Anticipating Change

How can theories and strategies on temporary and permanent architecture guide the design for dual-use, encountering the everyday life and future natural disasters.

2026

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Anticipating Change

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Abstract

Increased natural disasters, as an effect of climate change, are affecting a growing share of the global population causing economic loses, casualties, displacement and tends to worsen pre-existing inequalities (McCann et al., 2018). This is where the architectural practice can be implemented to support society through promoting a shared responsibility to mitigate the losses (Fitz et al., 2019).

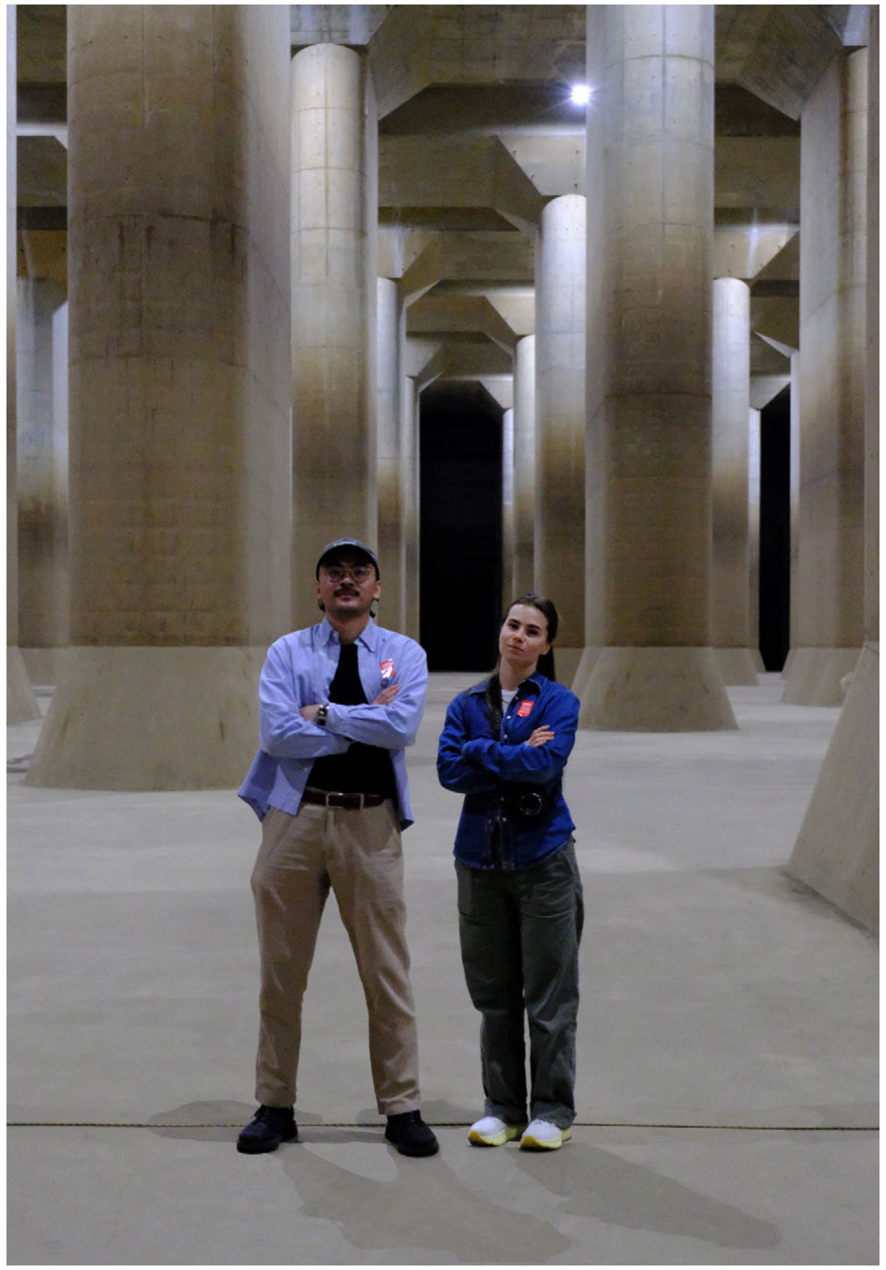
The thesis departs from the will of developing architecture with a civic purpose. This aim is the driving force for creating a public space with the main purpose of dealing with the current and future speculated climate related disasters.

Through an iterative design process, it uses a combination of theoretical and practical tools. The overall scope, a collection of reports, theories and case study to Japan, informs the speculative concept of a shelter made to satisfy multiple scenarios. Further theories inform the design and are translated to physical measurements by rapid prototyping, both digital and physical, to develop a structure that can meet the design principles.

The shelter design proposes the usage of different Muira-ori fold pattern to create both semi-permanent buildings and deployable structures to add value in several scenarios, in everyday life and disaster. The result is presented through physical models, isometric diagrams and drawings to create a comprehensive narrative that embeds the visions.

The thesis discusses how the cultural, functional and technical aspects are separated and intertwined and how it is expressed in the design proposal. Through speculative scenarios, the ability to stay relevant over time and simultaneously react and adapt is further validated. After reviewing the critical points of the deployable structures, the thesis still determines Miura-ori fold to be beneficial from an architectural and structural standpoint. To conclude, the thesis uses the design proposal as a springboard for speculative thinking and experimental design, encouraging architects to anticipate change in an uncertain future.

Keywords:
Temporary architecture, Permanent architecture, Speculative design, Scenario thinking, natural disasters, safety point.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"Architects mostly work for privileged people, people who have money and power. Power and money are invisible, so people hire us to visualize their power and money by making monumental architecture. I love to make monuments, too, but I thought perhaps we can use our experience and knowledge more for the general public..."

\- Shigeru Ban

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Introduction

1.1 Background

In the recent years, global climate indicators have continued to break records. Both the global mean near-surface temperature and the ocean heat content reach higher levels and at the same time the global mean sea level increment per year have more than doubled since 2002, from 2.1 mm to 4.7mm(The World Meteorological Organization, 2025).

Extreme weather events, intensified by climate change, are responsible to the highest number of new displacements since 2008, affecting a significant number of people in fragile and conflict affected areas. Many of the highest impact events was due to cyclones, such as for Typhoon Yagi in Southeast Asia, and hurricanes such as Helene and Milton in the United States of America. These causes severe flooding, casualties and huge economic losses. Southwest Asia also suffered abnormal cold conditions and highland snow with several flooding events following months, causing several hundreds of deaths. In contrast, drought during the wet season in north-western Africa caused agricultural losses (The World Meteorological Organization, 2025). In addition, a prolonged dryness and higher temperature contributed to the wildfires in Chile and the Brazilian Amazon. Several major heat waves were recorded in the world, and the full extent of heat related impacts are underestimated since heat related mortality could be higher than current estimates.

Furthermore, climate change will also generate new disaster geographies. Regions that are currently considered stable could face climate related disasters in the future (Intergovernmental Panel On Climate Change (Ipcc), 2023). Over a long-time horizon, a single location may experience vastly different environmental challenges. Flooding, extreme heat, drought, or even glacial conditions could all occur in the same region at different occasions.

Within the architectural field, several theories and concepts have emerged to guide responses to these challenges. One of these is holistic sustainable architecture, a design approach that integrates all aspects of sustainability through systems thinking. It emphasizes achieving high standards across environmental, social, and ethical dimensions, while addressing four key climate emergency challenges: mitigation, adaptation, restorative design, and climate justice. This approach calls for an ethical shift in architecture, where practitioners take responsibility for supporting both the planet and society (Pelsmakers & Donovan, 2022). Another approach is caring architecture that places responsibility on architects for the entire life cycle of a building. It begins with recognizing real needs and considers everyone affected, rather than focusing solely on the completed structure. This perspective expands sustainability to encompass long-term social and ecological impacts, challenges the separation between humans, nature, and craft, and promotes connectedness, shared responsibility, and more ethical, resilient environments (Fitz et al., 2019).

Looking at the time line in Figure 1 it also becomes clear that the relationship between short-term functionality and potential long-term use also needs to be considered. Designing for these shifting risks means to not only respond to current conditions but anticipate future spatial demands.

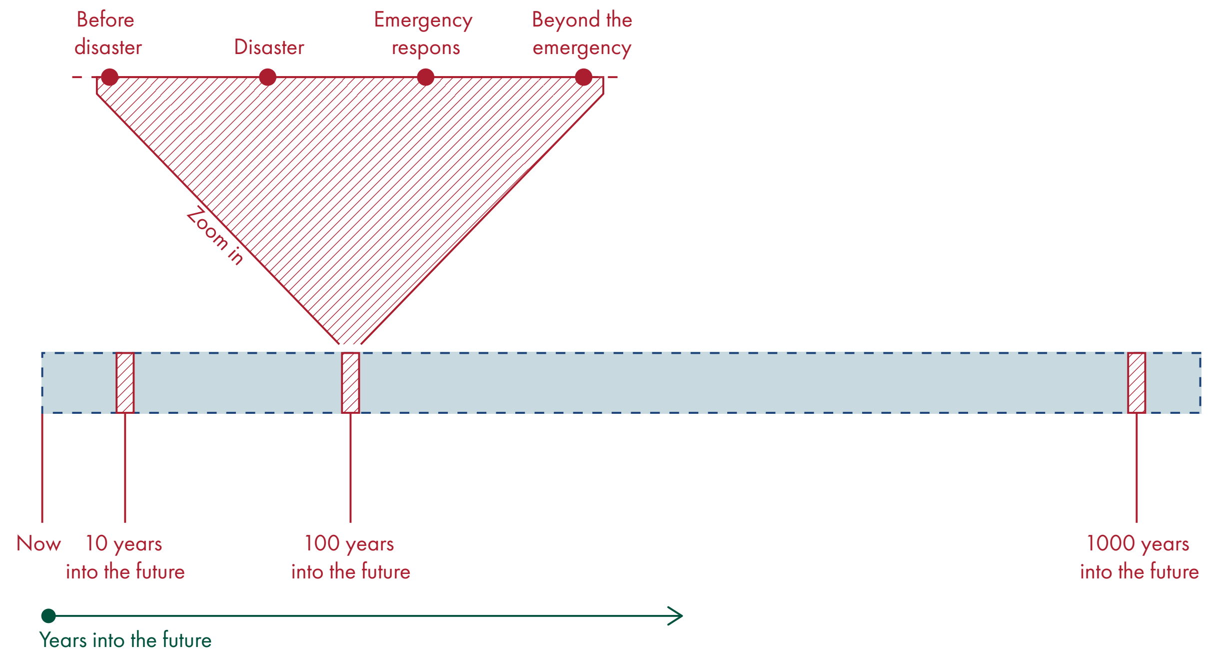


Figure 1. Time line diagram

1.2 Aim and Research questions

The aim of this thesis stems from the ambition of combining architecture with a strong civic purpose, more specifically an architecture that can mitigate the growing risks related to climate disasters. Central to this investigation is how the short- and long-term aspects, disaster and everyday life, intertwines and to explore their compatibility and possible synergies in design.

With the main question as:

> *How can an adaptive public shelter, for everyday life and disaster events, be designed through temporary and permanent architectural theories?*

With supporting the sub questions as:

> *How can speculative scenario thinking regarding future climate influence the architectural requirements for a public space?*

> *How can structures, shifting between different configurations be effectively designed?*

Introduction

1.3 Delimitations and Dictionary

The thesis will focus on...

> *Climate-related disasters, based on existing climate data, projected into the future.*

> *Architectural theories and the development of a conceptual design framework focusing on disaster planning, functional adaptability, and spatial properties.*

> *Qualitative and design-based research methods, which includes case studies, design experiments and scenario thinking.*

The thesis will touch on...

> *Social aspects for a public space, before and after public disasters occurring.*

> *Swedish and Gothenburg's strategies for public safety.*

> *Bosai culture, a preparedness culture originating from Japan.*

The thesis will not...

> *Focus on the entire post-disaster reconstruction process of society.*

> *Perform detailed structural analysis, logistical analysis, cost analysis or field testing.*

> *Design through community-based surveys and interaction.*
> *Include civil defence preparedness.*

1.4 Method and tools

This thesis was conducted through an iterative, design-based methodology where the outcome from one phase generated reflection and reaction in the other, a diagram representing the method can be seen in figure 2. Divided into three different main methods, research-for-design, research-on-design and research-by-design, the knowledge collected informed the design-process in various stages.

Exploring of the subject – planning ahead
The first phase aims to explore the relevant subjects for the project and create an overall understanding of its scope. The collection was made through reports and theories about scenario planning, Gothenburg's future climate disasters, risk mitigation and its relation to everyday life. A case study to Japan presented real life examples on how build in preparedness could be expressed in various scales and functions and collected through notes and photographs.

Concept – the transforming nomad
To conclude and reinterpret information from previous phase, a concept for a short-term and long-term shelter was made to set the overall guidelines of a design. Speculative scenario planning and visual communication was the main tool for this phase.

Design principles – shelter principles and metrics
This phase used the framework of the concept as a way of further determining the design principles through architectural theories. Collected literature was used to define shelter and how permanent and temporary architecture are intertwined and informs the design. The knowledge was summarized to create a better understanding of the similarities and differences connected with the concept of everyday and disaster scenarios.

Design Exploration – deployable structure
In the exploration phase, the focus was to translate the concepts and theoretical principles into physical measurements and try out which structures that could answer towards the concept and design principles. Besides information gathered from reports and literature, rapid prototyping was the main method, using both digital tools through grasshopper, plug-in to Rhinoceros 3D, and physical prototyping by laser cutting, 3D printing, sketch models and hand sketches. A context in Gothenburg was chosen to contextualise the design. With support from analyses by site visits, photographing and sketches a perception of its possibilities and constraints further on guides the adaptation of the design principles. The exploration of the design on the site was done through both physical and digital models and sketching.

Design implementation
Through the previous stages, of imagining, testing, reflecting, and adjusting, the design proposal becomes more refined each time. It is presented through a narrative through text, illustrative drawings and models on various scales. The outcome is not a fixed solution but a framed design proposal that is meant to work as a base to add new perspectives to the overall discussion.

