, unreinforced concrete, and inadequate structural connections can lead to building failure. When the building's structural elements cannot dissipate the seismic energy effectively, it can lead to collapse.

Failure of Soft Floors: Soft or weak-story buildings often have ground-floor columns that are less robust than upper floors. These soft-story buildings are susceptible to severe damage or collapse during an earthquake. The building's upper stories may lean or pancake onto the ground floor, causing a catastrophic failure.

Inadequate Building Codes: In some cases, building codes and construction standards may not have been updated or enforced to meet seismic safety requirements. Buildings constructed without adherence to these codes may lack the necessary reinforcement to withstand earthquake forces, making them more prone to collapse.

Personas

Creating personas from the interviews conducted was an impotant step in the research process, as it allowed for a more profound understanding of the diverse user groups affected by the seismic vulnerabilities of buildings in Zagreb. Through these insightful interviews, a tapestry of narratives, experiences, and unique needs emerged, highlighting the complexity of the issue. In response, personas were crafted to represent these relevant user groups, each persona embodying the characteristics, aspirations, and challenges of specific segments of the population.

These personas serve as indispensable tools for the forthcoming design exploration. They provide a human face to the research findings, making the design process more relatable and empathetic. By personifying the users, it is easier to envision the day-to-day realities, fears, and aspirations of those residing in these vulnerable structures.

This, in turn, aids in the creation of solutions that are not only technically sound but also responsive to the emotional and practical needs of these individuals.

The personas act as a compass, guiding the design process towards solutions that are tailored to the unique circumstances of each group, whether it's elderly residents seeking comfort and safety, families yearning for a secure environment for their children, or children dealing with stress and uncertainty. By utilizing these personas, the design exploration becomes a human-centered endeavor, one that strives to minimize human suffering and enhance the quality of life for the residents of 19th-century buildings in seismically active Zagreb.

Figure 10. - Created personas

Maja, 32 years old

Property type & Living situation

Lives with her husband and 2 children, in the apartment on the third floor of an old building in the city centre.

Frustrations

Constant fear of living in a seizmically active area, in an old building that already had damage from the 5.5 earthquake.

Fear for her children, is anxious to let them sleep in a separate room.

All of the renovations are very expensive, and they cannot afford to move in the current moment.

Lack of affordable solutions, feeling helpless.

Living in an unsafe apartment.

Wants

A sense of safety in her home, and a way to protect her children.

Nada, 54 years old

Property type & Living situation

Lives with her husband and 1 child, in the apartment on the second floor of a new reinforced concrete building in the suburbs.

Frustrations

Even though she knows she lives in a new and modern building, she is still unsure of the construction and doesn't know how the building would take an even stronger earthquake than the one that happened (for instance a 7.0).

She fears for the safety of her loved ones.

Is not sure which points in her home are the safest and which are the least safe.

Wants

Wants a sense of certainty in her home, wants to know her loved ones are safe in their home.

Maroje, 81 years old

Property type & Living situation

Lives with his daughter and her family in a reinforced concrete house that is 20 years old.

Frustrations

Cannot move fast, so isn't able to leave the house in time to safely evacuate. Because of this he feels like a burden to his family, since they stay with him.

Is worried for the uncertain future of his loved ones, and doesn't want them to live in fear of potential strong earthquakes

Is not certain of the construction of the house.

Wants

A safe environment for his family.

A way to be protected even if he can't leave the house quickly during an earthquake.

Tin, 5 years old

Property type & Living situation

Lives with his mother that is with child, his father, and his grandmother in an old apartment on the ground floor in the city centre.

Frustrations

Knows that earthquakes cause the shaking of the ground and his family's apartment, but still doesn't fully understand them.

Feels great fear whenever there are any vibrations (eg smaller earthquakes, or traffic outside of the house).

Wants

Want to know he and his family are safe, doesn't want his parents to be stressed because of the earthquake.

Earthquake injuries

Earthquakes can result in various types of injuries, some of which are directly caused by the seismic activity itself, while others are related to the aftermath and secondary effects of earthquakes. Here are some possible earthquake and earthquake-related injuries:

Traumatic Injuries:
Cuts, abrasions, and lacerations from flying debris, shattered glass, or building materials.
Fractures and broken bones due to building collapses, falling objects, or people being thrown to the ground.
Head injuries, including concussions and traumatic brain injuries, from falling objects or structural damage.
Crush injuries occur when individuals are trapped under collapsed buildings or heavy debris, leading to muscle and tissue damage.

Soft Tissue Injuries:
Contusions (bruises) from impact with objects or surfaces during the earthquake.
Sprains and strains due to sudden movements or falls during the shaking.
Dislocations of joints, often from trying to escape or protect oneself during the quake.

Respiratory Issues:
Inhalation of dust, smoke, or toxic fumes can lead to respiratory problems, including irritation, coughing, and exacerbation of pre-existing conditions like asthma.

Psychological Trauma:
Earthquake survivors may experience anxiety, post-traumatic stress disorder (PTSD), and other psychological distress, which can manifest in various ways, including panic attacks, insomnia, and depression.

Burns:
Fires caused by ruptured gas lines, electrical malfunctions, or other sources can result in burn injuries.
Scalds from hot liquids and steam, often related to damaged infrastructure like water heaters.

Electrocution:
Live electrical wires may become exposed or damaged during an earthquake, posing a risk of electrocution to individuals who come into contact with them.

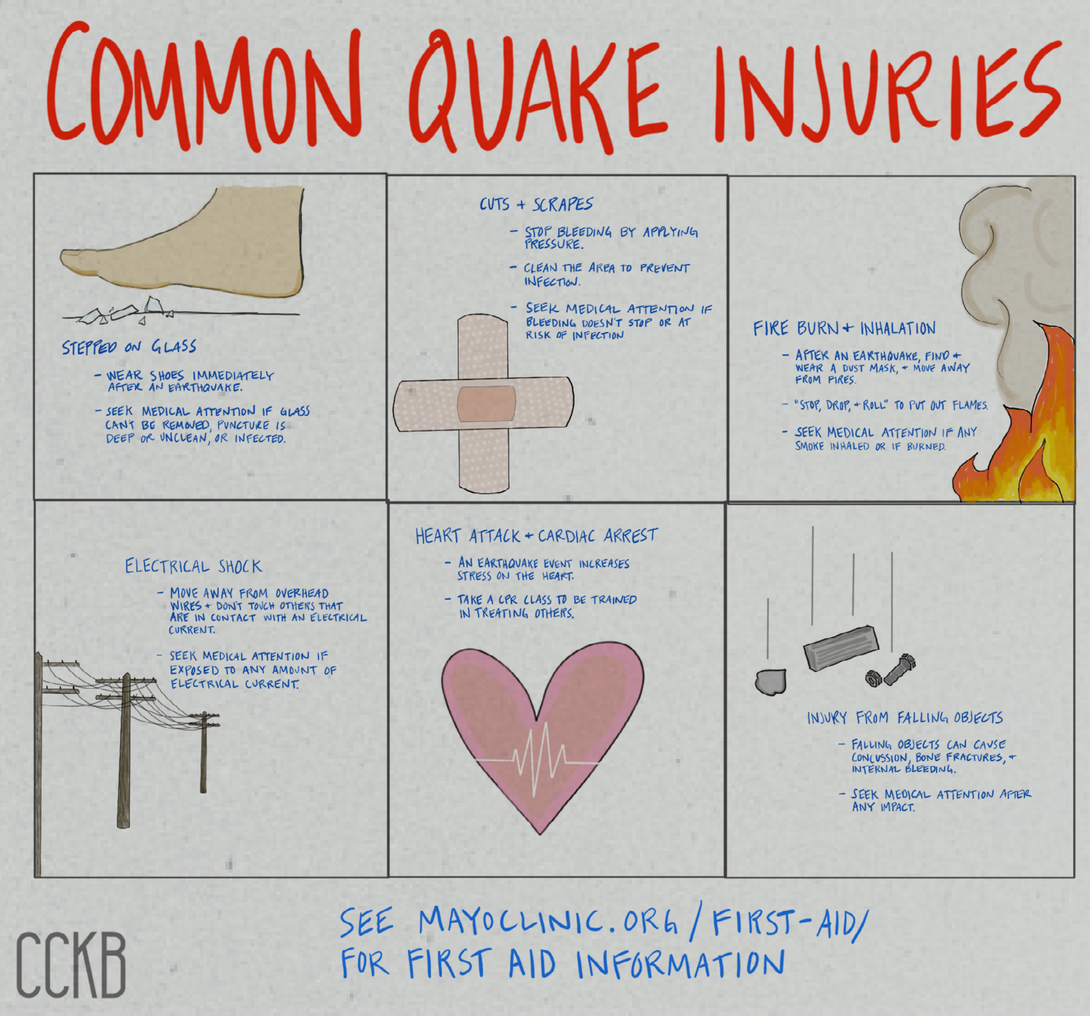
Falls:
People may fall from heights, such as stairs, balconies, or ladders, while attempting to evacuate or seek shelter.

Drowning:
Flooding or tsunamis triggered by undersea earthquakes can lead to drowning and water-related injuries.

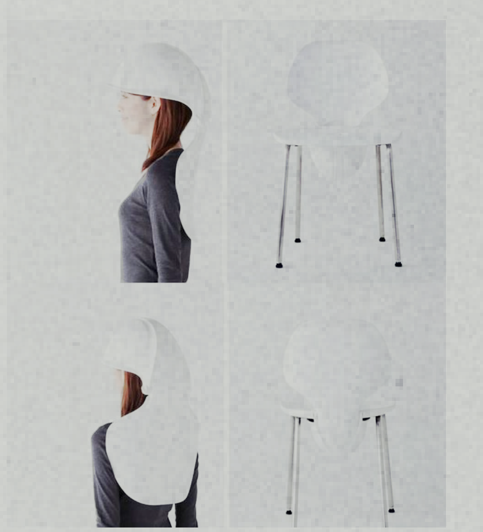
Disease Outbreaks:
Earthquake-damaged infrastructure, including water supply and sanitation systems, can contribute to the spread of waterborne diseases like cholera or vector-borne diseases like mosquito-borne illnesses (e.g., malaria, dengue).

Structural Injuries:
Individuals inside poorly constructed or unstable buildings are at higher risk of being injured during a quake, as these structures are more likely to collapse or suffer structural failures.

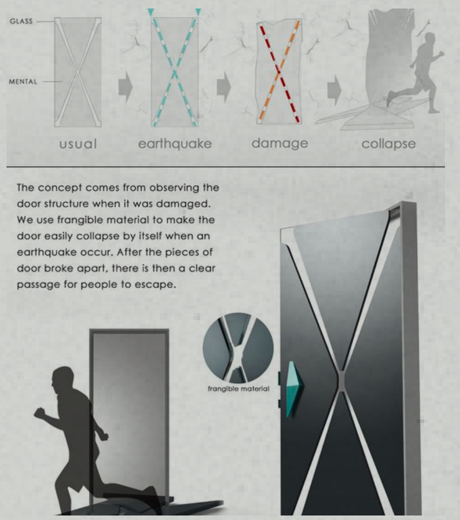
Hypothermia and Heat-Related Illnesses:
Depending on the environmental conditions following an earthquake, people can be exposed to extreme temperatures, leading to hypothermia (if it's cold) or heat-related illnesses (if it's hot).



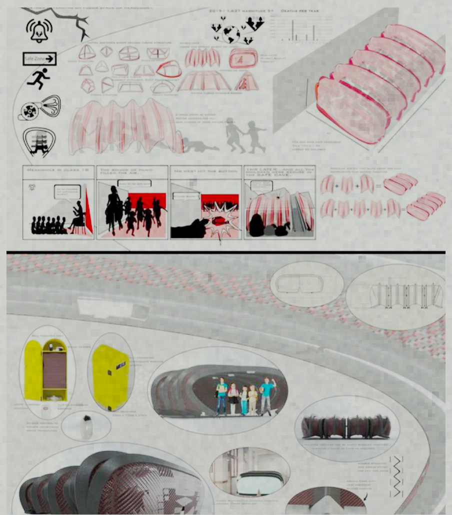
Existing design solutions



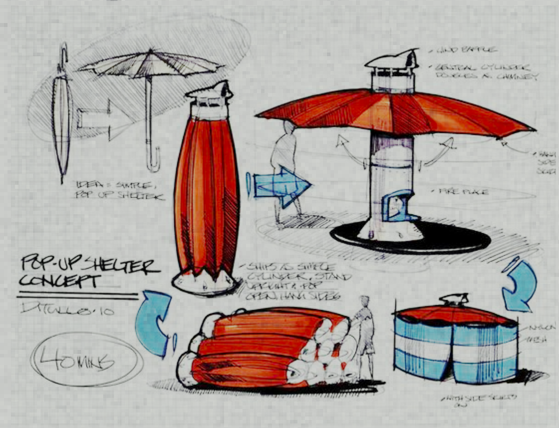
Object of every day use, a chair in this case, is designed in such a way to offer basic protection in case of an earth-quake. The design takes into account most common injuries, that often cause death, in the area of the head and back, and aims to prevent them.



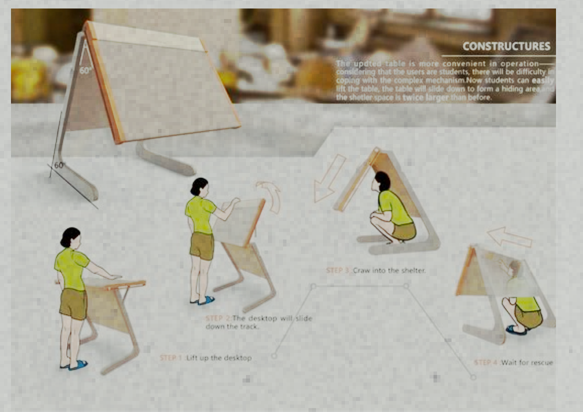
Design of doors which indicate when is the time to leave the property.
In this design the focus is on prevent-ing people from staying indoors during more intense shaking, and in such a way prevent injuries or death.



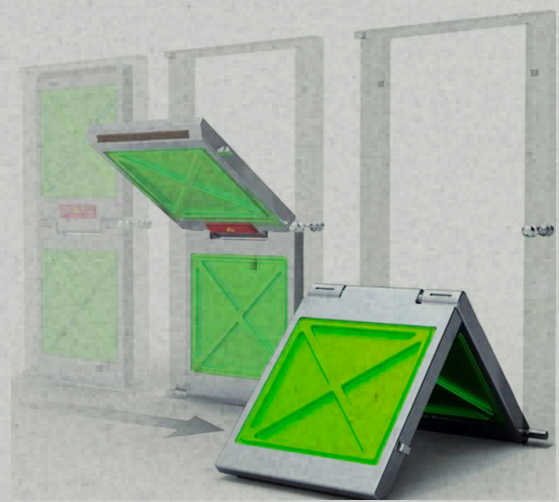
Design dedicated to provide a safe place ('shelter') for people that find themselves outside during an earth-quake. This designs aims to protect people against any objects which might fall on them. It is a modular design, which considers space around it.



This concept design provides tempo-rary protection against falling debris/ stones/materials. It is designed for pub-lic spaces, therefore can be colllapsed and in such a way use less space, when not used for protection.



Design of an every day object that turns into emergency protection for students - Triangle of life method.



Collapsable door design that protects from being crushed or injured from materials falling - Triangle of life method.

Interviews

Female, 29, old building in the centre

How much do you know about earthquakes?

I know the bare minimum about earthquakes

How much did you know about earthquakes before you experienced one?

I didn't know anything about earthquakes before

What kind of building/house are you living in?

I live in the center, old buildings, wooden beams, stone and shade in between, second floor

Cracks in the walls, they needed to be renovated
Reinforced with another row of beams on the floor and ceiling

Are you aware of the weaknesses of your housing? (in earthquake context)

The biggest problem is the chimneys and side walls, the chimneys are too big, they fall either inside the building or on the road, there are holes in the roof.
The gable walls of the upper floor were renovated with lightweight materials

Weak points - foundations, old materials, thick noise that cracks and falls; renovated everything, they want to strengthen the building; possible wall cracking in a strong earthquake

How did you adapt your home for seismic activity?

Renovation of the building - the entire building invested, in a loan of €250,000 - on the staircase, attic, basement, roof
The ceiling had to be restored, a network of chains holding the bricks (ceiling) was placed horizontally, injection technique
Only she did the strengthening of the floors

How did the 2020. earthquake affect you?

Very badly psychologically affected by the earthquake
Fear, restlessness, it is difficult to return to normal life
A lot of moving, a feeling of helplessness

How did you feel living in your home after the earthquake?

In the home after the earthquake - insecure, scared, inability to sleep, powerless to solve problems,
Additional solution, peace of mind - priceless, bought everything
At night they traveled with spoons and pots, lamps

How did you feel during the earthquake?

During the earthquake - great fear, shock, the greatest fear for the child, a feeling of helplessness, fear of letting the child go to the bathroom alone, fear of letting the child sleep alone in the room

How did you feel after the earthquake?

After the earthquake - adrenaline, protection, get out of there, not caring about the property

Did you, or anyone in your household get injured?

No one from the household was physically injured, but great psychological stress

Did you practice any protection methods during the earthquake?

During went under the stock, load-bearing wall

Did your life (in any way, physical or mental/emotional) change after experiencing the earthquake?

Life after - has changed, different thinking, greater caution, everything I buy I see that it is adapted for an earthquake, where I go I see what kind of real estate is
Life in fear, big change

How did the aftershocks affect you?

Aftershocks - no sleep, horrible, fear all over again

Home adapted - renovation, securing pictures on the wall, fixing furniture to the wall, moving heavy and fragile things from higher shelves to lower ones

Female, 60, old building in the centre

How much do you know about earthquakes?

How much did you know about earthquakes before you experienced one?

I know a little bit about earthquakes now, not too much, more about the Croatian area
I didn't know anything about earthquakes before

What kind of building/house are you living in?

I live in the center, old buildings, wooden beams, stone and shade in between, ground floor

Cracks in the walls, they needed to be renovated

Are you aware of the weaknesses of your housing? (in earthquake context)

The biggest problem is the chimneys and side walls, the chimneys are too heavy and big, not attached properly, they fall either inside the building or on the road, there are holes in the roof.

Weak points - foundations, old materials, thick wall fill that cracks and falls; renovated everything, possible wall cracking in a strong earthquake

How did you adapt your home for seismic activity?

Renovation of the building - the entire building invested on the staircase, attic, basement, roof
The ceiling had to be restored, and the walls near the ceiling

How did the 2020. earthquake affect you?

Very badly psychologically affected by the earthquake
Fear, restlessness, it is difficult to return to normal life
A lot of moving, a feeling of helplessness, fear for loved ones

How did you feel living in your home after the earthquake?

In the home after the earthquake - insecure, scared, inability to sleep, inability to solve problems created stress

How did you feel during the earthquake?

During the earthquake - great fear, shock, the greatest fear for the children, a feeling of helplessness, fear of being in different rooms, everyone should be in eyesight always

How did you feel after the earthquake?

After the earthquake - adrenaline, protection, get out of there, not caring about the property

Did you, or anyone in your household get injured?

No one from the household was physically injured, but great psychological stress

During went under the doorframe, load-bearing wall

Did you practice any protection methods during the earthquake?

Life after - has changed, different thinking, greater caution,
Life in fear, big change

Did your life (in any way, physical or mental/emotional) change after experiencing the earthquake?

Aftershocks - no sleep, horrible, fear all over again, fear for loved ones

Home adapted - basic renovation

How did the aftershocks affect you?

Male, 51, modern building on the outskirts

How much do you know about earthquakes?

I know roughly about earthquakes, why they occur, what they are, etc., basic things, I know about the consequences

How much did you know about earthquakes before you experienced one?

Before the earthquake - he knew what he saw on the news, he didn't think about it, it was always somewhere further away, the last he heard about the earthquake in Italy, a lot of damage and injuries
In our area, he had no knowledge about earthquakes before, that's all

What kind of building/house are you living in?

Type of building - modern construction, reinforced concrete, on the second (last) floor

The building passed without damage

Are you aware of the weaknesses of your housing? (in earthquake context)

Weak points - he doesn't know exactly, he hasn't seen the earthquake study, he knows that a fault line passes in front of the house

Safe points - it's not a big building, well-done reinforcement work
You need to stand next to a load-bearing wall, but you don't know exactly which wall it is in the apartment

How did the 2020. earthquake affect you?

Impact of the earthquake - quite shaken mentally, never experienced anything like that before
Very mentally disturbed, it took a long time for him to relax
Constantly waiting for a new blow
About a year
When a truck or bus passes by and a vibration is felt, everyone waits and watches to see if there will be an earthquake

Fear of the building collapsing, fear for the family

How did you feel during the earthquake?

During an earthquake - fear and panic, helplessness

How did you feel after the earthquake?

After the earthquake - panic, fear, the house scattered, broken windows, burnt pictures, the instinct to survive, get out of the building as soon as possible

Did you, or anyone in your household get injured?

Injuries? No one was seriously injured, stepped on the glass, scratches from the glass

How did you feel living in your home after the earthquake?

Feeling in the home - insecure, fear of repetition or a stronger earthquake, the question of what if, how the house will handle it

Did you practice any protection methods during the earthquake?

During the earthquake - no methods, the earthquake happened at 5 in the morning, juice and the inability to remember the methods

Did your life (in any way, physical or mental/emotional) change after experiencing the earthquake?

Change of life - experiencing an earthquake, awareness, learning about an earthquake

How did the aftershocks affect you?

Aftershocks - very unpleasant, additional stress, panic, fear, will there be a stronger impact

How did you adapt your home for seismic activity?