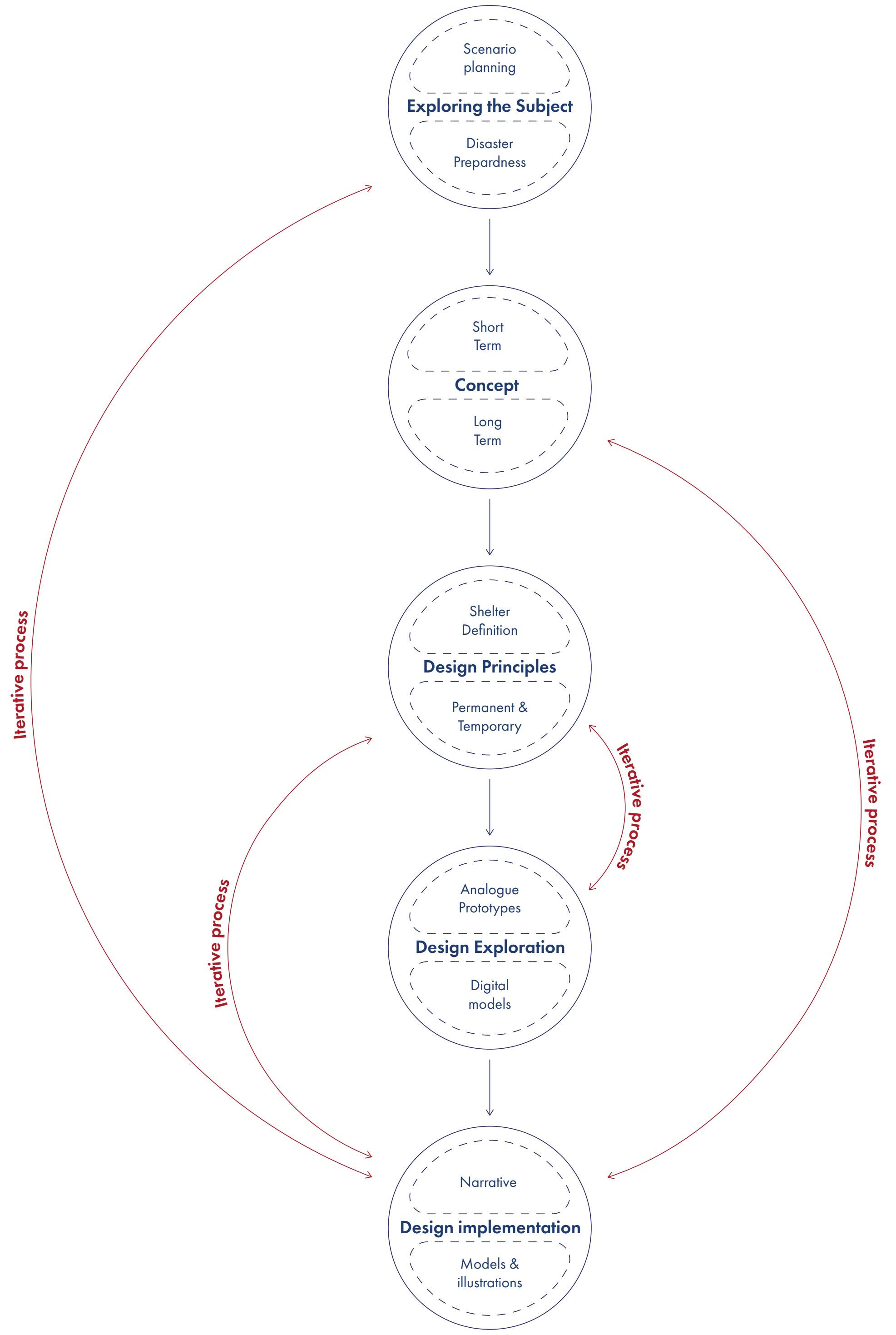


Figure 2. Method process diagram

Planning Ahead

2.1 Speculating through scenarios

To understand and grasp the complex implications of the future risks, influenced by climate change and its affecting consequences, we as architects could use probable future scenarios as a tool. The book Scenario planning: the link between future and strategy, highlights how this approach, compared to traditional methods, can give a push towards imagining more holistic perspectives and challenge the current paradigms. As uncertainties grow in the long-term horizon and every possible outcome can't be explored, these methods can reduce and uncover potential risks as well opportunities and prepare us for multiple possible futures. (Lindgren & Bandhold, 2010)

A relevant book that expands on this concept is Speculative everything, Design, Fiction, and Social Dreaming (Dunne & Raby, 2013). Detached from market pressures and business aspects mentioned by Lindgren and Bandhold, it connects the methods relevance to the role of design, specifically speculative design. Still grounded on scientifically possible futures, the fictional scenarios are used as mediums to understand our current situation, mirror the present, and to create debates and discussions about the futures we desire. Nevertheless, the preferable futures of today are mostly determined by industries and government where individuals power, by consuming or voting, is limited. This is where speculative design can become a catalyst, educate and help empowering people to participate and shape the future.

Further on, visionary architecture with its inherent social and critical agenda, sits on this fundamental applicable relationship between reality and unreality. Expanding towards critical design, which borrows a lot of methods from art but separates itself by becoming closer to the everyday, it has the potential to belong in the presence while its friction with reality suggests a relationship with a world that is yet-to-exist. Made successfully, the physical state act as an anchor is this world while the embedded visions and messages are located elsewhere and thus creating a co-existence called "complicated pleasure". (Dunne & Raby, 2013)

Planning Ahead

Figure 3. *Island City*, by P. Cook, 2011, Gallery Espace. Copyright by Peter Cook.

2.2 Uncertain city

Gothenburg is a city, like any other, that is already experiencing and will continue to be affected by climate change. Extreme weather events, such as autumn storms, hurricanes, and sudden torrential rains, have a long history in the city and provide insight into the challenges it may face in the future. Gothenburg's geographical position makes it particularly vulnerable to climate change, especially regarding heavy rainfall and rising sea levels (Berglund, 2021).

The gradual increase in temperature expects that by year 2100 the climate will become similar to today's Netherlands or even of central France, where heat waves during summer could continue for multiple weeks. The warmer climate results in water to vapor into the atmosphere, which together with dry periods would negatively affect the freshwater levels, both in lakes but also Gothenburg's most important drinking water supply, Göta river. Moreover, the dry periods increase the risks for extensive fires. (Stadsbyggnadsförvaltningen, 2026).

Additionally, the rain will be characterized by frequently short and heavier showers. This will affect the ground where pipe networks and the sewage system will find it difficult to handle the overload. Drinking water supply stands in the risk of worsening quality when the rain moves pollutants from the surface into the river (Stadsbyggnadsförvaltningen, 2026). Further on, flooding due to rising sea levels will have a large impact on Gothenburg and its surrounding area, with consequences such as disturbance of public service, infrastructure and water supply (Länsstyrelsen Västra Götaland, 2021).

In another future scenario, if the Atlantic Meridional Overturning Circulation, or AMOC, were to collapse due to the continuous global warming, a shift of the precipitation around the world is expected. The result of the shift would generate a warmer climate in the south and for instance in Northern Europe, which climate currently stays mild due to the AMOC, would face an overall colder environment. Nevertheless, stronger storms and higher sea levels are predicted when the currents of AMOC change. (MIT Climate Portal Writing Team, 2024).

In conclusion, looking at the larger horizon, the future will hold different challenges, and the growing risks of climate disasters will most likely effect society as a whole. However, being able to anticipate uncertain futures, resilient planning with the goals to mitigate the risks could end up preserving basic human needs when the disasters hits.

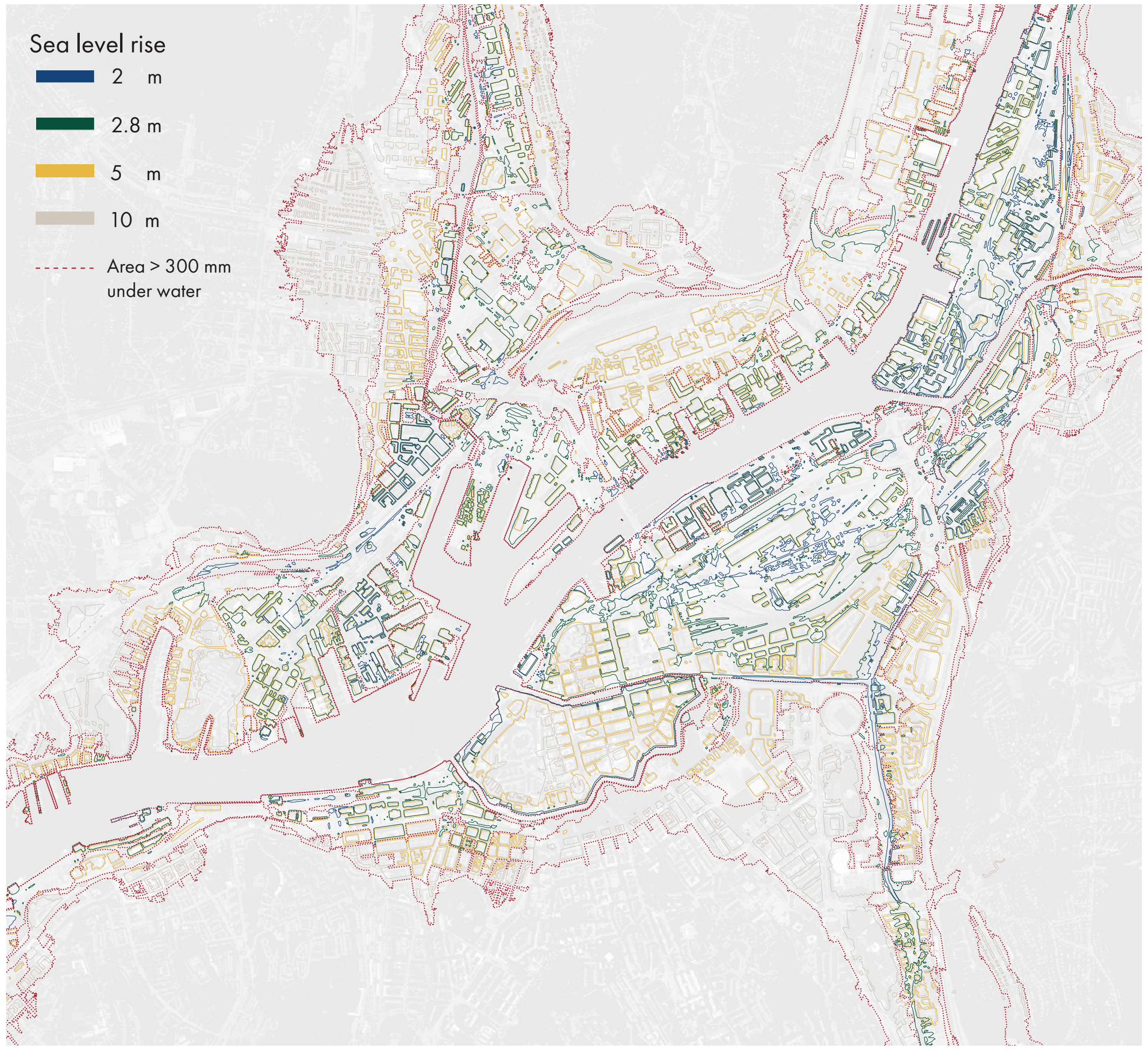


Figure 4. Illustration of the shifting landscape in Gothenburg due to sealevel rise.

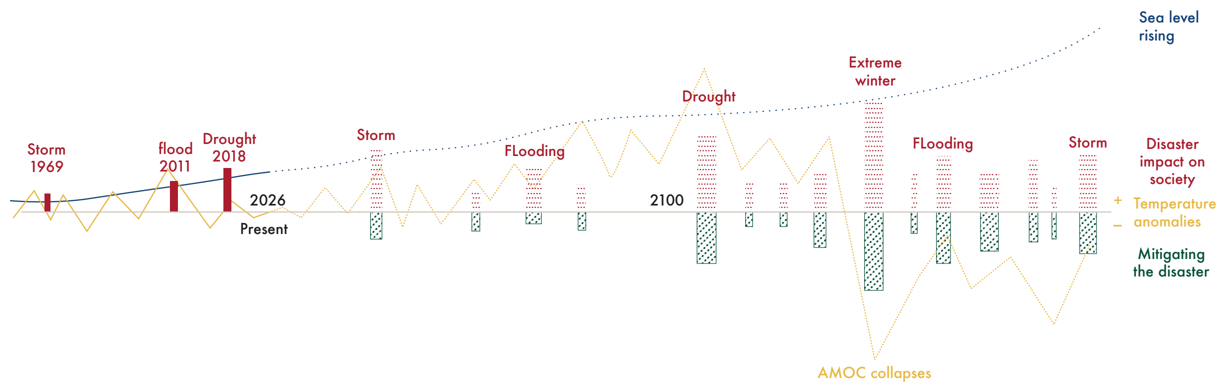


Figure 5. Illustration of the shifting climates for Gothenburg

2.3 Mitigating the risks

As many other countries and cities, Gothenburg also have implemented plans for how to face future risks of natural disasters, and the solutions are mainly focusing on the problematics of water. Since the much of the city centre is built on marshlands next to the Göta river, historically constructed as an important fortress to later transform to a harbour city which was once one of the largest shipyards in the world (Port of Gothenburg, n.d), the topography is mostly flat and risks becoming flooded when great fluctuations in the river occur (Berglund, 2021).

Because of this, the city has started a program called highwater protection. Finished by year 2040, one part of the program is to raise the riverfront to be able to handle a +2.3 meter water level, since most of the quays do not meet these requirements and are in need renovation. The design is not yet established but it states that it needs to make sure the room around the river is accessible for the public while still ensuring that essential infrastructure and public services can continue. The protection is mainly made with permanent solutions but could in some case be out of temporary characters. Another infrastructural part of the highwater protection is to build flood gates in certain sites (see figure 6) with accompanied pumps. In the centre gates are planned to create barriers between the river and the inner canals but other barriers for connecting water courses are planned, such as Kvillebäcken which is surrounded by large areas of existing buildings on low ground levels. By 2070, with the current scenarios for the future rising sea levels, there will be a need of large external flood gates towards the sea, see figure 6. (Stadsbyggnadsförvaltningen Göteborg stad, 2025).

Beside these engineered implementations, the Swedish system proposes that cities and settlements also need to have a built-in preparedness from a more holistic perspective. The proposal states that regions and municipalities should, during approximately two weeks, be able to maintain fundamental activities for a functional society using only their own available recourses in the event of a crisis (Sverige, 2024).Transferring this to a local scale service, which functions as a complement to the recommended seven days of home preparedness, is the municipal temporary safety points or also called special gathering places (Myndigheten för civilt försvar, u.å.). For example, some municipalities have prepared them to be placed in schools, sports halls, civic centres or in mobile tents designed for the specific purpose (source). The city of Gothenburg is planning for16 places around the city, four in each of its four urban areas (Göteborgs Stad, u.å.) and its overall functions will be further explained in the chapter Safety point.

Planning Ahead

Figure 6. Some of Gothenburgs planned interventions.

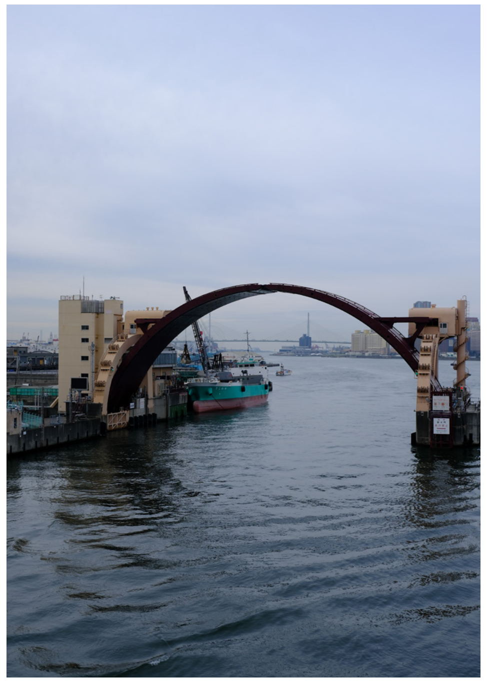


Figure 7. One of five river sluice gates, Osaka.

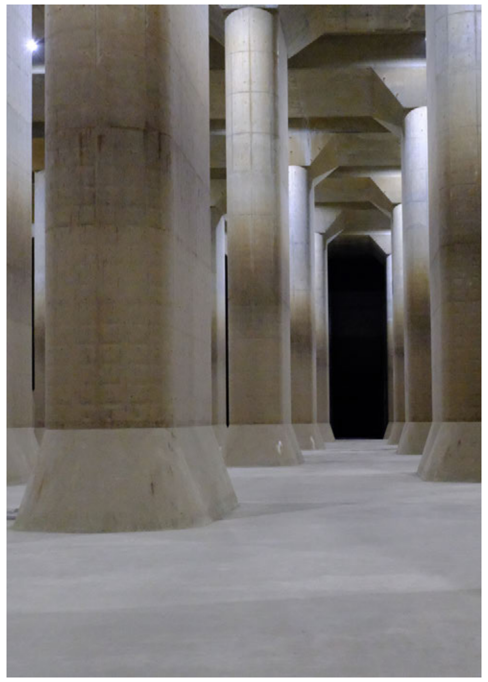


Figure 8. G-cans, Pressur-controlled tank or "the underground shrine" , Kasukabe.

2.4 Safety points

The information about the safety points, or special gathering places, is a collection gathered from guidelines provided from the Swedish Civil Defense Agency and Gothenburg City. To summarize this typology, it could be explained as a municipally driven logistic hub where people seek support during crises that have disrupted society to function as normal. This support includes both physical and mental and can take place indoor or outdoor depending on the specific function and weather at the time. The place itself needs to meet certain standards to be able to meet the needs and provide safety for the users.

Examples of what could activate them:

- Heat outage
- Power outage
- Telecommunications outage (in which case the safety point essentially becomes an information point)
- Extensive fires
- Attempted attacks
- Accidents
- Release of hazardous substances
- Events leading to large-scale evacuations, in or outside the municipality, where the safety point could be used as a gathering place for residents prior to evacuations.

For whom they are catered to:

- Mainly for those who live or otherwise regularly visit the municipality. Most of those who seek out a special gathering place will only show there for a few hours and to have their urgent needs met.
- For evacuated or fleeing persons from other municipalities during qualified peacetime crisis situations and heightened preparedness, as well as for foreigners who, during heightened preparedness, seek protection in Sweden due to war in their home countries. However, the safety point acts a as a reception location and does not refer to a residential accommodation or other accommodation.

What they could provide:

- Protection against weather influences.
- Information about what has happened and the measures taken by society.
- Drinking water.
- Hot water for example, porridge and freeze-dried food. Coffee, tea and, for example, rosehip soup should be available on site
- Possible to cook food
- Possibility to charge phones and electronics.
- Access to a first aid kit.
- Access to a toilet and hygiene articles or shower.
- Lighting, which is a prerequisite for being able to provide information and security.
- Information about the nearest open shelter, pharmacy, fuel, medical clinic and grocery store. Reference to crisis support. Also reference to sleeping and eating options in the event of longer events.
- Possibility to call 112.

Overall guidelines and recommendations:

- A place where people meet, can feel a sense of community and get help.
- Open during some hours to months, depending on the crises.
- It can be outdoor: tents, trucks and containers are flexible. Also, existing buildings can be used.
- Accessible by being placed close to public transport or central points.
  - It's important that people know the location.
  - Access for Trucks or buses (transportation vehicles)
- Area with enough space for the people.
- Backup power: Need to plan for which type of electricity/ energy source is needed.
- Toilettes placed with distance from drinking water to minimize contamination.
- The basic functions of a safety point do not include overnight accommodation at the safety point itself. However, in certain incidents, the safety point staff need to be able to direct people to where sleeping facilities are available.

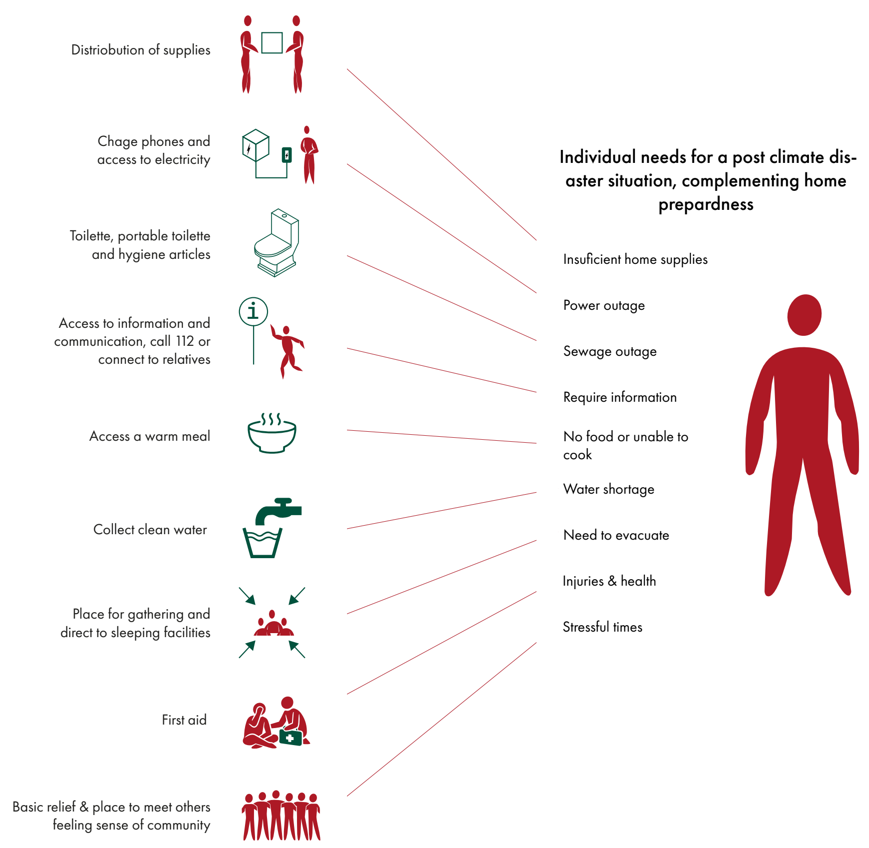


Figure 9. Functions and elements supporting a safety point during times of disaster

Figure 10. Open space surrounded by necessities in neighboorhood park, Higashi-Shirahige.

Figure 11. Solar- and wind-powered street light, Tokyo Rinkai Disaster Prevention Park .

"Wherever you can invent design outcomes to help society be more resilient beforehand, it is not at exorbitant cost. You can design for exceptional everyday spaces but embed other infrastructure and flexibility in there, so when there is a flood event or earthquake, those buildings have more capability."

Miho Mazereeuw, Assistant Professor and Director of The Urban Risk Lab at The MIT

2.5 Everyday meets disasters - Anticipatory design

A country which has constantly been under attack from climate disasters, from reoccurring earthquake and tsunamis to typhoons and flooding, is Japan. Even though the country places fourth in terms of exposure, it also, ranks among the highest in levels of "coping capacities" (Mazereeuw, 2025). The recently published book Design before disaster, Japans culture of preparedness illustrates this relationship. A culture known as Bōsai, translated to disaster prevention, have emerged through centuries of responding to the surrounding conditions with the aim of mitigating the loss from natural hazards.

The famous blossom of the cherry trees in Japan, which attracts people to gather on benches or picnic blankets to enjoy the vivid canopies and change of seasons, is inherently an act of disaster mitigation. The pressure on the ground of people and their feet helps to compress the earth and when planting the cherry trees next to a riverbank it prevents the soil, which during winter naturally softens, to erode and instead protect from spring flood (Mazereeuw, 2025). This tradition of recreational activities disguising preventative measures captures a great deal of what this dual mindset can provide.

Today, the evolution of the bōsai culture in Japan can be recognized in multiscale networks and is a result of strong participation and collaboration from national, regional, local and individual level. And even though earthquakes and tsunamis are not disasters occurring in Gothenburg, there are multiple lessons to be learned from a social and spatial point of view when understanding how the investment for disasters prevention can create added value connected to everyday situations. (Mazereeuw, 2025).

Connecting to the Swedish idea of safety point, similar concepts can be found in Japan and are called bōsai-hubs, which can take in many shapes and programs (See Apendix A). One of these typologies is called bōsaikōen, disaster prevention parks spread around the city creating a network of open spaces that each withhold specific infrastructure and functions for evacuated people. From Mazereeuw's research, there is a clear strength in combining the emergency needs with the functions of everyday. It not only communicates their role in the city and informing people, both visitors and residents, on where to seek protection in case of a disaster, but this synergy also have the possibility to affect the design process and make these public spaces for the everyday scenarios more useful, interesting and memorable.

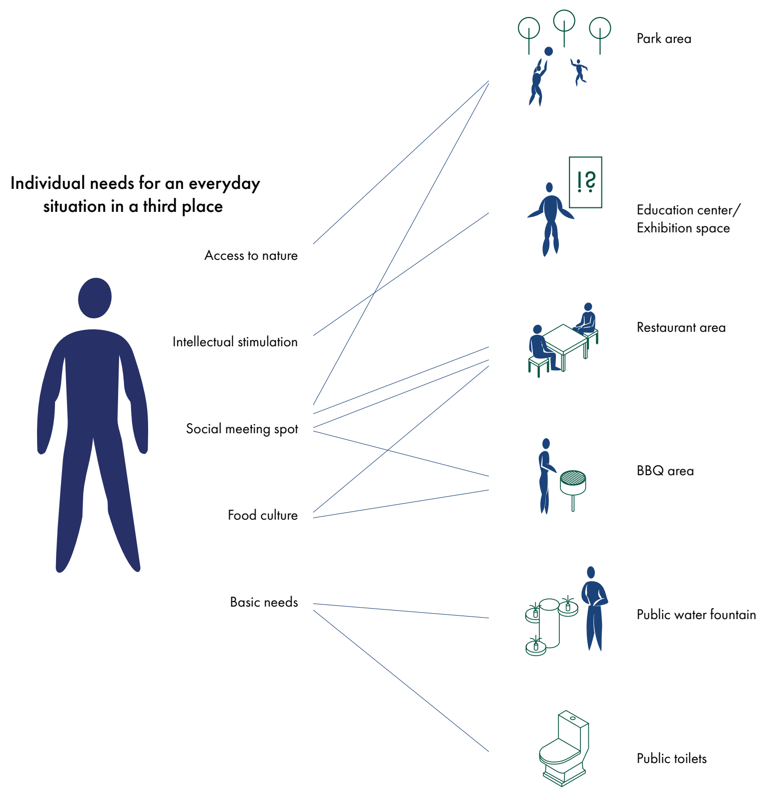


Figure 12. Functions and elements supporting everyday life in a public space

Figure 13. Guided disaster prevention tour, Tokyo Rinkai Disaster Prevention Park

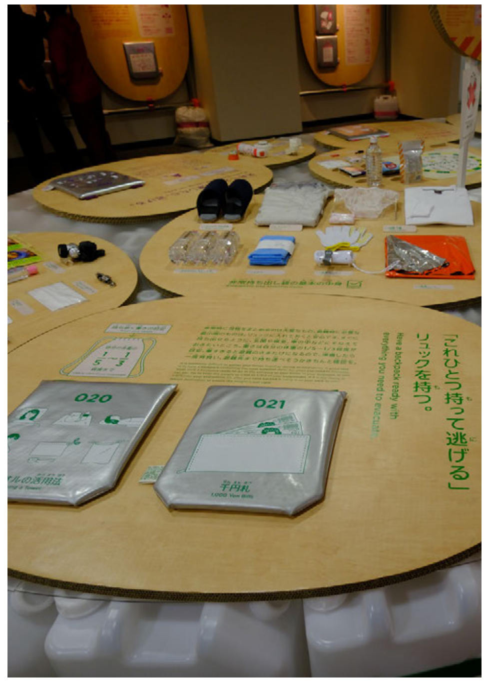


Figure 14. Examples of disaster relief supplies, Tokyo Rinkai Disaster Prevention Park

The transforming nomad

3.1 Short term - The transformer

As natural disaster stands in the risk of becoming more frequent in the future, varying in character and intensity, they could become a natural part of living on earth when they start to happen every 5 year or even multiple times per year. This means that the need for protective measurements and places to take shelter and receive support during troubling times will increase and become even more important for the future societies, keeping basic functions running and protecting people. Nevertheless, in between these events, the everyday takes place and, compared to the duration of disasters, this state stands for majority of time. Combining these conditions, it creates a time cycle that loops and, in a way, relates to each other (see figure 15).

Expanding on this concept, influenced by the criteria for a safety point and by the Japanese anticipatory design of bōsaikōen, it could mean that a shelter planned for disaster life could also give something to the situation of ordinary life. Connecting the functions where the disaster criteria act as base, the functions for everyday gets influenced and can use this as a springboard to what the shelter could be used for in another scenario. For example, the needs for being able to cook and serve food in a safety point could mean the place can be used as a restaurant since these functions share similar needs. Since the everyday functions will be in use most of the time, it's important that their spaces also influence the design to insure their quality. The shift in between these functions also showcases a decrease and increase of different needs of its functions, where the use of the space must be able to follow along. Since the natural disasters can strike at any time and its effects can quickly disrupt society, the functions need to be prepared at all time and responsive in some hours. This calls for flexible spaces that can easily transform from one state to another.

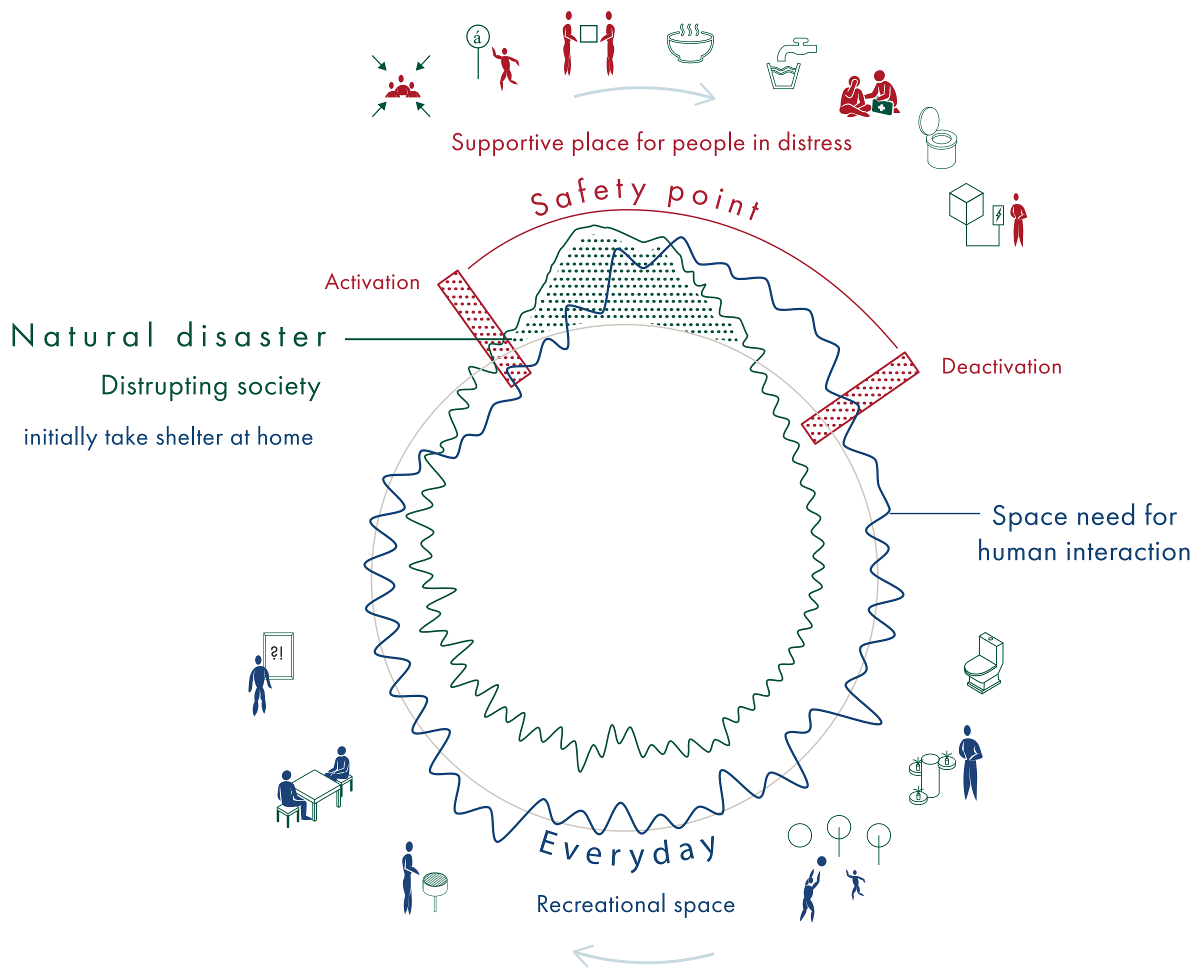


Figure 15 . Conceptual cycle for a site with dual use during a cycle between everyday and disaster events.