Adaptation of the home - I did not adapt the home, there is no damage

Female, 55, modern building on the outskirts

How much do you know about earthquakes?

I have basic knowledge about earthquakes, definitely learned more after I've experienced it

How much did you know about earthquakes before you experienced one?

Before the earthquake - I didn't have much knowledge, it always felt like something that happened in other places, not in my country
I knew big earthquakes could have catastrophic consequences

What kind of building/house are you living in?

Type of building - modern construction, reinforced concrete, on the second floor

The building passed without much damage, some paint cracks in the hallway

Are you aware of the weaknesses of your housing? (in earthquake context)

Weak points - not sure, I am assuming it could be the buildings hallway (the staircase); knows that a fault line passes in front of the house

Safe points - it's not a big building, well-done reinforcement work
You need to stand next to a load-bearing wall, but you don't know exactly which wall it is in the apartment

How did the 2020. earthquake affect you?

Impact of the earthquake - quite difficult emotionally, never experienced anything like that before, immense amount of stress during and much after earthquake
Very mentally disturbed, it took a long time for him to relax
Constantly waiting for a new earthquake
When a truck or bus passes by and a vibration is felt, everyone waits and watches to see if there will be an earthquake

Fear of the building collapsing, fear for the family

How did you feel during the earthquake?

During an earthquake - fear and panic, helplessness, rush of adrenaline to gather everyone together

How did you feel after the earthquake?

After the earthquake - panic, fear, the house scattered, broken windows, burnt pictures, the instinct to survive, get out of the building as soon as possible

Did you, or anyone in your household get injured?

Injuries? No one was seriously injured, husband stepped on the glass, scratches from the glass

How did you feel living in your home after the earthquake?

Feeling in the home - insecure, fear of repetition or a stronger earthquake, not knowing how the building will handle it, constant fear for the family

Did you practice any protection methods during the earthquake?

During the earthquake - no methods, the earthquake happened at 5 in the morning, shock and inability to remember the methods

Did your life (in any way, physical or mental/emotional) change after experiencing the earthquake?

Change of life - experiencing an earthquake, awareness, learning about an earthquake, more stress and thinking about everything that we put in the home

How did the aftershocks affect you?

Aftershocks - very unpleasant, additional stress, panic, fear, will there be a stronger impact

How did you adapt your home for seismic activity?

Adaptation of the home - I did not adapt the home, there is no damage; moving the heavy things to the lower heights

Female, 53, modern building in the city

How much do you know about earthquakes?

I know enough about earthquakes, how they manifest, and what is the likeliness for them in Croatia, and at which areas, definitely learned more after I've experienced it

How much did you know about earthquakes before you experienced one?

Before the earthquake - I didn't have much knowledge

What kind of building/house are you living in?

Type of building - modern construction, reinforced concrete, on the sixth floor, a bigger building, it has a wide base

The building passed without any damage

Are you aware of the weaknesses of your housing? (in earthquake context)

Weak points - not sure

Safe points - it's a big building, well-done reinforcement work
You need to stand next to a load-bearing wall

How did the 2020. earthquake affect you?

Impact of the earthquake - a lot of stress, mostly fear for my children and family, stress if we all weren't in the same place, not knowing how to contact them...
Very mentally disturbed, it took a long time for him to relax
Waiting for a new earthquake
When a truck or bus passes by and a vibration is felt, the stress comes back

Fear for the family

How did you feel during the earthquake?

During an earthquake - fear and panic, helplessness, rush of adrenaline to gather everyone together, also shock

How did you feel after the earthquake?

After the earthquake - panic, fear, the house scattered, the instinct to get out of the building as soon as possible

Did you, or anyone in your household get injured?

Injuries? No one was injured

How did you feel living in your home after the earthquake?

Feeling in the home - The earthquake did bring a lot of stress, but I felt secure in our home because I had trust in the building

Did you practice any protection methods during the earthquake?

During the earthquake - no methods, just shock and waiting for the shaking to stop

Did your life (in any way, physical or mental/emotional) change after experiencing the earthquake?

Change of life - experiencing an earthquake, awareness, learning about an earthquake, more stress

How did the aftershocks affect you?

Aftershocks - very unpleasant, additional stress, panic, fear, will there be a stronger impact

How did you adapt your home for seismic activity?

Adaptation of the home - I did not adapt the home, there is no damage

Male, 56, modern building in the city

How much do you know about earthquakes?

I have basic knowledge about earthquakes, mostly about Croatian area

How much did you know about earthquakes before you experienced one?

Before the earthquake - I had similar knowledge

Type of building - modern construction, reinforced concrete, on the sixth floor, a bigger building

What kind of building/house are you living in?

The building passed without any damage

Weak points - not sure, I don't think there are any significant ones

Are you aware of the weaknesses of your housing? (in earthquake context)

Safe points - it's a big building, well-done reinforcement work
You need to stand next to a load-bearing wall

Impact of the earthquake -some stress, although I think it didn't impact me as much as it did my family, mostly I cared that everyone was safe
The earthquake didn't impact me long term

How did the 2020. earthquake affect you?

How did you feel during the earthquake?

During an earthquake - shock and confusion, especially as it happened while we were still sleeping, then fear and instinct to gather everyone and leave as soon as possible

How did you feel after the earthquake?

After the earthquake - panic, fear, the house scattered, instinct to get out asap, checking if everyone is okay

Did you, or anyone in your household get injured?

Injuries? No one was injured

How did you feel living in your home after the earthquake?

Feeling in the home - The earthquake did bring some stress, but I felt secure in our home because I had trust in the building

Did you practice any protection methods during the earthquake?

During the earthquake - no methods, just shock and waiting for the shaking to stop

Did your life (in any way, physical or mental/emotional) change after experiencing the earthquake?

Change of life - experiencing an earthquake, awareness, learning about an earthquake

How did the aftershocks affect you?

Aftershocks - unpleasant, additional stress

How did you adapt your home for seismic activity?

Adaptation of the home - I did not adapt the home, there is no damage

Female, 82, old building in the centre

How much do you know about earthquakes?	I know the basics about earthquake, don't have extensive knowledge
How much did you know about earthquakes before you experienced one?	Before the earthquake - I didn't have much knowledge
What kind of building/house are you living in?	Type of building - old historic building, I live on the ground floor with my daughter
Are you aware of the weaknesses of your housing? (in earthquake context)	The building had a lot of damage, cracks to the wall, damaged chimneys, damaged facade
	Weak points - not sure, I would say the whole building is weak
	Safe points - to my knowledge you should go under a doorframe, or a weight bearing wall, so I think those are the safe points of the apartment
How did the 2020. earthquake affect you?	Impact of the earthquake - a lot of stress, mostly fear for my family, I cannot move as fast as them, and I fear of being a burden or holding them back and putting them in danger, I fear for my grandchild
How did you feel during the earthquake?	During an earthquake - fear and panic, helplessness, didn't know what was happening, it was difficult to move because of shaking
How did you feel after the earthquake?	After the earthquake - panic, fear, the house had cracks, everyone was very scared, wanting to get out
Did you, or anyone in your household get injured?	Injuries? No one was injured
How did you feel living in your home after the earthquake?	Feeling in the home - The earthquake did bring a lot of stress, I don't care so much for me but more for my daughter and grandchild
Did you practice any protection methods during the earthquake?	During the earthquake - no methods, just shock and waiting for the shaking to stop
Did your life (in any way, physical or mental/emotional) change after experiencing the earthquake?	Change of life - experiencing an earthquake, awareness, learning about an earthquake, more stress for loved ones
How did the aftershocks affect you?	Aftershocks - very unpleasant, additional stress, fear...
How did you adapt your home for seismic activity?	Adaptation of the home - my daughter had the apartment renovated, but there is only so much that can be done in an old building...

Female, 6, old building in the city centre

How much do you know about earthquakes?	I know the earth moves, from what my mom explained
How much did you know about earthquakes before you experienced one?	Before the earthquake - I didn't know anything
	Our house was shaking a lot, there were a lot of things falling on the ground, it was very noisy
Are you aware of the weaknesses of your housing? (in earthquake context)	Weak points - I don't know :/
	Safe points - mom said to go under the doors, but whenever there is shaking I get really scared and want to go to mom
How did the 2020. earthquake affect you?	Impact of the earthquake -I was really scared, and didn't know what happened, I was sad later because mom was scared and crying
How did you feel during the earthquake?	During an earthquake - really scared, I was with my mom, and there was a lot of noise
How did you feel after the earthquake?	After the earthquake - it was scary, wanted to leave, didn't know what was happening
How did you feel living in your home after the earthquake?	Feeling in the home - I was scared, I don't like to be alone in rooms, I also feel scared for my mom, and I feel sad because she gets sad
How did the aftershocks affect you?	Aftershocks - they are really scary, I always cry and feel sick sometimes

Interview with expert, building engineer - ir. Ivan Kutija

buildings in the centre - masonry buildings with wide walls (60, 70 cm), on top wooden construction (wooden beams) and in between **šuta** (serves as sound isolations), and trska, and plaster

then until 1968 (earthquake in Skopje) - buildings with weak concrete, and after goes reinforced concrete constructions, until eurocode (currently)

three ways of building today in ZG - reinforced masonry, reinforced concrete houses/buildings, and prefabricated houses (wooden...) - all okay with the eurocode

the most dangerous areas (prone to collapse) are old buildings in the centre (basically the whole centre is made out of old buildings)

what contributed to the danger of old buildings was their irregular renovations - for instance creating too big windows (4/5 meters) on the ground floor for shops etc., the base of the construction is weakened, in this way soft ground floors are created and the whole building is weakened due to the worsened foundation

another danger - floor rotation - when the raster is irregular (when parts of the building are renovated not properly) this happens - a lot of examples in Zagreb where people renovated their apartments without taking into consideration the whole building, for instance putting concrete ceilings or floors into old buildings that are based with wooden beams and bricks, as well as removing walls and creating a different raster than the floor below or above

Old buildings that are regularly and properly kept/renovated have handled the earthquake well - keeping the foundations dry, keeping the raster regular, checking the materials, basement has to be well isolated

type of buildings depend on the part of the city, most of the buildings outside of the centre are reinforced concrete buildings, and further than that (outskirts) are masonry buildings

regular checking of construction

regular raster

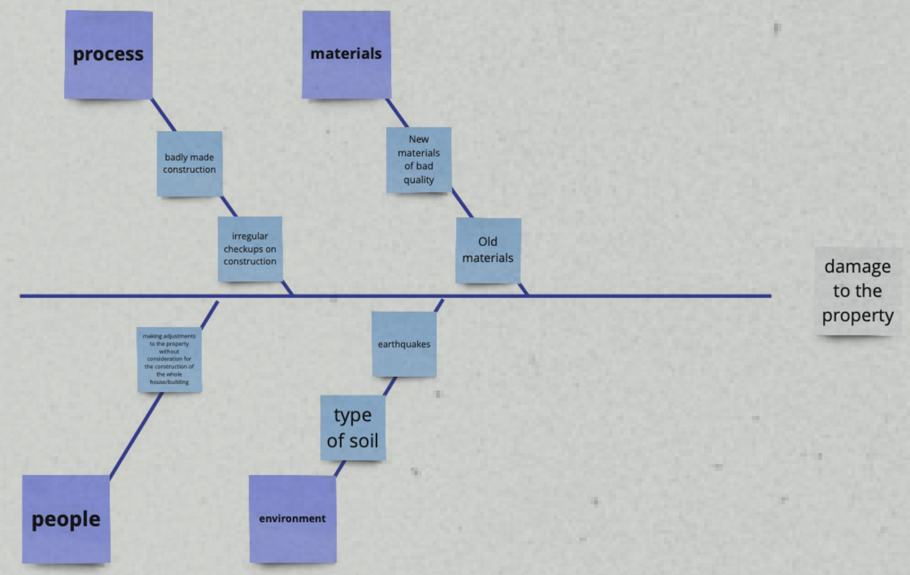
dry and well isolated basement and foundations