3.2 Long term - The slow nomad

Focusing instead on the long horizon, 100, 200 or even longer than 1000 years, the future becomes more uncertain. If the climate change continues in a negative direction, where our way of living on this earth continues to push the environment in an extreme direction, the consequences grow on the time-axis. In the case of Gothenburg, the heightened sea levels could become too extreme for its protective infrastructure to handle. Some of its landscape might no longer be possible to protect from becoming under sea level. At the same time, locations that are under risk of becoming under the sea level, especially in a city as Gothenburg where large part of the city centre lies in proximity to the river, could still be seen as possible sites for new built environments. However, they must be aware of the future risks. Furthermore, comparing long term scenarios with the short term, the shift between events or trends are less rapid and instead slowly altering in the background of the everyday-disaster-cycle. This means that the transformation that might need to happen, due to the climate changing the overall conditions, does not need to occur with the same acceleration.

Taking all this in consideration, the long-term scenarios reveal a concept for a built structure that one day might need to be moved, if it places itself in proximity to a watercourse and still wishes to be used. This idea argues for a deployable design which, depending on the future sea level events, is relocated to serve a new site. Compared to the short-term transformation, this transformation do not need to occur as rapid and could use another method of transformation, i.e. installation and disassembly. It's more about the dynamics between sites than on site.

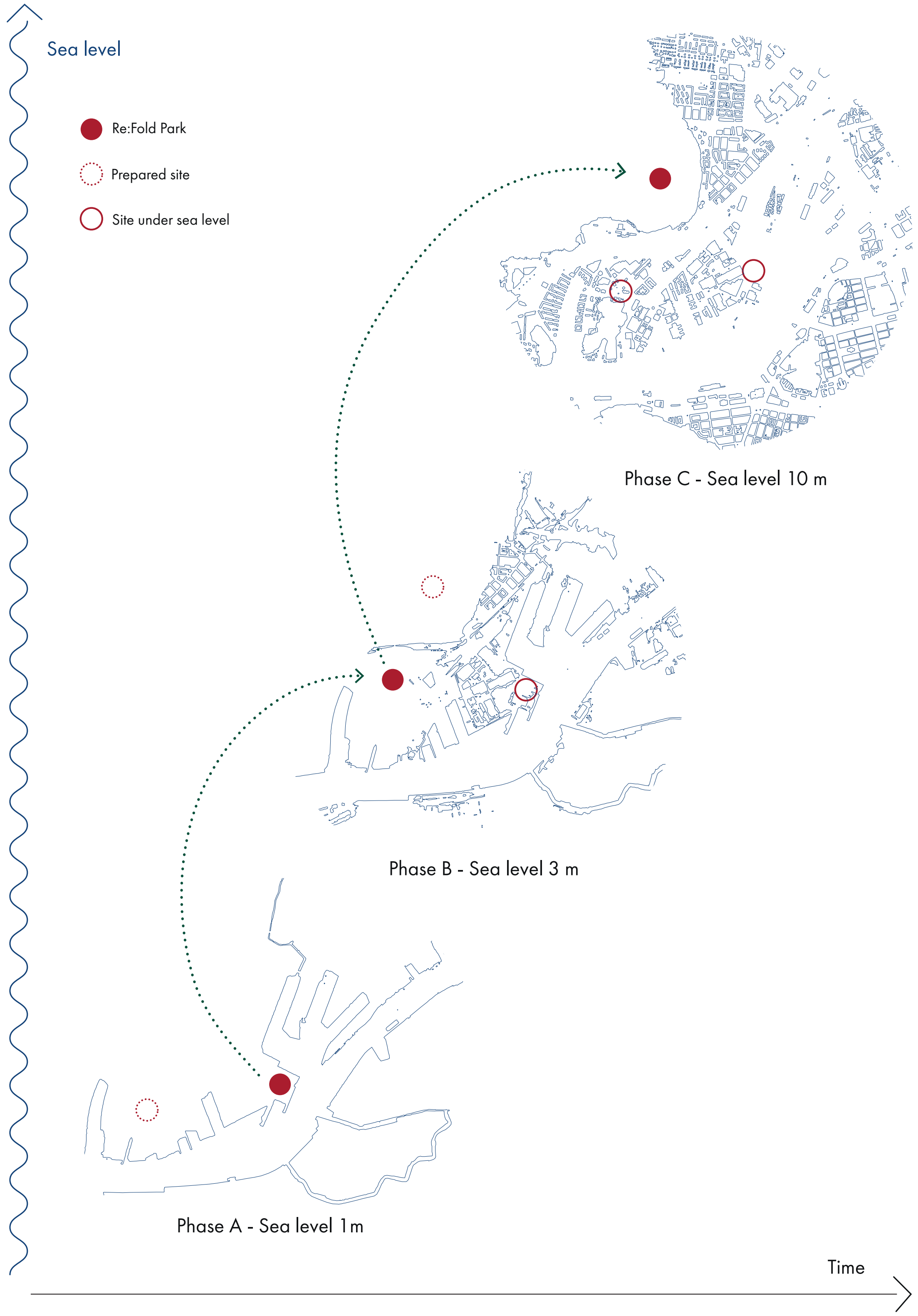


Figure 16 . Conceptual idea of the dual use elements and how they connect to the the scenarios of everyday and disaster scenarios.

Design Principles

4.1. Back to basic - taking shelter

According to the Cambridge Dictionary, the definition for a shelter is: (a building designed to give) protection from bad weather, danger, or attack (Cambridge University Press, 2026). While from a humanitarian point of view, a shelter is defined as the household living space which includes the items necessary to support daily activities and is related to Settlement which refers the wider location where community and people live (McCann et al., 2018). Further on, a shelter should also provide security and dignity by giving people a safe space from the outside world and privacy within their own space. These definitions, shelter and settlement, is often use in NGO activities to ease the logistic behind large scale humanitarian work.

From an architectural point of view, the shelter can instead be understood as the first architectural intention to give protection from climatic forces and to provide the first condition for inhabitable space. In this thesis the shelter is interpret and defined as a safe space that is to cover four main aspects: environmental, spatial, structural , and human-scale. Architectural philosophers such as Vitruvius, Semper and Le Corbusier all have addressed these core ideas in different ways:

The environmental aspect - where the space should provide protection from weather and climate, Vitruvius explains how the discovery of fire by the early humans made them gather in larger groups and the assembly of shelters began (Vitruvius et al., 1960). Continuously observing and learning from each other's shelters and improved details, the knowledge of how to protect from the climate conditions advanced. Today, the attention to the climate can still be seen in buildings in both major and minor details, however architecture adapted to its climate is mainly found in vernacular architecture where the climate conditions on site influences the architectural forms (Dahl & Institut for Arkitekturens Teknologi, 2010).

The human-scale *aspect*, how spaces are measured and experience by the scale of a human, originates from how the early builders used their own bodies, the pace, foot, elbow and finger, to organize space. Constructing a unit of measurements is highlighted as the first condition for being able to build well. In contrast to the natural environment that is irregular and disordered, these common units of measurement establish an order which also ensures practical space for the human body. (Le Corbusier, 1989).

The structural *aspect*, where the spaces respond to loads and materiality, are based on one of Vitruvius triads; firmitas. Firmitas refer to a building's durability through right choice of material and can be interpreted as the shelter's structural integrity. Firmitas, together with Utilitas (referring to utility and function), and Venustas (referring to delight and beauty), form the Vitruvian Triad which are the core principles for good architecture according to him(Vitruvius et al., 1960).

The spatial aspect, how the spaces difference from inside and outside, Semper introduces the idea of the four elements of architecture being the *hearth protected by three elements being the roof, the enclosure and the mound.* He then uses the differences between structural wall that exist for structural reasons and hanging textile carpets that exist purely as space dividers as an example to explain how spatial elements differs from structural elements (Semper & Mallgrave, 2010).

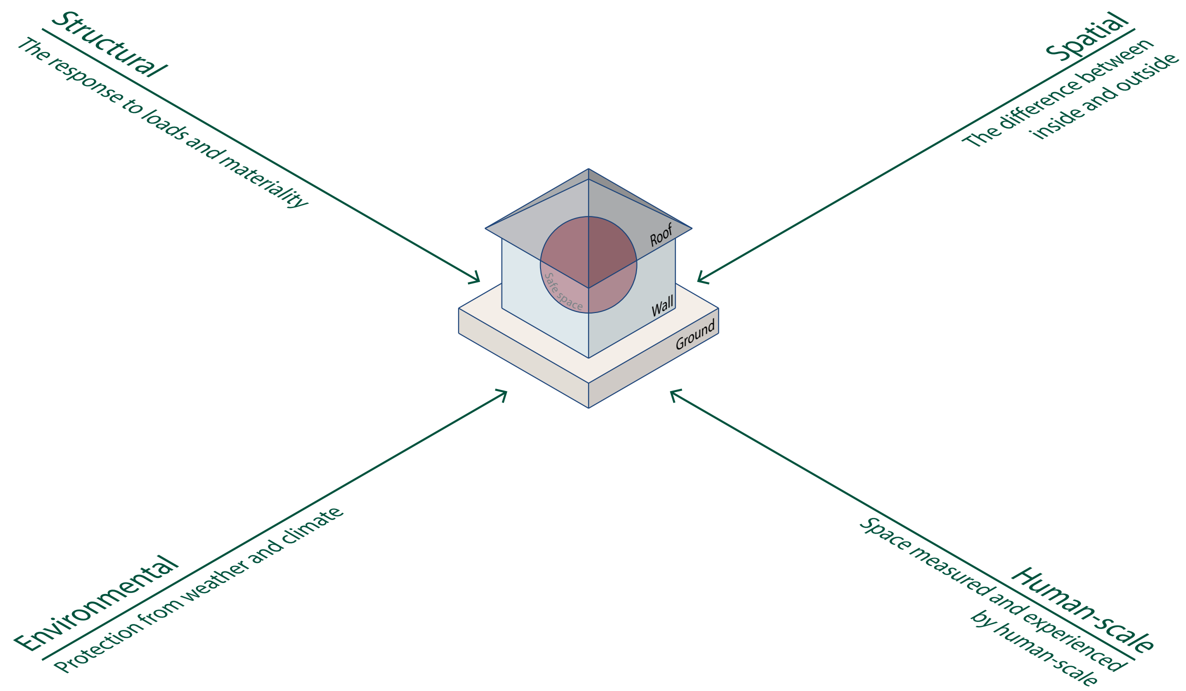


Figure 17. Conceptual diagram of the four aspects shelter definition according to the thesis.

With this it can be concluded that the shelter is not meant to be interpreted solely as a primitive structure but instead as a conceptual architectural idea that brings protection, space and human interaction together. The physical form of protection could be found in the environmental and structural aspect, while on the other hand the psychological form of protection could be found in the spatial and human-scale aspects.

The shelters, or so called buildings, of today have developed and exist both in permanent and temporary forms, where different architectural strategies address and cover various stages of human needs. Consisting of permanent to temporary buildings, architecture has the possibility to provide people a safe space. Therefore, in this case when investigating the safe space for both the long-term and short-term scenario, not only one but both permanent and temporary architecture become highly relevant. The question then becomes: what is the difference between these typologies and how can this inform the design for a shelter facing different time scenarios?

Figure 18. Kiyomiizu-dera temple in Kyoto. The temple has endured for over a millennium thanks to the resilience of its wooden joinery, providing flexibility in earthquakes, and regular maintenance and reconstructions carried out by successive generations. In combination with its important cultural background, the temple is have become a UNESCO world heritage site.

4.2 Permanent and Temporary architecture

There is no official definition for permanent or temporary architecture, but it could be interpreted through the built architecture and its presence on a site and in society. An architecture designed for a certain service life and to remain useful over one time through durability, maintenance and/or adaptability. Therefore, both permanent and temporary architecture can be explained through four aspects: Technical, Functional, Cultural and Institutional. While a building can appear to be permanent or temporary by only considering one of the aspects, its permanence or temporality is enhanced when meeting as many aspects as possible.

Institutional permanence - To support a buildings existence, institutional permanence handles the legal, political and economic aspects. Regulations and laws can support a buildings existence and therefore its permanence. For example, according to Eurocode, permanent buildings have a design life of 50 or 100 years, depending on the building type (European Committee for Standardization, 2002).

Institutional temporality - Similar to the institutional permanence, this supports temporary architecture to exist through the regulations, laws and planning conditions that make it possible for it to exist for a limited period and to be defined temporary. For example, compared to a permanent building a temporary structure has only an intended service life of 10 years (European Committee for Standardization, 2002).

Technical permanence - Coming back again to one of Vitruvius triads, firmitas, the technical permanence consider the durability, structural lifespan, maintainability and service life of a building (Vitruvius et al., 1960). Technical permanence therefore refers to the physical durability and materiality of a building.

Technical temporality - Refer to the materiality and structural properties for short term existence. This results in a short lifespan and often made by lightweight construction, which often use recyclable or easily assembled materials to allow both rapid construction and dismantling (Trisno et al., 2025). Within temporary architecture is the concept of deployable architecture, which focus on structures designed to transform from a compact state to an expanded state with new functions. This can result in structure that are easy to store and transport with the ability to be deployed rapidly when needed. Retractable roofs, space structures and folding shelters are some of the existing examples (Pellegrino, 2001).

Functional permanence - Buildings with adaptive reuse in mind have a higher chance of avoiding destruction and therefore extending its lifespan (Conejos et al., 2015). The functional permanence depends on flexibility and spatial generosity and describes the architecture's ability to remain functional in times of changing conditions in social, economic and technological context.

Functional temporality - is referring to architecture characterised by its temporal limits of its action, adaptability and flexibility (Al-Musawi & Ali, 2025). The ability to appear and disappear, for instance in an urban setting, is one of the main attributes for temporary architecture and differs from permanent architecture by being a space for experimentation, new materials, spatial concepts and technologies while at the same time responding to changing needs in social and urban settings (Trisno et al., 2025).