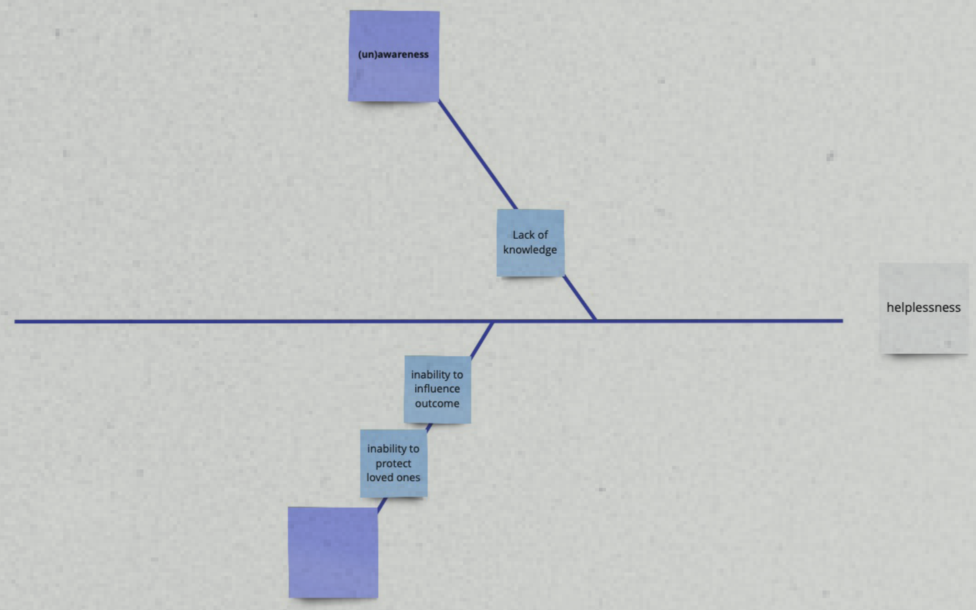
Old and improper build

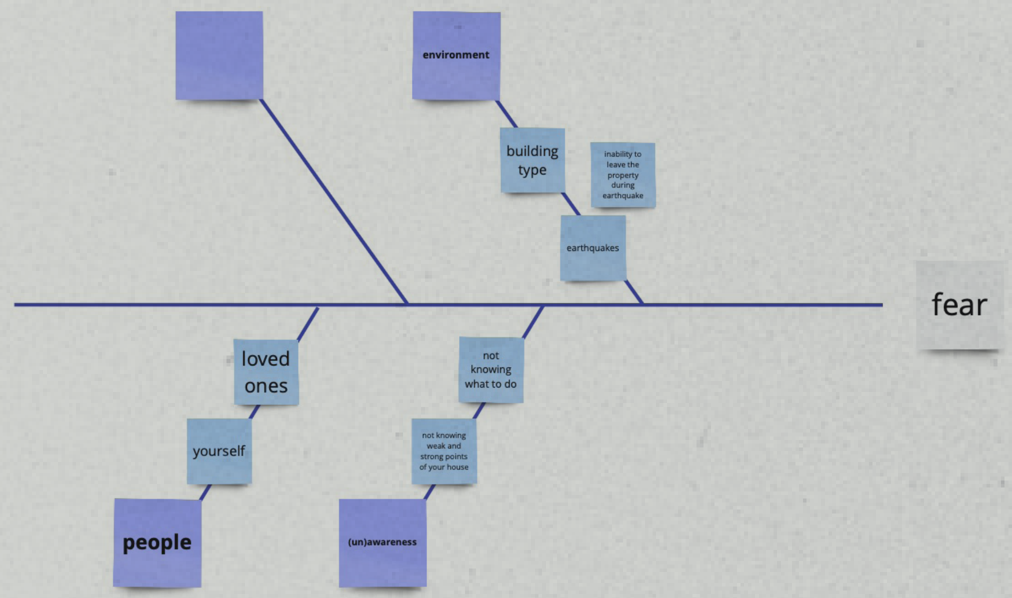
bad interventions

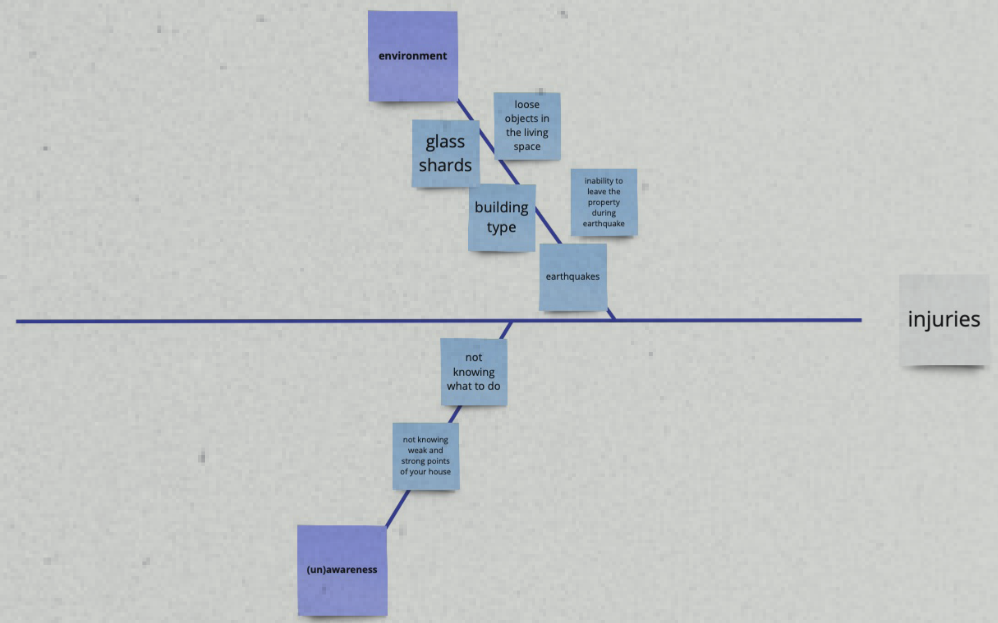
bad upkeep of building

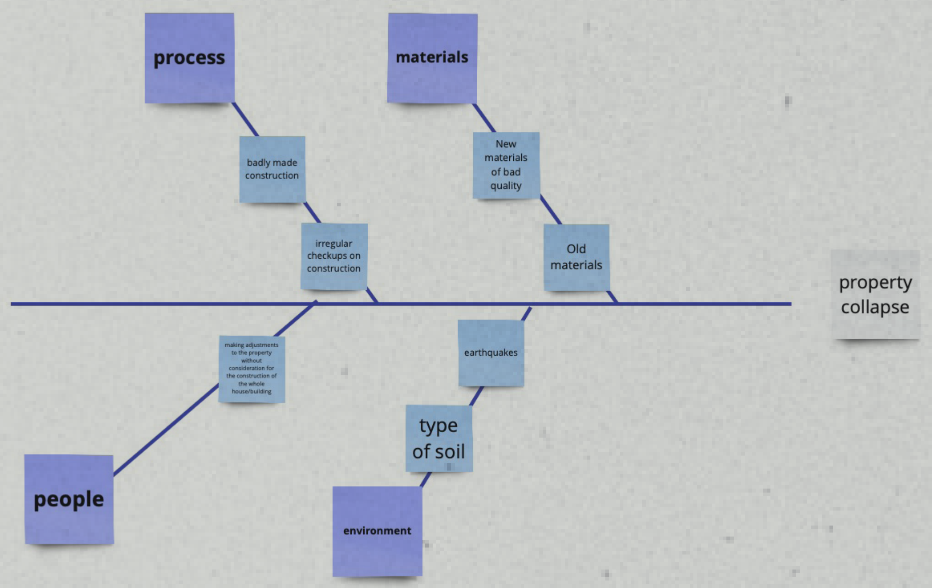
Cause-effect analysis

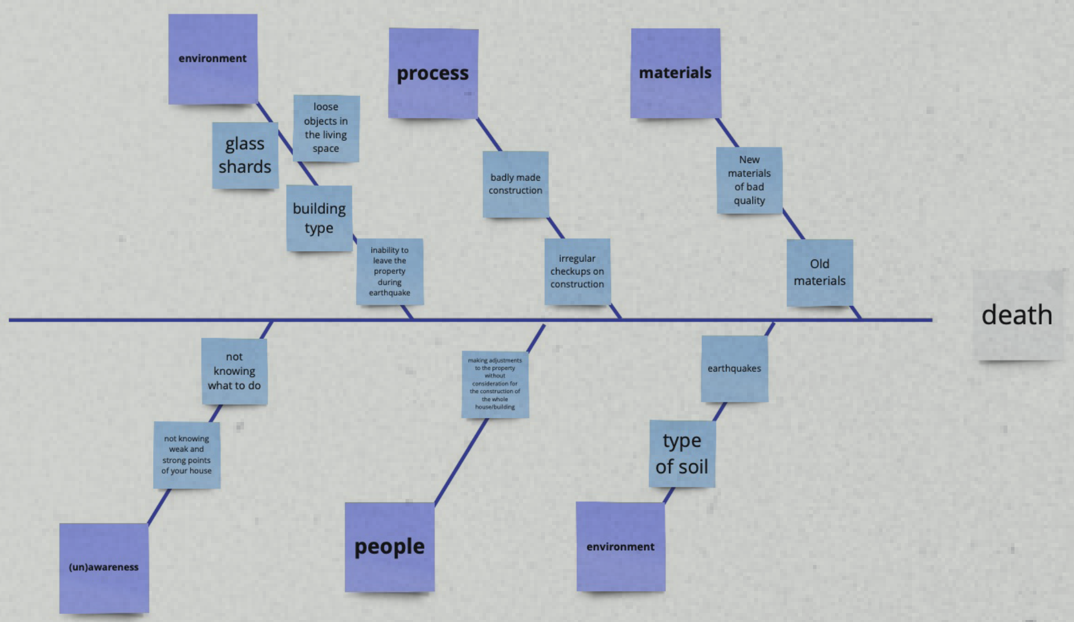








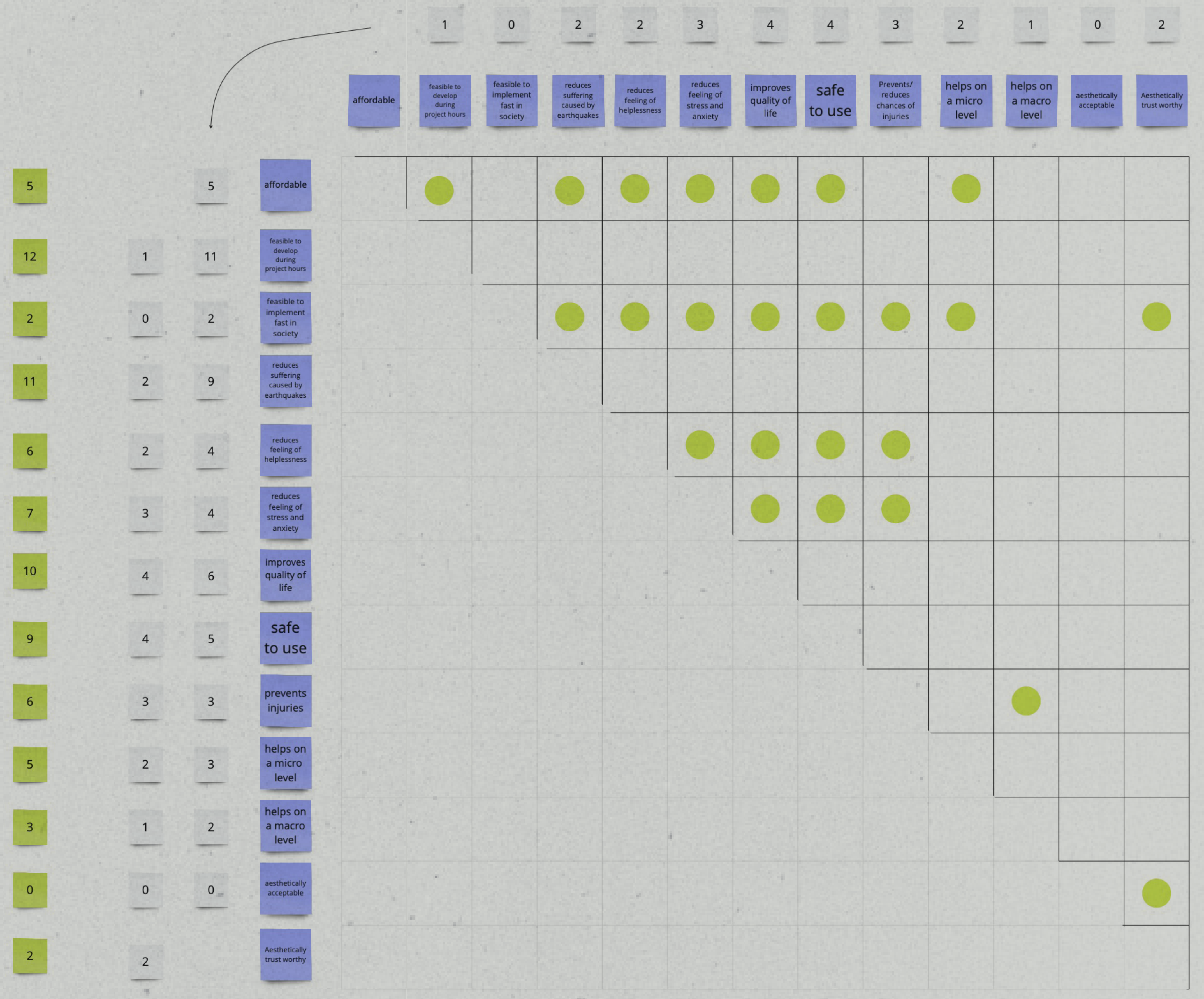

process
materials
badly made construction
New materials of bad quality
irregular checkups on construction
Old materials
property collapse
making adjustments to the property without consideration for the construction of the whole house/building
earthquakes
type of soil
people
environment


environment
process
materials
glass shards
loose objects in the living space
badly made construction
New materials of bad quality
building type
inability to leave the property during earthquake
irregular checkups on construction
Old materials
death
not knowing what to do
making adjustments to the property without consideration for the construction of the whole house/building
earthquakes
not knowing weak and strong points of your house
type of soil
(un)awareness
people
environment

Requirements evaluation

The evaluation of requirements in this project was a process designed to establish a hierarchy of importance among the identified criteria. To accomplish this, each requirement was systematically compared to one another, employing a method that assigned points based on their relative significance. The initial step in this evaluation process involved listing and defining the requirements that were deemed essential for the project's success. These requirements were drawn from a synthesis of research findings, user needs, and practical constraints. Each requirement was then ranked and weighed against the others, considering their potential impact on the overall effectiveness of the proposed solution.

Comparative analysis was the core methodology employed to evaluate the requirements. Each requirement was paired with another, and the question of which one held greater importance was posed.
The points assigned during these comparisons were then summed, and the more points a requirement received, the higher it ranked in terms of importance.
The final outcome of this evaluation process was a hierarchy of requirements, ranging from the most to least important. This hierarchical structure provided a clear framework for decision-making, ensuring that the project's focus remained aligned with the most essential criteria.



Scope & Product Vision

Casing of the product

Materials
Ergonomics
Colour pallets
Details (lines, edges, closings, connections...)

Inside of the product

Technical components
Connections
Placement inside of casing
Protection of pieces

Charging system

Wireless / wired
battery type
speed

Reducing human suffering

Sturdy and durable

Micro electronic components

Compact product with basic needed information

Satellite based communication?

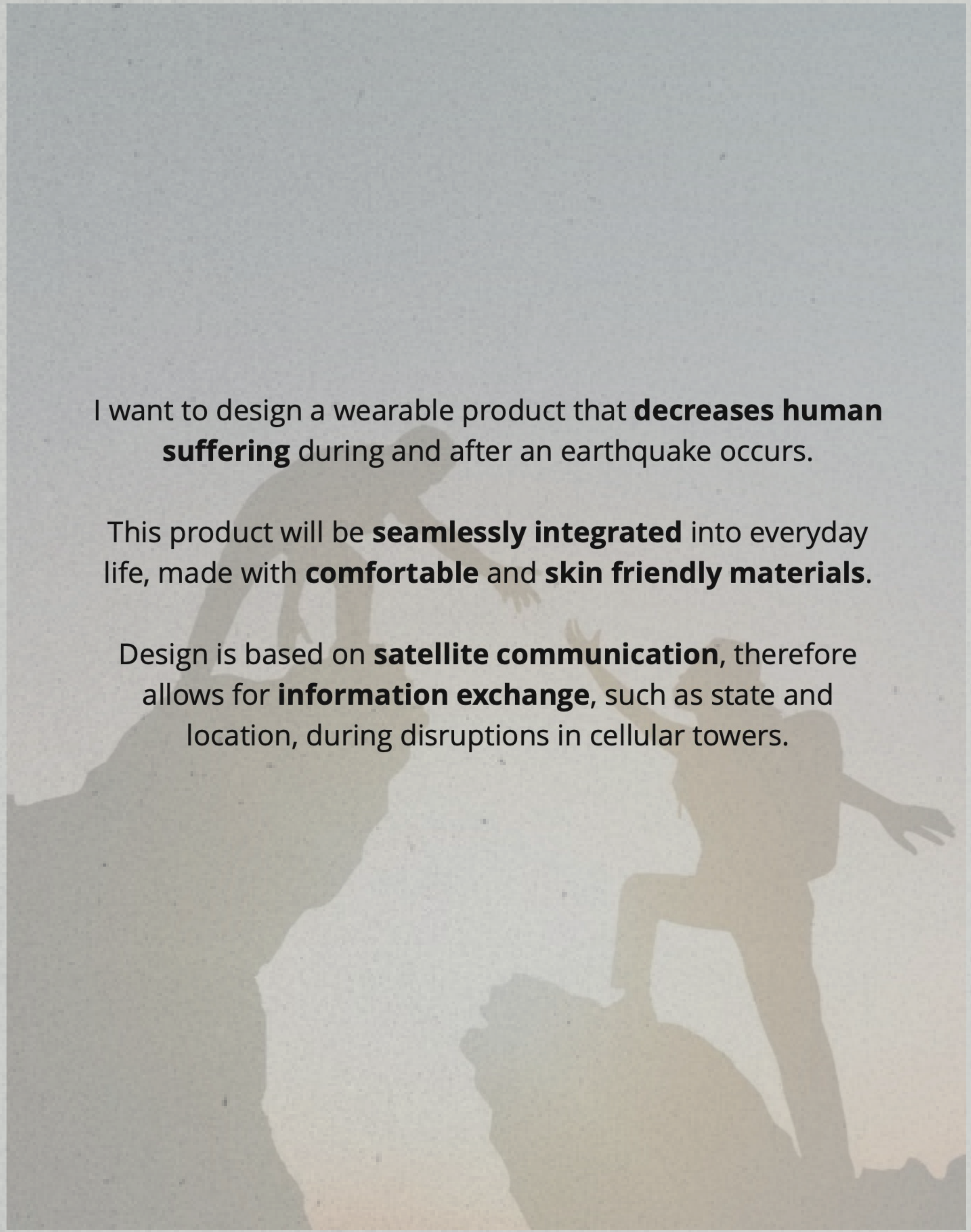
Fast charging

Minimalistic and seamless casing design

Skin tone palettes

Skin friendly materials

Adjustable sizes



I want to design a wearable product that **decreases human suffering** during and after an earthquake occurs.

This product will be **seamlessly integrated** into everyday life, made with **comfortable** and **skin friendly materials**.

Design is based on **satellite communication**, therefore allows for **information exchange**, such as state and location, during disruptions in cellular towers.

Components overview

Turn me around

Ergonomics

In the design of Embrace, considerations were made regarding ergonomics and wrist circumference sizes. The design primarily focused on the 50th percentile of wrist sizes, representing the median or average wrist circumference. However, to ensure inclusivity and accommodate a wide range of potential users, Embrace's sizing approach took into account a spectrum from the 5th to the 95th percentile of wrist sizes. This approach aims to provide a comfortable and secure fit for a broad user demographic, making Embrace a wearable solution accessible to a diverse population. For specific percentiles, please refer to the accompanying graphic.