Cultural permanence - This is the architectural ability to retain identity, meaning and symbolic value. Cultural permanence is linked to heritage, atmosphere, history and social continuity. A way to be kept meaningful to society through time. Therefore, the values and meaning of the buildings are not derived solely through its physical form but from socially constructed cultural framework that is developed over time (Pendlebury, 2013). To build something that protects people but at the same time is innovative, unique and beautiful takes time. But is often worth it because people tend to care and maintain for what they love (Mazereeuw, 2025).

Cultural temporality - Act around the temporary experience. Temporary architecture often appears in situation such as events, pop-up stores, emergency shelters or other urban activities where spatial requirements change rapidly. Even after the temporary architecture disappears, the effects often remain by challenging the interpretation of space and possibilities for urban transformations (Trisno et al., 2025).

4.3 What is permanent and what is temporary?

In conclusion, permanent and temporary architecture uses different approaches to respond to environmental, social and spatial demands. Permanent strategies emphasize durability, longevity and stability while aiming to create architecture that can endure long periods of time. On the other hand, temporary architecture instead prioritizes flexibility, mobility and rapid response to allow structures to adapt to changing conditions or short-term events. The intended lifespan expressed through material and scale gives the ability to express different architectural ideas. Despite their differences, permanent and temporary architecture share important similarities. Both make use of adaptability where their structures and spaces respond to changing social, cultural and technological contexts.

Therefore, the boundaries between temporary and permanent architecture are not strictly defined but coexist in a fluid relationship, where the architecture can shift between the states depending on needs. Permanent buildings can gain temporary attributes when their function changes or when they become obsolete, while temporary structures can become permanent when they gain social, cultural or symbolic value over time. Buildings that should last for centuries are getting demolished after 20- 30 years while temporary installations intended for a few months can last several decades (Tabassum, 2025). An example is the Paper Church in Kobe, designed by Shigeru Ban after the 1995 Great Hanshin earthquake. It was built as a temporary replacement for the destroyed Takatori Catholic Church and as a place of community gathering. The church was constructed in just five weeks with the help of 160 volunteers and donated materials. It was intended as a short-term solution but remained in use in Kobe for ten years and in 2005, then dismantled and relocated to Taiwan, where it continues to serve as a community space.

This overlap reveals a grey zone between permanent and temporary architecture where architecture unfolds through processes of adaptation, reuse and shifting needs in a social, cultural and environmental context, which is to be further investigated in this thesis.

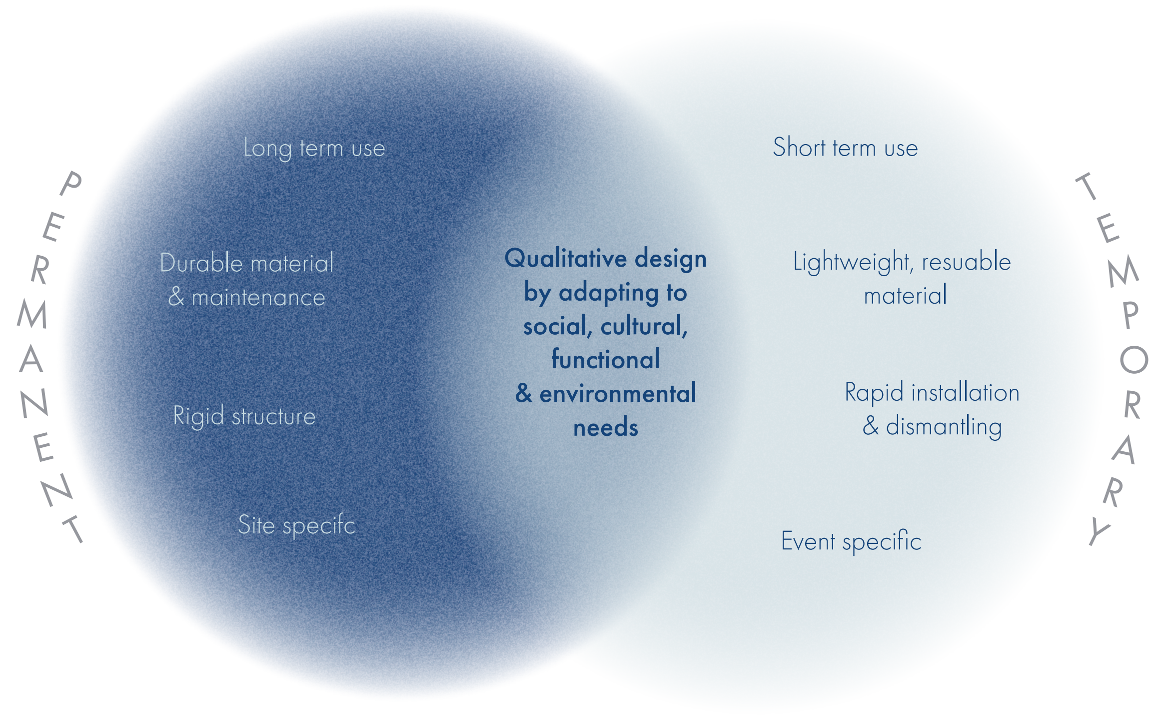


Figure 19. Diagram of the intersection of permanent and temporary architecture.

4.4 Design criterias

Based on the shelter definition from chapter 4.1 and on two main scenarios, design criteria's are defined around the environmental, structural, spatial and human-scale aspect as seen below in table 1. These will be used as guidelines and goals to test the design.

Table 1. Design principles based on the shelter aspects

		SHELTER ASPECTS			
		Environmental	Structural	Spatial	Human-scale
DESIGN PRINCIPLES	Disaster	A design that provide protection to survive harsh climate conditions.	A design that support or redirect hazardly load from extreme climate and that offer the opportunity to be repaired.	A design that function as a relief area that can reorganize its functions effectively and provides aid to displaced people	A design that feel dignified and inclusive for people in distress, where the individual feel safe and emotionally calm
	Everyday life	A design that provide a comfortable and enjoyable outdoor space by providing thermal comfort, sufficient protection against rain.	A design that support a clear construction logic with high structural durability through right choice of material, low assembly complexity and easy maintanence	A design that function as an open and public recreational space that can serve several public purposes during time of peace	A design that feel dignified and accessible with the comfort for the human-scale in mind that form a relation to the user

Design Exploration

Design exploration

5.1 Deployable Structures

Deployable structures are explored due to its rapid and effective transition between two modes. Its ability to react to unpredictable event and the ability to change its spatial and functional properties make it highly intriguing to investigate. Deployable structures are assemblies of "rigid" parts connected to movable joints that are arranged in such way that allows two configurations, a packaged one and a deployed one.

An important aspect is that unlike mechanical linkage used in mechanical engineering, the parts from the deployable structures need to be considered as structural components. Therefore, the movable joints that often are placed along the load path often are weak links. The joints need to be able to rotate which often reduce the stiffness. To solve this latching, elements are often included in the design or to simplify the design to decrease the number of freedoms. In this thesis two types of deployable structures, pantograph structures and folded-plate structures, are investigated to see how it responds to the design criteria (Pellegrino, 2001).

5.2 Pantograph structures

The pantograph is a structural mechanism, which in its simplest form is a scissor-structure consisted of straight elements of equal length that is connected by pivots in middle and at the ends. When several pairs are connected to each other a module could freely be folded and deployed by changing a single parameter, the folding angle, α. With that in mind the whole structure could now deploy at the same time by only changing one parameter.

To test this structure two types of pantograph structures where explored, the line-like pantograph structure and the ring-like pantograph structure. For both structures, digital simulations where produced in grasshopper, a plug in to rhino3d, to simulate the deployment by changing only the folding angle. Using that as support, a physical prototype is then produced by laser cutting the bars from wood and using M2 screws and bolts for the joint.

The first type of structure was a line-like pantograph structure, the simplest version of a pantograph structure that in this case consist of five scissor elements. Considering the structures boundary area, it is noticed that the area the structure can cover after deployment is approximately three times larger compared to before deployment. The end pieces are acting as latching elements. The physical prototype can be seen in figure. 20 -21.

The second type is the ring-like pantograph structure. It is developed from the same principles as the line-like pantograph but differs but consisting of three different sizes of the scissor element. With this configuration the structure size changes in three dimensions and the deployed boundary area in the digital simulation proved to be 72 times bigger than the packaged one in the digital model. However, this structure also demands a more complex joint solution. Angled joint is designed and 3D-printed to allow the ring shape. Tolerance issues between the bolts, bars and joints itself proves to be a challenge and several versions are printed before they fit properly. A physical prototype can be seen in figure 22-23.

Pantograph structures proved through the exploration that it could provide a controlled deployment and area coverage while only changing one parameter, folding angle, α . So, when one part moves the whole structure follows. The disadvantage is that the structure itself does not provide much shelter or shade but need to be complimented with either some kind of membrane that also could deploy. An example of this could simply be a flexible membrane like tents. With that the structure itself is not stiff enough to act as a load bearing structure itself but need to be complimented with cables, latches or pre-stress.

5.3 Folded structure

Folded structures are a type of surface-active structures that consist of flexible but tension-, compression- and shear- resistant flat surfaces. Where the redirection of forces is affected by surface

Figure 20 Line-like pantograph, before deployed.

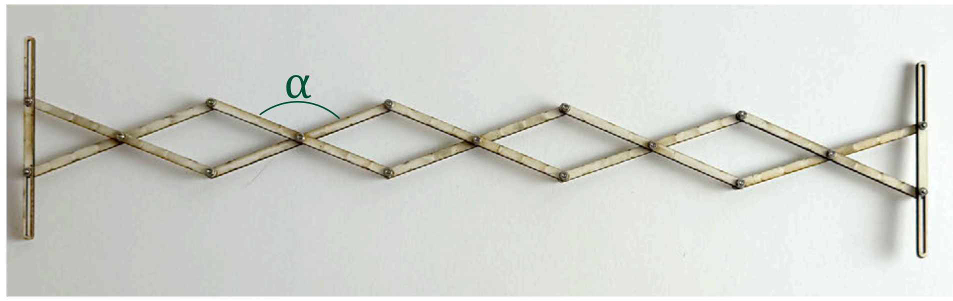


Figure 21. Line-like pantograph, after deployed.

Figure 22. Physical Ring-like pantograph structure prototype, before deployed.

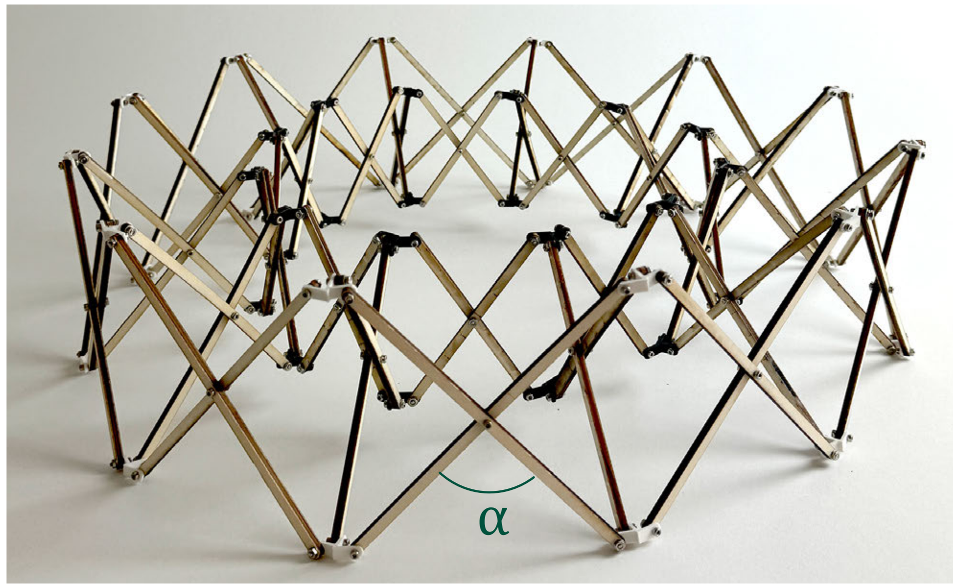


Figure 23. Physical Ring- like pantograph structure prototype, after deployed

resistance and surface design. The surfaces are connected to each other along the edges and while the surfaces act as a structure they will also naturally provide space enclosure and shape (Engel & Rapson, 2007). Individually flat plates have limited stiffness but when they work as a system in a configuration in three dimensions the system become a remarkably efficient load-bearing structure which allows thinner plates and longer spans (Engelsmann & Spalding, 2017). A critical point for folded structure, both architecturally and structurally, is the edges. Each fold act as a rigid support where the edges between the panels must be shear-resistant, that means that the edge joint between the folds must allow the forces to transfer between plates. Both the architectural and structural consequence could vary due to the many parameters such as material, cross-section and if the joint should be permanent or detachable. For example, and increasement of folds in the cross section would redistribute the forces more for each fold making the structure behave more close to an arch (Engel & Rapson, 2007).

5.4 Rigid-panel structure

Since folded structure is not in nature deployable, an investigation expanded to find how to transform this system to a deployable one. An interesting concept is the rigid-panel structure. A rigid-panel structure is a concept where the structure consists of rectangular panels which are connected on the parallel edges with hinges. While the structure is in the package configuration, the panels are stacked alongside the support structure. Then in the deployed configuration the structure becomes a flat cantilever from the support. This type of structure is often used in solar arrays for spacecrafts where the use the package configuration during launch to later deploy when the spacecraft is in orbit (Pellegrino, 2001).

5.5 The Yoshimura pattern

The next step was to find a fold pattern that satisfied our criteria's. The Yoshimura pattern is a folding pattern that is characterized by its X-pattern which created triangular shape panels. The pattern makes it possible to turn a flat sheet into a shell-like surface where the triangular panels and shell-like shape provide substantial stiffness and is commonly used for longer spans and shells (Cai et al., 2016). An example of the Yoshimura pattern is presented in figure 24a). The usage of the Yoshimura pattern is considered due to the fact that it has been widely used in various engineering fields (Fei et al., 2025) but also due to the architectural properties which comes with it, where the span and pattern is highly intriguing.

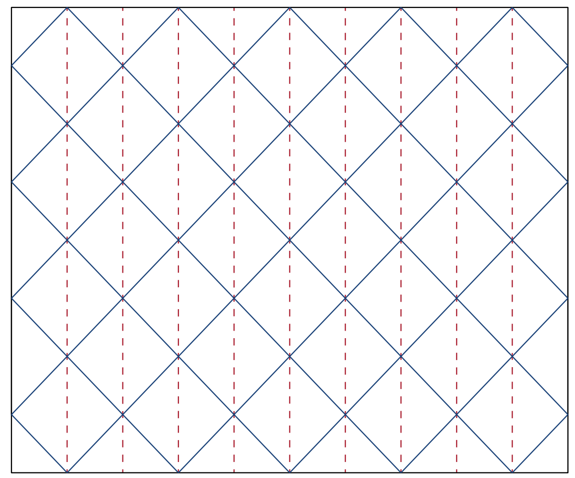
A disadvantage is that this folded pattern does not act as a mechanism and therefore does not offer a controlled deployment. This is proved through both physical prototypes and digital simulations. The folding behaviour between the Yoshimura pattern and the Muira-ori pattern is compared digitally in figure 25 and physically in figure 26-27. This flaw is highly critical and the main reason why the Muira-ori pattern is explored instead.

5.6 The Muira ori pattern

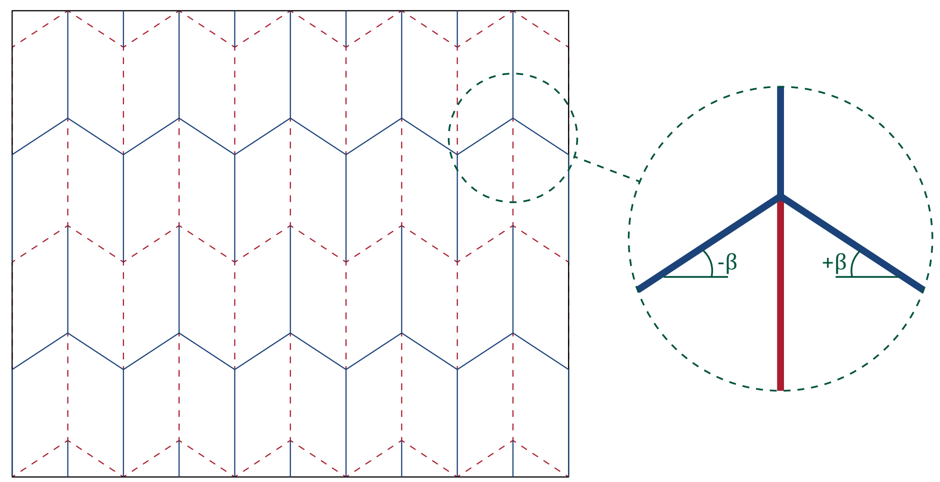
Miura-ori is a folding pattern that instead consist of parallelogram panels capable for turning a rectangular sheet to a compact flat package but still allowing it to unfold in a controlled way. The Miura-ori fold combine vertical folding lines with lines in that zig-zags creating a V-pattern, with angles of + β and - β to the vertical lines. This change make it possible to the membrane to unfold biaxially (Pellegrino, 2001). However, a typical Miura- Ori fold do not inherently turn to a geometry that could span over a space like the Yoshimura fold so to turn the folding to a canopy one of the V-pattern need to rotate 180 degrees, see figure 24c). The architectural response from the patten varied by changing the length between the V-pattern and the angle β for V-pattern. Like the pantograph structure the Miura-ori have the advantage of synchronous deployment, where the system is only controlled by a single degree of freedom.

Another configuration of the Miura-ori pattern is investigated is to assemble them into tubes (Filipov et al., 2015). Filipov created paper tubes by mirroring two Miura-ori sheets, creating a foldable tube. His team then investigated different coupling

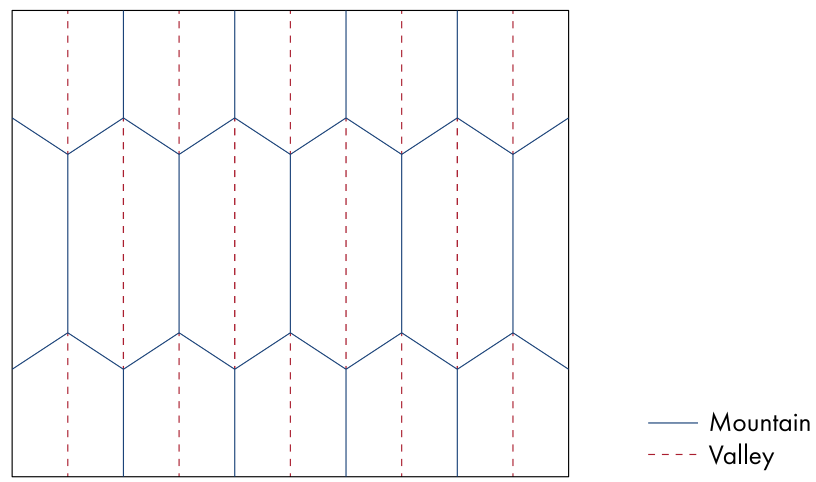
Design exploration



a) Yoshimura folding pattern



b) Typical Miura-ori fold



c) Architectural response of the Miura-ori pattern

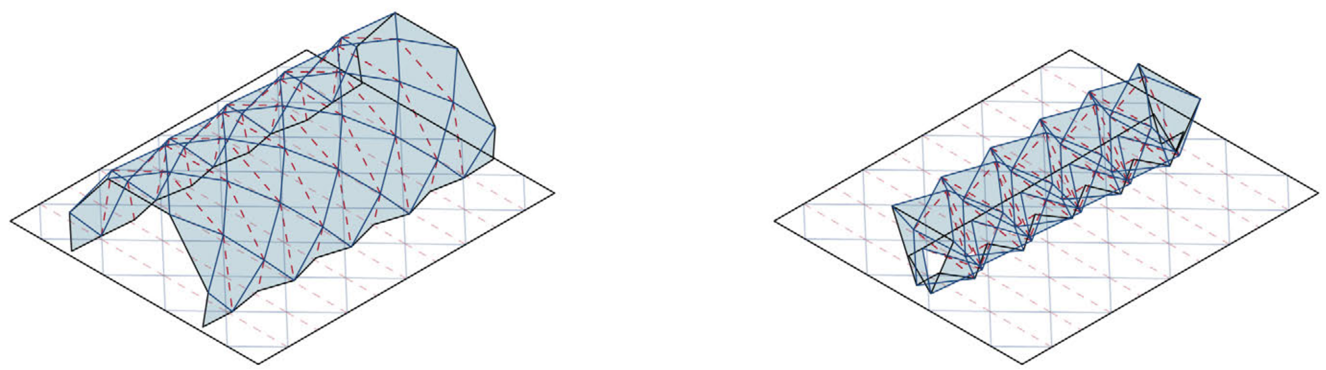
Figure 24. Different explored folding pattern

method, aligned-coupled tubes, zipper- coupled tubes and internally coupled tubes. These tubes could then be assembled in various of ways to create different architectural elements such as bridges and canopies. The biggest advantage of this system is that it is stronger on bending and twisting. However, prototypes of this idea where produced and tested physically, see Appendix B, and while the tube proved to be deployable and promising structurally, the complexity and the number of panels resulted with the idea to get dismissed.

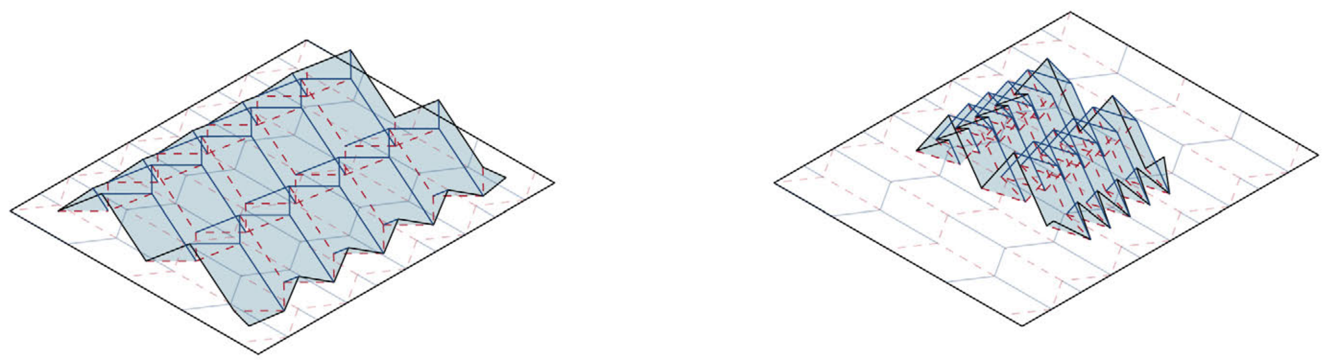
Several different prototypes are produced to challenge the Miura-ori fold. The initial ones are simply physical prototypes using paper sheets models which are produced to understand the pattern itself and to experience its synchronous behaviour, see figure 26-27. A digital model is also created to be able to simulate the folding sequence of pattern. With that it is possible to track the movement and direction that pattern wants to move in. A great amount of time was spent to solve the edge joint between the plates. When thickness is added to a folded structure the placement of the hinge becomes crucial. Due to the panel thickness the hinge placement will be shifted. Other than the hinge itself, element such as the bolt and screws will obstruct on a smaller scale and need to be considered. The hinge axis needed to be offset to be either above or under the crease axis. When the thickness increase the risk for panel collision increase as well where the most critical point often lies around the vertices(Pellegrino, 2001).The first prototype where thickness is considered, seen in figure 28, consist of eight panels connected with 3D-printed hinged that are fastened with one bolt on each side of the hinge. While the prototype can fold to an extend the folding stops when the long bolts hit each other or the plate. Furthermore, the hinge could not simulate an edge joint due to being fastened in only one point of the edge, which allowed the plates to slide along the edges, as seen in figure 28c).

The second prototype, seen in figure 30, was modified and used bigger panels to ease the manufacturing of the prototypes. Longer hinges with two holes for fastening are produced to lock the edge in place. In this prototype the vertices where several folding lines are met resulted with collision between the panels exactly as Pellegrino mentions. To solve this, material was reduced to give space to the rotation. For the same reason the hinges for the V-lines needed to be designed with and angle to allow space in the vertices, see figure 29b). Again while being able to fold the model stop its folding when the bolt hit each other, see figure 30b).For the third prototype, shown in Figure 31, the installation process was explored. Larger panels with simplified hinges, consisting of stapled textiles, were used. The focus of this prototype was to investigate where the hinges needed to be placed and how the behaviour changed as the panels began to scale up. For example, the prototype needed an initial "push" to start its folding process. Due to the complication from the bolt hinges, living hinges (a thin flexible hinge made from the same material as the rigid part) are tested through 3D- printing. First two quick models are printed to test out the living hinge thickness. Then a model with the Miura-ori pattern is printed. This prototype managed to fold and unfold but also cracked on some places proving again that the critical points are the edge joints. The living hinge prototypes could be seen in Appendix B.

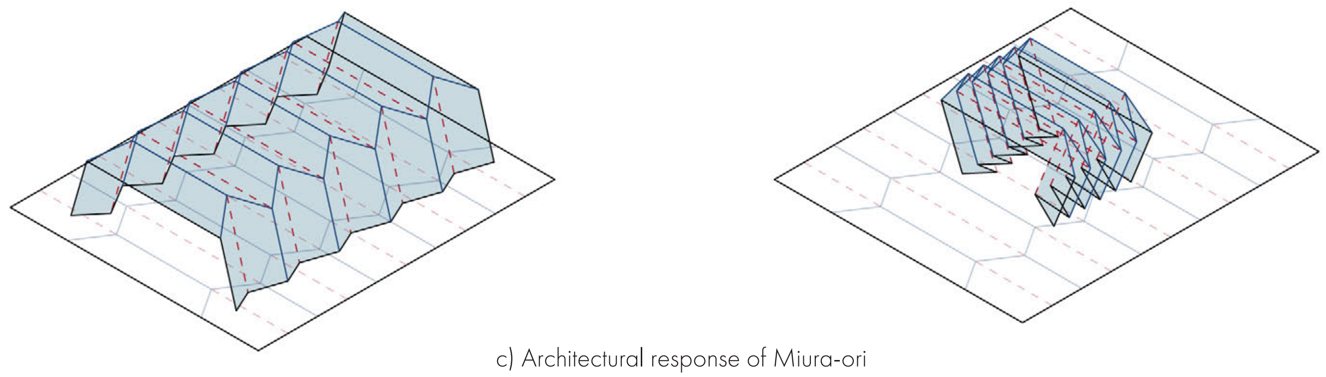
The fourth prototype is created to understand and track how the Miura-ori structure would move on a locked plane. The movement is tracked through the digital simulation then a physical model is constructed to confirm it. A simple folding model are created with cardboard paper, and tape is used as hinges. The rail is laser cut and raised from the ground the paper model is fastened with steel wires. Seen in figure 33, the model transition between package and deployed configuration be moving along the rail confirming that the digital simulation is accurate. Therefore, it can be concluded that this could also be upscaled. A similar physical model was made where the panels had cut out holes for opening the explore the architectural properties of that configuration.



a) Yoshimura pattern

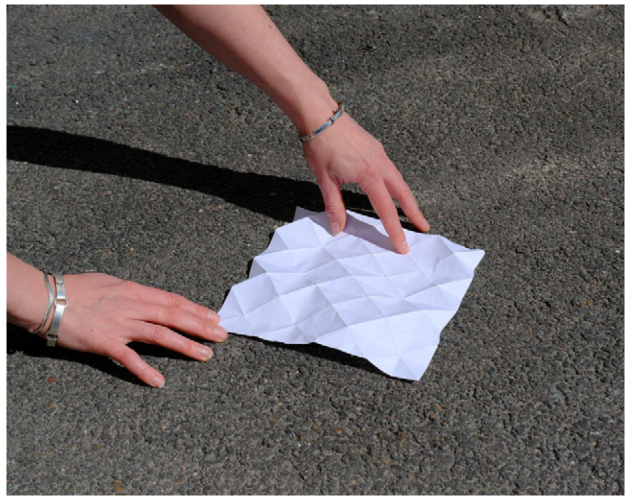


b) Traditional Miura-ori pattern

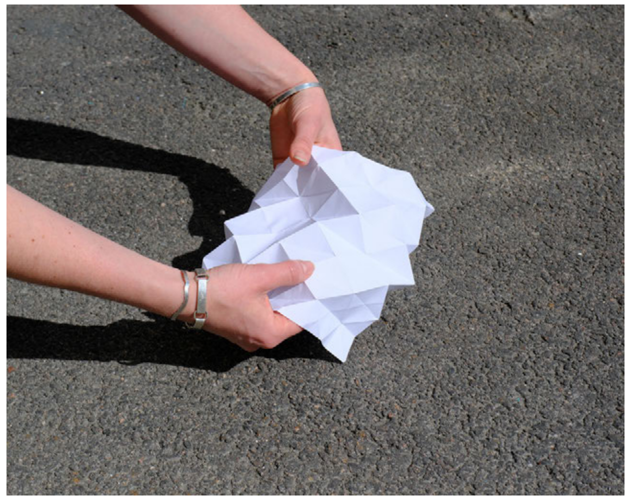


c) Architectural response of Miura-ori

Figure 25.



a) Flat sheet mode



b) Deploy process

c) Deployed process

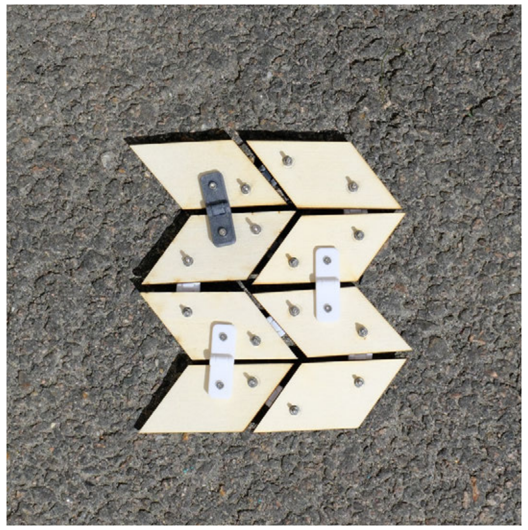
Figure 26. Yoshimura pattern, physical fold behaviour.

a) Flat sheet mode

b). Deployed mode

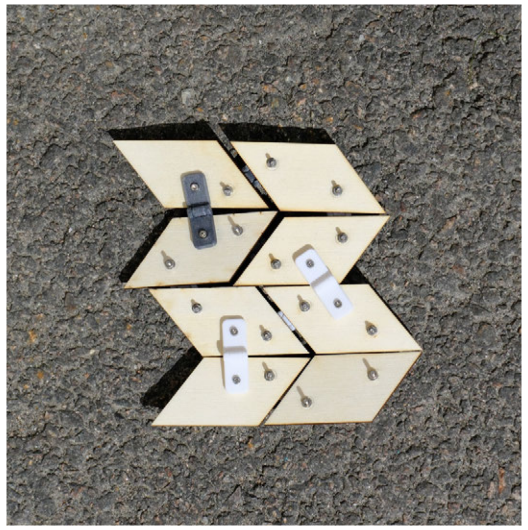
c) Packaged mode

Figure 27. Yoshimura pattern, physical fold behaviour.