THE PERCENTILES

FEMALES			MALES	
CM	INCHES		CM	INCHES
13.61	5.36	1ST	15.59	6.14
13.78	5.43	2ND	15.81	6.23
13.89	5.47	3RD	15.95	6.28
14.03	5.52	5TH	16.[illegible]	6.35
14.26	5.61	10TH	16.[illegible]	6.46
14.41	5.67	15TH	16.[illegible]9	6.53
14.54	5.72	20TH	16.73	6.55
14.65	5.77	25TH	16.86	6.64
14.74	5.80	30TH	16.98	6.68
14.84	5.84	35TH	17.09	6.73
14.92	5.88	40TH	17.19	6.77
15.01	5.91	45TH	17.29	6.81
15.10	5.94	50TH	17.40	6.85
15.18	5.98	55TH	17.50	6.89
15.27	6.01	60TH	17.61	6.93
15.37	6.05	65TH	17.72	6.98
15.46	6.09	70TH	17.84	7.02
15.57	6.13	75TH	17.97	7.07
15.69	6.18	80TH	18.12	7.13
15.84	6.23	85TH	18.29	7.20
16.02	6.31	90TH	18.51	7.29
16.23	6.42	95TH	18.84	7.42
16.47	6.49	97TH	19.05	7.50
16.61	6.54	98TH	19.21	7.56
16.82	6.62	99TH	19.44	7.66

Percentiles used as a reference for adult sizes - 1988 anthropometric survey of U.S. army personnel

Age (years)		Percentiles										
		3rd	5th	10th	15th	25th	50th	75th	85th	90th	95th	97th
Boys	n											
6	127	11.47	11.60	11.82	11.99	12.27	12.92	13.65	14.01	14.23	14.56	14.75
7	174	11.70	11.84	12.06	12.23	12.52	13.18	13.91	14.27	14.50	14.82	15.02
8		11.99	12.12	12.36	12.53	12.83	13.50	14.23	14.59	14.82	15.14	15.34
185												
9	156	12.31	12.46	12.70	12.88	13.19	13.86	14.59	14.95	15.18	15.51	15.71
10	179	12.67	12.83	13.08	13.27	13.58	14.27	15.00	15.36	15.59	15.92	16.12
11	168	13.05	13.21	13.48	13.68	14.00	14.69	15.42	15.78	16.01	16.34	16.55
12	126	13.42	13.59	13.88	14.08	14.41	15.11	15.83	16.19	16.43	16.76	16.97
13	139	13.79	13.98	14.28	14.50	14.84	15.54	16.26	16.62	16.86	17.20	17.42
14	153	14.19	14.39	14.71	14.94	15.29	15.99	16.70	17.08	17.32	17.68	17.91
15	223	14.55	14.76	15.10	15.34	15.69	16.39	17.11	17.50	17.76	18.15	18.40
16	217	14.80	15.03	15.38	15.63	15.99	16.69	17.41	17.82	18.11	18.54	18.83
17	84	14.92	15.16	15.54	15.79	16.16	16.85	17.58	18.02	18.33	18.83	19.17
Girls	n											
6	135	10.70	10.87	11.16	11.37	11.70	12.41	13.08	13.37	13.55	13.78	13.91
7	175	11.09	11.26	11.55	11.76	12.09	12.80	13.48	13.78	13.96	14.21	14.35
8	191	11.51	11.68	11.97	12.17	12.51	13.21	13.89	14.21	14.40	14.66	14.81
9	162	11.92	12.09	12.38	12.58	12.91	13.60	14.29	14.62	14.82	15.10	15.27
10	193	12.35	12.52	12.80	13.01	13.33	14.02	14.72	15.05	15.26	15.56	15.74
11	136	12.81	12.98	13.26	13.46	13.78	14.46	15.15	15.50	15.72	16.04	16.23
12	165	13.21	13.38	13.65	13.84	14.16	14.82	15.51	15.86	16.09	16.42	16.62
13	167	13.53	13.69	13.96	14.15	14.45	15.10	15.78	16.13	16.36	16.69	16.90
14	150	13.80	13.95	14.21	14.39	14.69	15.32	15.99	16.33	16.56	16.88	17.09
15	379	13.97	14.12	14.36	14.54	14.83	15.44	16.09	16.43	16.64	16.96	17.15
16	413	14.04	14.18	14.43	14.60	14.89	15.49	16.12	16.43	16.64	16.96	17.15
17	133	14.09	14.24	14.49	14.67	14.95	15.54	16.15	16.46	16.65	16.96	17.15

Age indicates whole age group (e.g. 7.00-7.99 years, etc.)

Percentiles used as a reference for childrens and adolescent sizes

Power consumption calculations

① Sleep Mode – 97%

- Kinetis µprocessor 5 µA
- GPS module 3 µA
- LoRa module 2 µA

10 µA

$10 \mu A \times 3{,}5 V = 35 \mu W$ → power consumption in sleep mode

$35 \mu W = 35 \frac{J}{s} = 35$

→ 6 months (180 days)

$= 180 \times 24 \times 3600 = 15 \cdot 10^6 s$

Energy = Power × time

$= 35 \cdot 10^{-6} J/s \times 15 \cdot 10^6 s = 525 J$

battery $= 0{,}22$ wh $= 0{,}22$ J/s $\cdot 3600$ s $= 792$ J

633 ← 80% ↙

② Connect Mode – 3%

- Kinetis 35 µA
- Lora 50 µA
- GPS 25 µA

110 µA

$110 \mu A \times 3{,}5 V = 385 \mu W$

↓ power consumption in connect mode

$385 \mu W = 385$ J/s $= 385$

→ 6 months

$= 180 \times 24 \times 60 = 259.000$

En $= 385 \cdot 10^{-6}$ J/s × ~~259~~ $259 \cdot 10^3$ s

$= 99.715 \times 10^{-3} = 99{,}7$ J

③ Active Mode

Kinetis
Lora
GPS

385 μW pC in AM

HR sensor - 275 μA
Thermas Sensor - 370 μA
Accelerometer - 11 μA
LED - 272 mA = ~~272,000~~ μA

6050
~~272,300~~ μA
5,440 μA

Vibration motor - 42 mA → 1 sec

22 385
→ ~~953,750~~ + 385 = 954 μW
22 770

21 600 s = 21.6 × 10^3

~~000~~ 770 . 10^{-6} × 21.6 × 10^3
= ~~20,600~~ J
= 991 = 490 J

Connect + sleep mode = 100%
↓
six months

= 525 + 99.7 = 625 J

battery (80%) E = 633 J

→ if it wakes up every 2 minutes
= 312,5 J /2 = 3 months
156

↓ six months waking up every 2 mins
+
6 hours of active mode

312 + 490 = 802

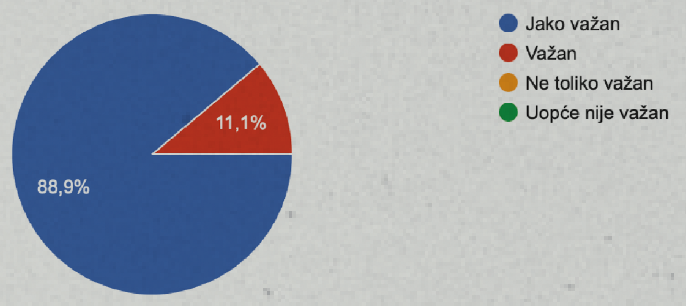
640 ←

Questionnaire results

Što mislite koliko bi komunikacijski uređaj poput ovog mogao biti važan tijekom potresa?

Kopiraj

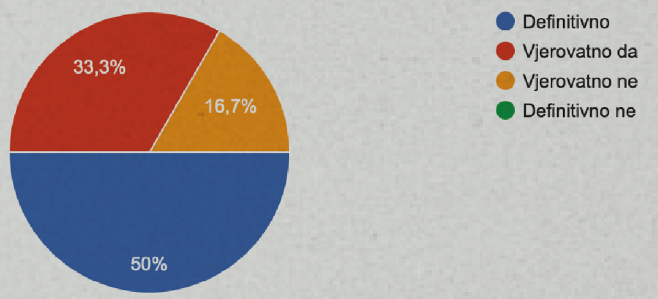
18 odgovora



Biste li bili voljni nositi ovu narukvicu tijekom svojih svakodnevnih aktivnosti, znajući da može pomoći u hitnim slučajevima potresa?

Kopiraj

18 odgovora



Group 1

Postoje li dodatne značajke ili funkcije koje biste željeli vidjeti u ovakvom uređaju?

18 odgovora

Ne

Kontaktiranje hitnih službi

Mogućnost poziva i drugih brojeva koji nisu u kontaktima, tipa hitne službe u slučaju opasnosti

Ne ovo je dovoljno, lokacija?

Mislim da pruža dovoljno podataka

Ne

Da. Nadodao bih jos neke elemente oko pracenja vitalnosti, zdravlja osobe. Popvezivanje aplikacijom. Nesto u smjeru Oura Ringa ali takav pristup zasigurno povecava cijenu proizvoda.

Vrijeme i datum

Mislim da pruža dovoljno podataka

Ne

Da. Nadodao bih jos neke elemente oko pracenja vitalnosti, zdravlja osobe. Popvezivanje aplikacijom. Nesto u smjeru Oura Ringa ali takav pristup zasigurno povecava cijenu proizvoda.

Vrijeme i datum

Ne znam

Bilo bi zgodno kada bi postojala opcijap sa satom.

Mislim da ima sve sto je potrebno

Sve je obuhvaćeno

Ne, bar na prvu ruku.

Kakvi su vaši prvi dojmovi o dizajnu i izgledu narukvice?

18 odgovora

Elegantna i neprimjetna

Izgleda jako elegantno

Fenomenalan dizajn, diskretna i elegantna

Jako dobro i funkcionalno

Elegantno, izuzetno korisno, inovativno, odgovara za sve vrste stila.

Elegantna, moderna, praktična

Wow

Jako je lijepa narukvica i prigodna za svakodnevne aktivnosti a uz to i zaista korisna te pruza covjeku osjecaj sigurnosti

Svida mi se elegantan i minimalistican dizajn

Konkretan opis, nije predugacak. Daje dobre i jasne informacije osim kako ce se narukvica prilagoditi velicini ruke. Mozda je one size fits all? Dodao bih jos tu recenicu (o velicini ili prilagodbi narukvice).

Jako lijep i jednostavan dizajn. Svida mi se sto su raznovrste i moze se bieati izgled.

Super izgleda, lijepo dizajnirano

Jako lijepo

Super

Elegantna je, lijep dizajn, moze se nositi kao pravi nakit.

Izgleda elegantno i ako ne znate namjenu narukvice pomislili bi da je nakit.

Predivna ideja

Koji čimbenici bi utjecali na vašu odluku da redovito nosite ili ne nosite narukvicu?

18 odgovora

Potreba za tako nečim s obzirom na učestalost potresa u području u kojem živim

Da izgleda elegantno i može se nositi i uz poslovnu odjeću

Lijepa i elegantna, korisna i u drugim nesrecama ne samo u potresu

Definitivno bi ju nosio zbog straha od potresa

Izgled i korisnost kao pozitivni čimbenici.

Težina narukvice

Djeca

Udobnost, dizajn, jednostavnost korištenja

Ucestalost potresa

Da zivim u seizmicki vrlo aktivnom i opasnom podrucju.

Kolika je opasnost od potresa

Tjelesna aktivnost, poslovi

Vise potresa u kratkom razdoblju

Sigurnost

O seizmickoj aktivnosti zemlje u kojoj se nalazim. Npr.na putovanje u strane azijske zemlje definitivno.