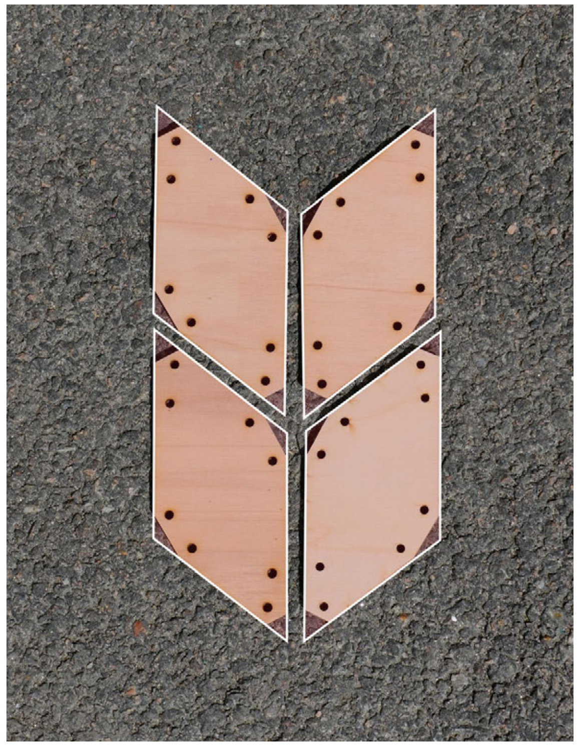
a) Flat mode

b).Deployed mode



c). By only being fastened with one bolt on each side of the hinge, the prototype glides along the edge

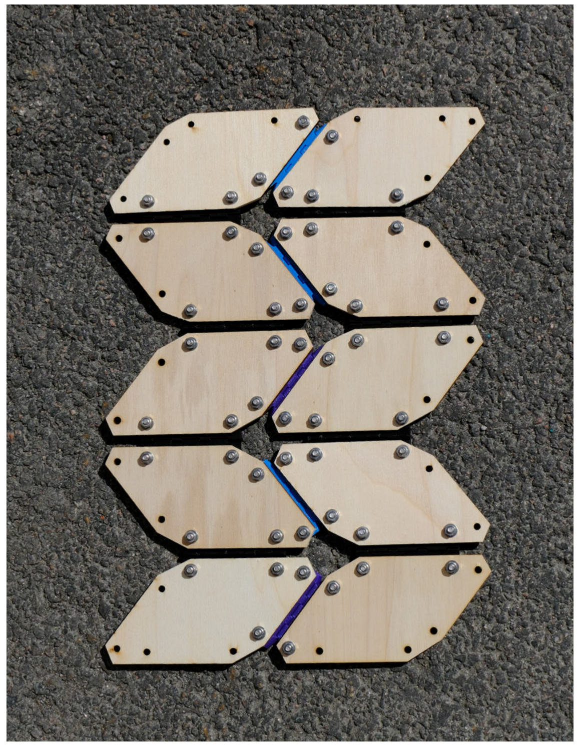
Figure 28. Early prototype to investigate the edge hinges



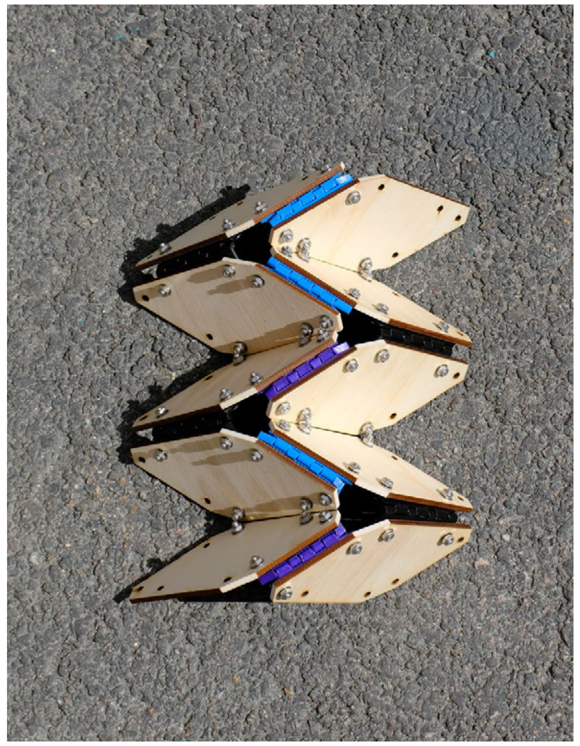
a) Material around the vertices had to be reduced.

b) Hinges (blue) had to be adjusted to fit around the

Figure 29. Example of tolerance issues.



a) Flat mode

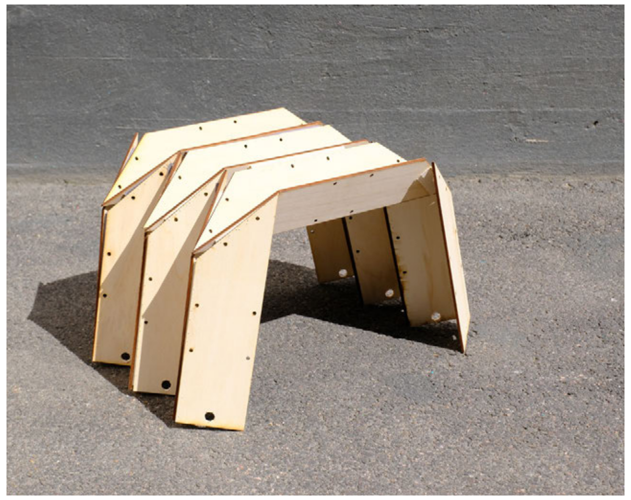


b) Deployed mode

Figure 30. A prototype investigating edge hinge tolerance that show the bolt collision.

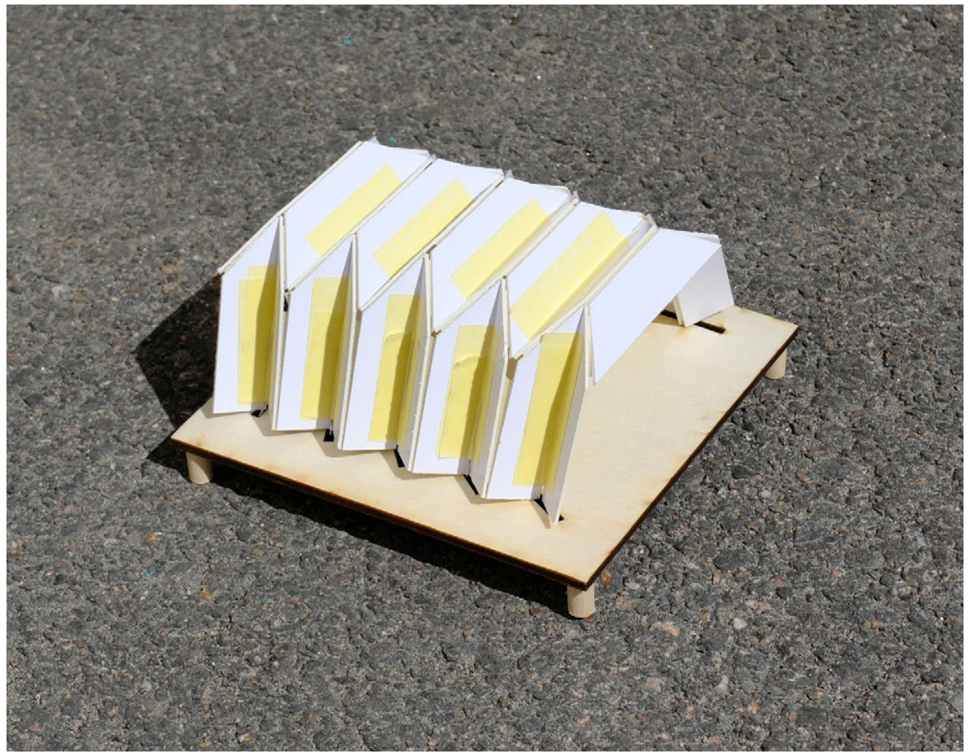
a) Flat mode

b) Deployed mode

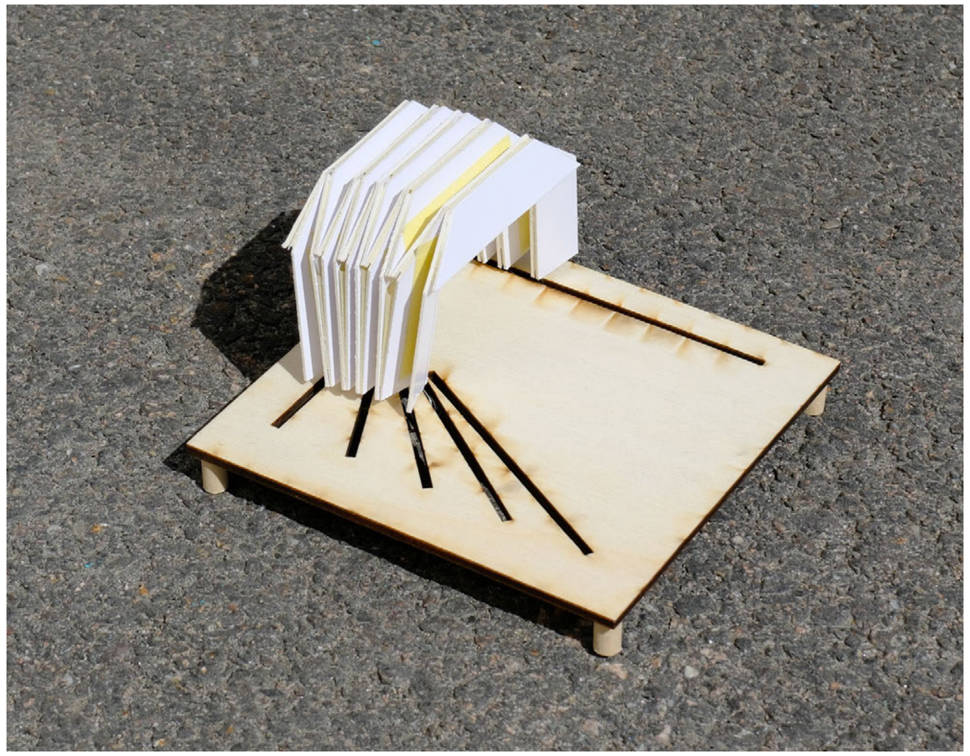


c) Packaged mode

Figure 31. Prototype for investigating the installation process, where hinges are textile stripes



a) Deployed mode



b) Packaged mode

Figure 32. Prototype for confirm the rail system from the digital simulation.

5.7 Contextualising the design

A site was chosen for the design to be able to be contextualised on, giving spatial properties and existing conditions to relate the design towards.
The site located next to the north side of the river in Gothenburg, a former site left from the old shipyard industry that is currently partly functions as a parking area, serving the nearby buildings. The site consists of a is a flat approximately 10 000 sqm rectangular area with surface out of asphalt and gravel and enclosed by fences. The city is planning to build a pedestrian and bike bridge that starts from this site, stretching over to the south side of the city, with the goals of creating more connections over the river and is expected to be constructed by 2033 (Göteborgs Stad, n.d).

Qualities derived from the site reveals there are potentials in transforming this area and make it accessible to the public. The construction of the bridge could potentially make this an important connecting site in the city. The open space give great access to direct sunlight since there are no surrounding building or topography shadowing the place. The flat topography also response well from an accessibility perspective. Then the proximity to the river adds multiple values to the qualities of the space. Surrounding buildings also adds value for the place to become a safety point where a sport hall and hotel could act as an infrastructure for handling emergency accommodation.

On the other hand, the site's closeness to the river and the low topography opposes a threat towards flooding and threat for erosion. From this perspective, the ground conditions on the site are not optimal, especially since the ground sits on filled ground on marshland. This thesis speculates that due the construction for the planned bridge it could be motivated that this nearby site also invests in stabilizing its ground conditions. From the design metrics in chapter 4.4 metrics can now be contextualized as seen below in table 2.

Table 2. Metric based on the size of the site.

	Highlighted design metric	
	Area // days	10 000m2 // 14 days
Disaster	Indoor temperature: 15-19 C° Capacity: 5m2/person Toilets: 1 per 20 persons 1 per 10 children Water needs: 5 litre/person/day Storage integrations: 0,025 m3/ person 3 days	Indoor temperature: 15-19 C° Capacity: 2000 persons Toilets: 100 toilets Water needs: 140 m3 Storage integrations: 233 m3
Everyday life	Indoor temperature: 18-24 C° Capacity: 35 m2/person Toilets: 1 per 50 persons 1 per 20 children	Indoor temperature: 18-24 C° Capacity: 300 persons toilets: 6 toilets

Figure 33. The site seen from the north with views of the river and siluette of the other side.

Figure 34. Traces from the old harbour area and the rail system.

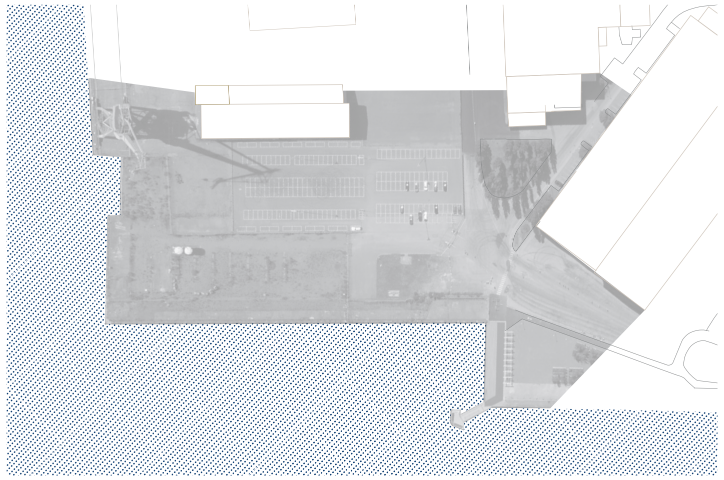


Figure 35. The site today.