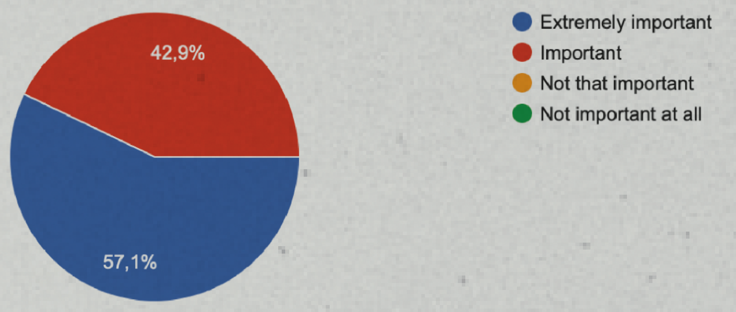
Osjecala bi se sigurnije sa njom

Nosila bi ju jer se plašim potresa i brinem za svoje bližnje kada dodje do takve situacije

Učestalost potresa i udaljenost od bližnjih.

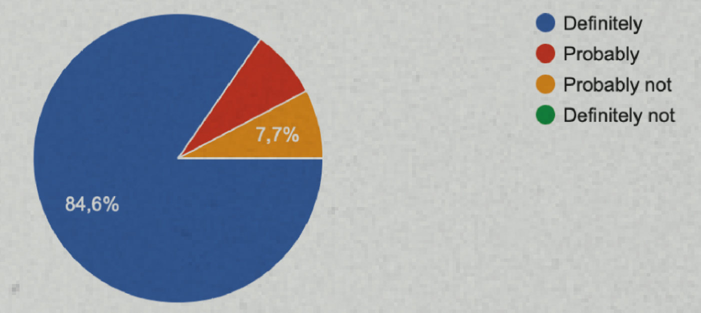
How important do you think a communication device like this could be during an earthquake emergency?

14 odgovora



Would you be willing to wear this bracelet during your daily activities, knowing it could help in earthquake emergencies? If you lived in an earthquake affected area.

13 odgovora



Group 2

What are your initial impressions of the bracelet's design and appearance?

14 odgovora

It's pretty. It doesn't have to stand out so much if you want it to be solely for safety. But it's nice to have the option to make it into something more like jewelry. In order for people to maybe find them more attractive to use, I would also integrate more colors other than just skin color. Also: I wonder how readable the letters are. When I look at the first picture, if that is indeed the font used (the dots) I wonder how much written information you can display. It was a little hard for me to read. Especially if you use a lighter skintone color bracelet, white lights might not stand out enough.

I like the skin tone variations and the fact that it is not very noticeable. I would definitely wear it

Simple, somewhat elegant but not fancy. All in all, pretty set within the current standards.

Very usefull

It is very pretty. Though, for me its not ideal that it is skin toned, I like it better when it adds the piece of jewelry as an accessory.

I like the design and functions

The bracelets seem to have a neutral impact on your look, with the possibility to accentuate it's appearance with the rims if so desired by the user. The bracelet seems like it would be comfortable to wear.

Very stylish for something meant for emergencies, in a good way. Because you do not want people to refrain from wearing because they are ugly.

Fantastic! Very much a fan of the minimal design.

It looks fancy!

I like the offerings of all skin tones. A simple black one would also be nice to have. Looks simple and stylish

Really like the concept of skin-colored bracelets, because otherwise people might feel like they impact their looks too much on non-earthquake days. I think the shape has a good balance by not being too dull, but also not too 'extra'. Extra props for the customizability, sorry for the exclusively positive feedback because you were probably looking for pointers but I believe this is exactly what such a tool should look like, great work!

Elegant, subtle, clear

It looks clean and well-designed. I would wear it.

Are there any additional features or functions you would like to see in a device like this?

14 odgovora

Maybe hart monitoring or as a glucose meter

Not really

Since I don't live in an area that's prone to earthquakes, I could only see myself using this if presented with a different usecase. For instance, if I was into diving, working as a fireman or if I would have children of which I want to know the whereabouts and well-being, I could see myself using this or having it be used.

See above. Additionally I think the skintones and subtle appearance are very applicable and desirable for fitness trackers as well!

I think this functions could be added to an existing smart watch

BLE connectivity, being able to use it as a generic fitness tracker, display time.

I dont know if the light is always on? Perhaps only activate the light when it is touched or else it could disturb sleep.

Maybe I'd think of a complementary option where the materials are cheap and the design is less 'luxurious' but purely from a practical standpoint. Areas with a lot of seismic activity often aren't the wealthiest, or their infrastructure and buildings are tailored to the risk (e.g. Japan) and therefore people might not perceive the danger as equally significant and feel less urgency to buy a device like this.

No.

Perhaps link it to other natural disasters such as storms, wildfires en flooding too

A way to personalize it to differentiate it from the other members of my family or household that would be wearing the exact same band.

Could be attached to a watch

Would be awesome to have it sincronized with your closest family and you could have a light indicating if they have preset the button on their bracalets.

I don't think so. Keeping it simple and true to what it's designed for make sure less can go wrong with the

'hat factors would influence your decision to wear or not wear the bracelet regularly?

odgovora

The overall looks and idea of the bracelet. If I would live in an area where earthquakes happen often, I would wear it

The different designs

The frequency in which I would have to charge it

If it measures additional data such as a fitness tracker it would be even better. I have never lived in an earthquake sensitive area so maybe that is why I would like additional features.

Living in a place where earthquakes happen, having this device could bring me anxiety as a reminder that it can happen. I tend to be very scared with earthquakes, i know this is important, but it just adds a layer of the latent fear that something terrible can happen. i would prefer this functionalities added to the smart watch I use every day, seamlessly, not specifically to a device just for this.

Predicted higher risk of earthquakes, possibility to use as a generic vitals monitor for health apps

Definitely if i lived in an earthquake prone environment, but also perhaps when i would go skiing or hiking and could get trapped underneath a landslide or avalanche

The occurrence and strength of seismic activity in my area of living would be THE decision factor for me. If I lived in high-risk areas, I would probably wear them even if they'd be ugly. For me, the functionality and usage of the bracelets by the people dear to me are much more important in my decision to buy it than its design.

Also; I would buy it for €50 but not for €200 because of the "bad things (dangerous situations from earthquakes) only happen to other people" train of thought.

Likelihood of getting trapped in a collapsed building are slim.
Other devices such as a smartphone can do the same function as the bracelet.

The probability of an earthquake in the area you live

I would wear it every day but I might forget to but it back in after I work out.

Price

The area where I am located and the risk. If the bracelet is not heavy weighted i would also be more inclined to wear it

For me personally, I would only wear it in an environment that is prone to earthquakes. I personally live in a country that does not experience any earthquakes, so I would probably not use it. However, if I were to live in a country that does experience frequent earthquakes, I would. But Maybe also depending on how many of my contacts would use them. If no one in my network uses them, then there wouldn't be anyone who receives my information anyways.

Project brief

DESIGN FOR our future

TU Delft

IDE Master Graduation

Project team, Procedural checks and personal Project brief

This document contains the agreements made between student and supervisory team about the student's IDE Master Graduation Project. This document can also include the involvement of an external organisation, however, it does not cover any legal employment relationship that the student and the client (might) agree upon. Next to that, this document facilitates the required procedural checks. In this document:

- The student defines the team, what he/she is going to do/deliver and how that will come about.
- SSC E&SA (Shared Service Center, Education & Student Affairs) reports on the student's registration and study progress.
- IDE's Board of Examiners confirms if the student is allowed to start the Graduation Project.

USE ADOBE ACROBAT READER TO OPEN, EDIT AND SAVE THIS DOCUMENT

Download again and reopen in case you tried other software, such as Preview (Mac) or a webbrowser

STUDENT DATA & MASTER PROGRAMME

Save this form according the format "IDE Master Graduation Project Brief_familyname_firstname_studentnumber_dd-mm-yyyy". Complete all blue parts of the form and include the approved Project Brief in your Graduation Report as Appendix 1 !

family name: Kljaic
initials: KK given name: Korina
student number: ___
street & no.: ___
zipcode & city: ___
country: ___
phone: ___
email: ___

Your master programme (only select the options that apply to you):
IDE master(s): (★) IPD ( ) Dfl ( ) SPD
2nd non-IDE master: ___
individual programme: ___ (give date of approval)
honours programme: ( ) Honours Programme Master
specialisation / annotation: ( ) Medisign
( ) Tech. in Sustainable Design
( ) Entrepeneurship

SUPERVISORY TEAM **

Fill in the required data for the supervisory team members. Please check the instructions on the right !

** chair ___ dept. / section: ___
** mentor ___ dept. / section: ___
2nd mentor ___
organisation: ___
city: ___ country: ___

comments (optional)

Chair should request the IDE Board of Examiners for approval of a non-IDE mentor, including a motivation letter and c.v..

Second mentor only applies in case the assignment is hosted by an external organisation.

Ensure a heterogeneous team. In case you wish to include two team members from the same section, please explain why.

TU Delft

Procedural Checks - IDE Master Graduation

APPROVAL PROJECT BRIEF

To be filled in by the chair of the supervisory team.

chair ___ date ___ signature ___

CHECK STUDY PROGRESS

To be filled in by the SSC E&SA (Shared Service Center, Education & Student Affairs), after approval of the project brief by the Chair. The study progress will be checked for a 2nd time just before the green light meeting.

Master electives no. of EC accumulated in total: ___ EC
Of which, taking the conditional requirements into account, can be part of the exam programme ___ EC
List of electives obtained before the third semester without approval of the BoE

( ) YES all 1st year master courses passed
( ) NO missing 1st year master courses are:

name ___ date ___ signature ___

FORMAL APPROVAL GRADUATION PROJECT

To be filled in by the Board of Examiners of IDE TU Delft. Please check the supervisory team and study the parts of the brief marked **. Next, please assess, (dis)approve and sign this Project Brief, by using the criteria below.

- Does the project fit within the (MSc)-programme of the student (taking into account, if described, the activities done next to the obligatory MSc specific courses)?
- Is the level of the project challenging enough for a MSc IDE graduating student?
- Is the project expected to be doable within 100 working days/20 weeks ?
- Does the composition of the supervisory team comply with the regulations and fit the assignment ?

Content: ( ) APPROVED ( ) NOT APPROVED
Procedure: ( ) APPROVED ( ) NOT APPROVED

comments

name ___ date ___ signature ___

Initials & Name KK Kljaic Student number ___
Title of Project Reducing Earthquake Suffering: Solutions for Vulnerable groups

Reducing Earthquake Suffering: Solutions for Vulnerable groups — project title

Please state the title of your graduation project (above) and the start date and end date (below). Keep the title compact and simple. Do not use abbreviations. The remainder of this document allows you to define and clarify your graduation project.

start date 04 - 09 - 2023 13 - 02 - 2024 end date

INTRODUCTION **

Please describe, the context of your project, and address the main stakeholders (interests) within this context in a concise yet complete manner. Who are involved, what do they value and how do they currently operate within the given context? What are the main opportunities and limitations you are currently aware of (cultural- and social norms, resources (time, money,...), technology, ...).

In numerous regions worldwide, natural disasters pose significant challenges, frequently impacting communities and leading to devastating socio-economic and environmental consequences. Earthquakes, occurring in many countries globally, continue to pose a persistent concern with varying levels of preparedness and responsiveness among affected regions. However, a critical issue persists at both national and local levels: living spaces ill-equipped to withstand seismic shaking. Factors such as inadequate construction, materials and details, subpar building structures, or ageing material properties contribute to the vulnerability of these dwellings. As a result, when earthquakes occur, these living spaces suffer severe damage or total collapse. The inability of individuals to afford proper architectural / engineering expertise during construction or post-earthquake strengthening further exacerbates the problem. As a result, people lose their homes, get injured, or, in the worst cases, lose their lives.

The primary stakeholders in this project are individuals residing in earthquake-prone areas who have built their own houses, possess concerns regarding the quality of existing structures, or seek enhanced security for their living spaces, particularly when they are unable to afford existing solutions. As the project progresses, the potential involvement of construction industry or an interested company introduces an additional stakeholder. Therefore, it is crucial to consider both user requirements, encompassing product quality and functionality, and production methods, materials, and sustainability to align with the interests of potential companies.

The primary opportunity presented by this project is addressing the needs of individuals unable to afford existing solutions for controlling earthquake damage or the complete collapse of their living spaces. By focusing on developing innovative cost-affordable and accessible alternatives, the project aims to bridge the gap and provide a viable option for these vulnerable communities.

space available for images / figures on next page

introduction (continued): space for images

image / figure 1: Glina, Croatia, 2020.

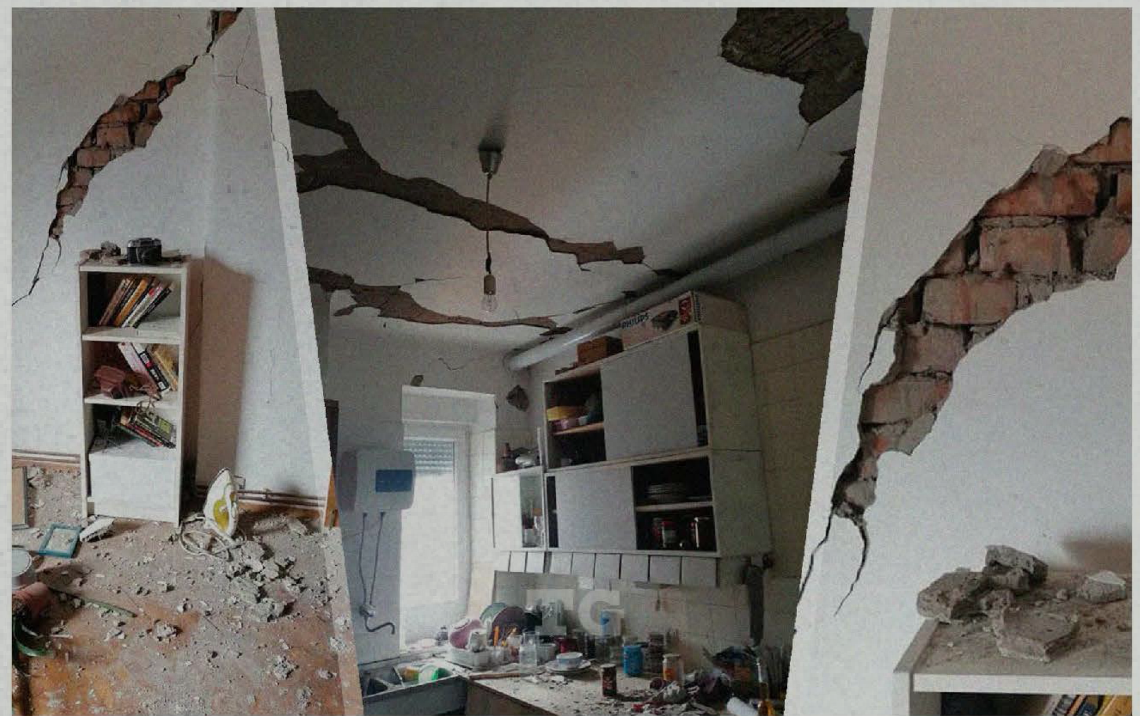


image / figure 2: Zagreb, Croatia, 2020.

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PROBLEM DEFINITION **

Limit and define the scope and solution space of your project to one that is manageable within one Master Graduation Project of 30 EC (= 20 full time weeks or 100 working days) and clearly indicate what issue(s) should be addressed in this project.

As an industrial designer, I will apply methods and conduct research to generate concepts. This project will focus on:

- Researching traditional seismic-resistant technologies, as well as current design solutions, materials and construction methods;
- Developing innovative design concepts that address human suffering and damage to living spaces;
- Creating a model and testing to validate the effectiveness of the proposed solutions;
- Conducting a cost-benefit analysis to ensure affordability of the proposed solutions;
- Integrating sustainability principles into the solutions, considering low-carbon materials and eco-friendly practices, considering the environmental impact of damaged or collapsed buildings;
- Aesthetic Integration: while functionality and safety are paramount, the solution should also consider aesthetics to ensure a seamless integration.

The project will aim to develop practical and cost-effective solutions that can serve as an intervention for existing low-to-mid rise residential structures. The focus will be on addressing the specific issues faced by individuals who are unable to afford existing seismic-resistant measures. The solutions will prioritize addressing the damage and/or collapse, and primarily human suffering that occurs during earthquakes. The project will strive to achieve a balance between functionality, safety, affordability and sustainability.

ASSIGNMENT **

State in 2 or 3 sentences what you are going to research, design, create and / or generate, that will solve (part of) the issue(s) pointed out in "problem definition". Then illustrate this assignment by indicating what kind of solution you expect and / or aim to deliver, for instance: a product, a product-service combination, a strategy illustrated through product or product-service combination ideas, ... In case of a Specialisation and/or Annotation, make sure the assignment reflects this/these.

Design a solution for individuals living in seismic-prone areas who experience the consequences of earthquakes in their living spaces. This solution aims to address human suffering by being affordable, aesthetically acceptable, and controlling damage, thereby ensuring adequate protection for individuals who cannot afford current solutions.

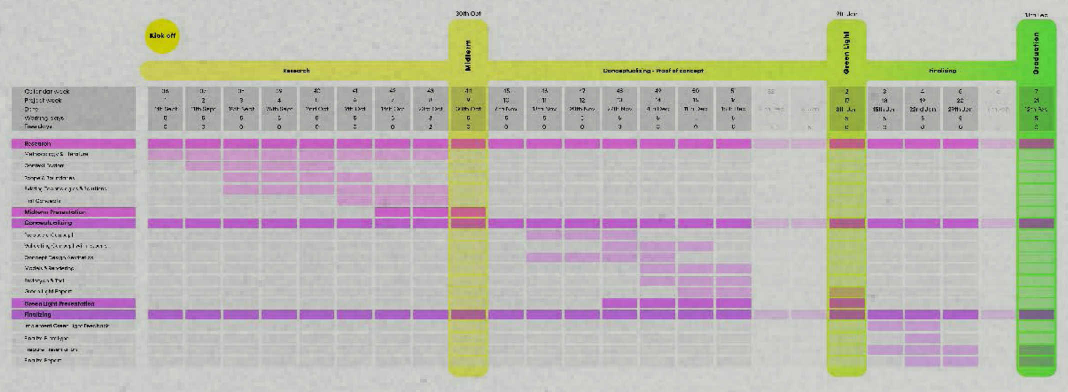
Expected Solution: Adjustable product line; Model

TU Delft

PLANNING AND APPROACH **

Include a Gantt Chart (replace the example below - more examples can be found in Manual 2) that shows the different phases of your project, deliverables you have in mind, meetings, and how you plan to spend your time. Please note that all activities should fit within the given net time of 30 EC = 20 full time weeks or 100 working days, and your planning should include a kick-off meeting, mid-term meeting, green light meeting and graduation ceremony. Illustrate your Gantt Chart by, for instance, explaining your approach, and please indicate periods of part-time activities and/or periods of not spending time on your graduation project, if any, for instance because of holidays or parallel activities.

start date 4 - 9 - 2023 13 - 2 - 2024 end date



MOTIVATION AND PERSONAL AMBITIONS

Explain why you set up this project, what competences you want to prove and learn. For example: acquired competences from your MSc programme, the elective semester, extra-curricular activities (etc.) and point out the competences you have yet developed. Optionally, describe which personal learning ambitions you explicitly want to address in this project, on top of the learning objectives of the Graduation Project, such as: in depth knowledge a on specific subject, broadening your competences or experimenting with a specific tool and/or methodology, ... Stick to no more than five ambitions.

The motivation behind this project stems from a personal experience and a keen observation of the negative consequences of earthquakes on people's lives. Having personally experienced an earthquake in Croatia three years ago, the devastating impact and long-lasting effects on communities became evident. It became clear that there is a significant gap in the market when it comes to affordable solutions for individuals who cannot afford the current seismic-resistant measures available.

Witnessing firsthand the destruction caused by earthquakes and the subsequent challenges faced by those with limited resources, an idea began to take shape. The desire to address this pressing issue and provide viable solutions for people in similar circumstances became a driving force for this project.

Understanding the importance of safe and secure living spaces, it is essential to bridge the gap and offer practical and affordable options for those who are unable to invest in costly retrofitting or reconstruction measures. However, it is equally crucial to consider the aesthetic integration of these solutions into people's lives.

The aesthetic integration of these solutions plays a vital role in ensuring their acceptance and adoption by individuals and communities. Striving for aesthetically acceptable solutions, it is aimed to create adjustable solutions that integrate seamlessly, enhancing both safety and visual appeal.

This approach recognizes the importance of creating an environment that promotes emotional well-being and a sense of comfort. By offering aesthetically pleasing adjustable solutions, individuals are empowered to feel a sense of harmony and tranquility in their homes while simultaneously ensuring their safety. This integration of functionality and aesthetics creates a more holistic solution, enhancing the overall quality of life for individuals in earthquake-prone areas.

To sum up, by undertaking this project, I aim to deliver adjustable solutions that decrease human suffering during and after earthquakes, and are affordable and effective. Through careful design considerations, I plan to create a harmonious balance between functionality, safety, affordability, and visual appeal, ensuring that individuals and communities feel a sense of satisfaction in their protected homes.

By addressing the aesthetic integration of these solutions, I aim to remove barriers and encourage wider adoption, ultimately leading to safer living spaces for individuals who have faced the challenges of earthquakes.

FINAL COMMENTS

In case your project brief needs final comments, please add any information you think is relevant.

"Communication is the bridge that connects hearts, minds, and souls, transcending boundaries and fostering understanding."