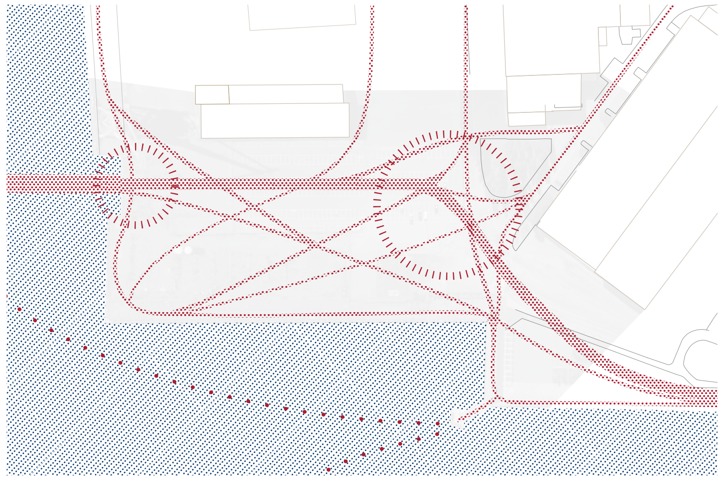


Figure 36. The new flows and connecting points

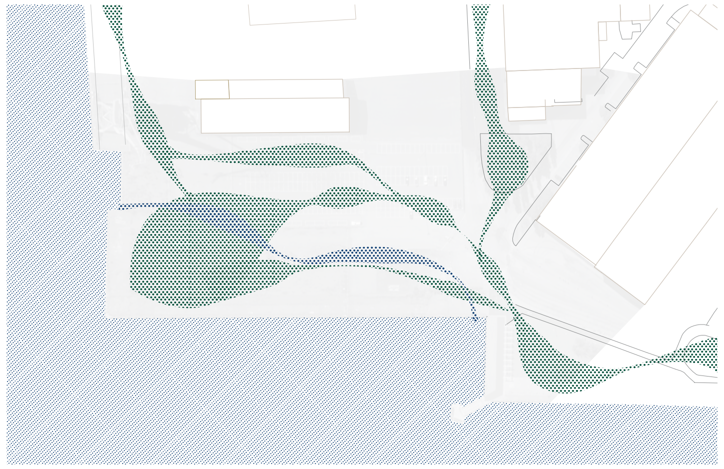


Figure 37. The new green and blue links.

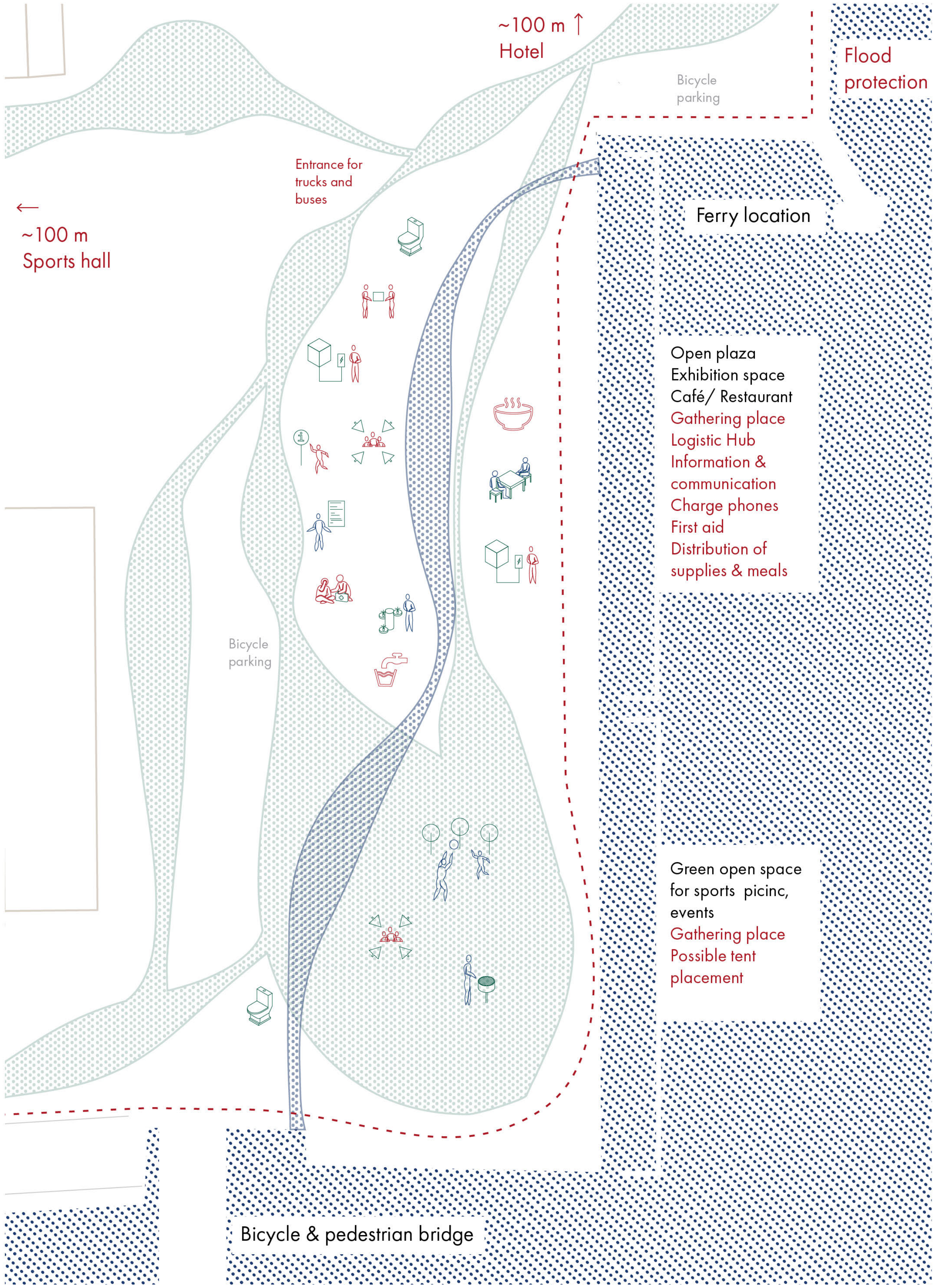


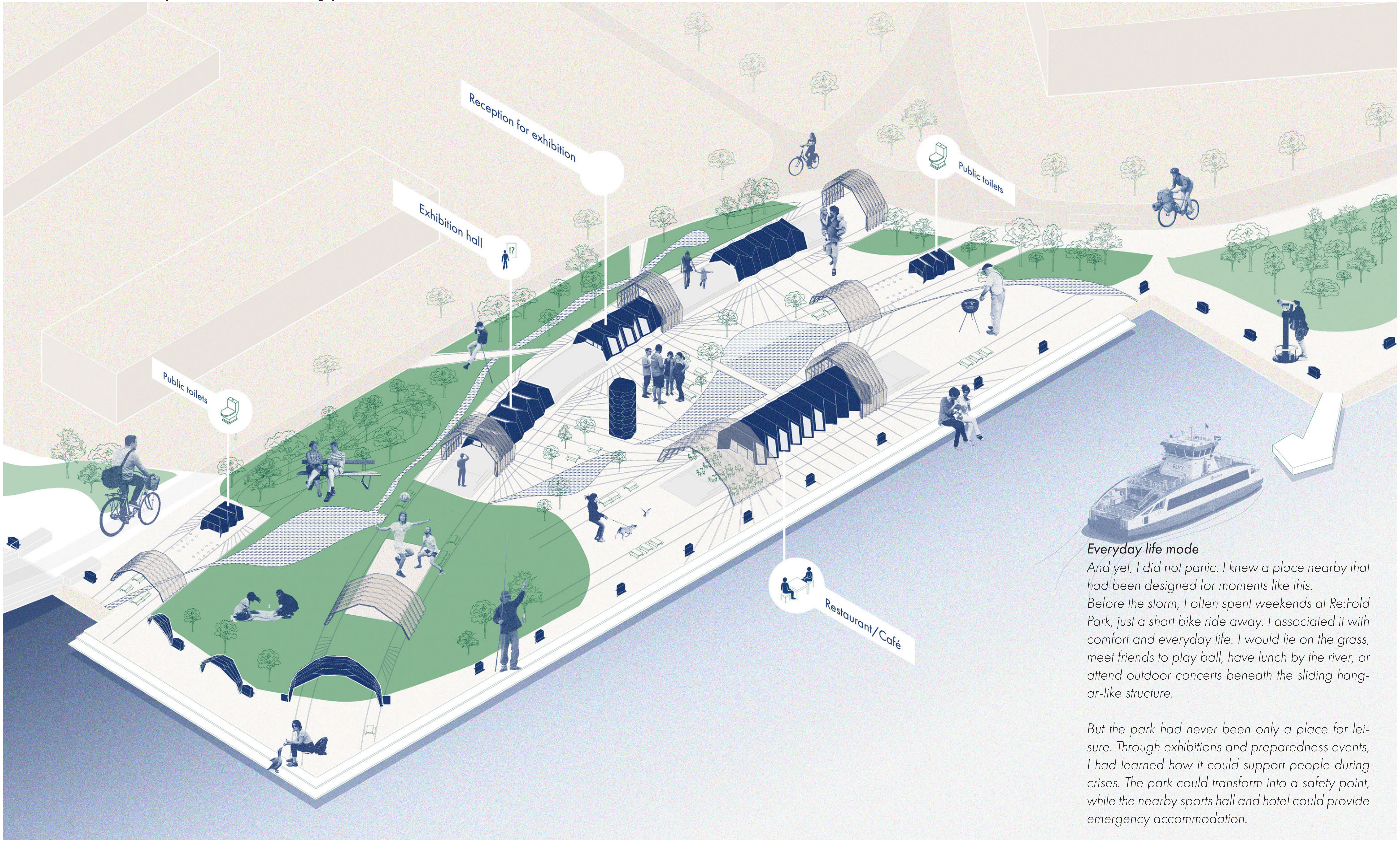
Figure 38. Placement of the functions on site.

Re:Fold park - Design implementation

Six days had passed since the storm hit Gothenburg. *Strong winds had brought down trees, injured people, and blocked roads, stopping both commuters and deliveries. Heavy rain had overwhelmed the pipe networks, flooding streets and disrupting the sewage system. Since then, I had not been able to use the toilet normally, and the drinking water had become contaminated. The power was still out, and society was focusing only on the most urgent problems. I had managed to stretch my own supplies longer than expected, but now my food and water were almost gone. My phone was dead, and I could not contact my family or friends. With no news, no signal, and no clear answers, the uncertainty was becoming exhausting.*

Re:Fold park - Design implementation

6.1 From a notebook by a resident in Gothenburg, year: unknown



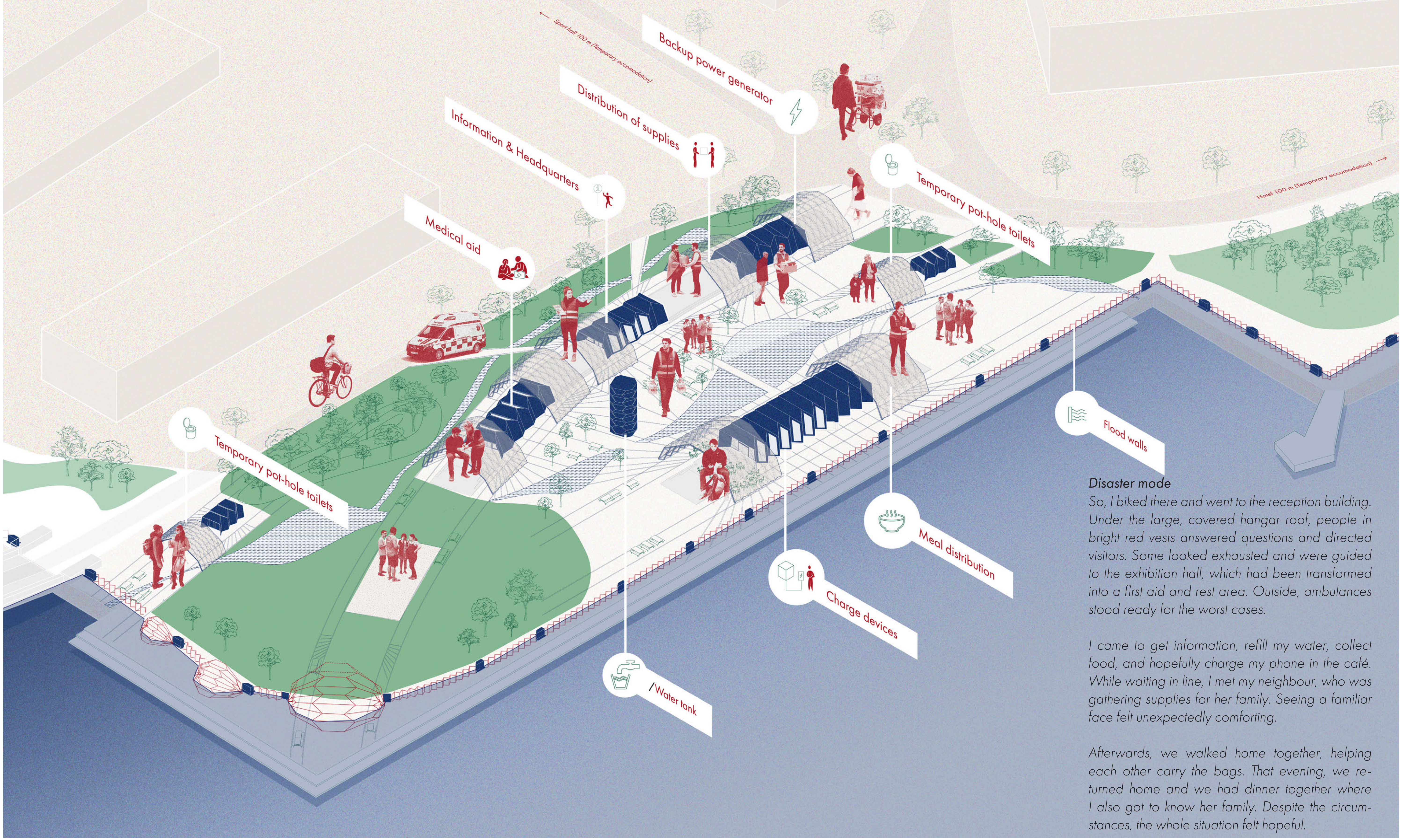
Everyday life mode

And yet, I did not panic. I knew a place nearby that had been designed for moments like this. Before the storm, I often spent weekends at Re:Fold Park, just a short bike ride away. I associated it with comfort and everyday life. I would lie on the grass, meet friends to play ball, have lunch by the river, or attend outdoor concerts beneath the sliding hangar-like structure.

But the park had never been only a place for leisure. Through exhibitions and preparedness events, I had learned how it could support people during crises. The park could transform into a safety point, while the nearby sports hall and hotel could provide emergency accommodation.

Figure 39. Re:Fold park, Everyday life configuration

Re:Fold park - Design implementation



Disaster mode

So, I biked there and went to the reception building. Under the large, covered hangar roof, people in bright red vests answered questions and directed visitors. Some looked exhausted and were guided to the exhibition hall, which had been transformed into a first aid and rest area. Outside, ambulances stood ready for the worst cases.

I came to get information, refill my water, collect food, and hopefully charge my phone in the café. While waiting in line, I met my neighbour, who was gathering supplies for her family. Seeing a familiar face felt unexpectedly comforting.

Afterwards, we walked home together, helping each other carry the bags. That evening, we returned home and we had dinner together where I also got to know her family. Despite the circumstances, the whole situation felt hopeful.

Figure 40 Re:Fold Park, Disaster configuration

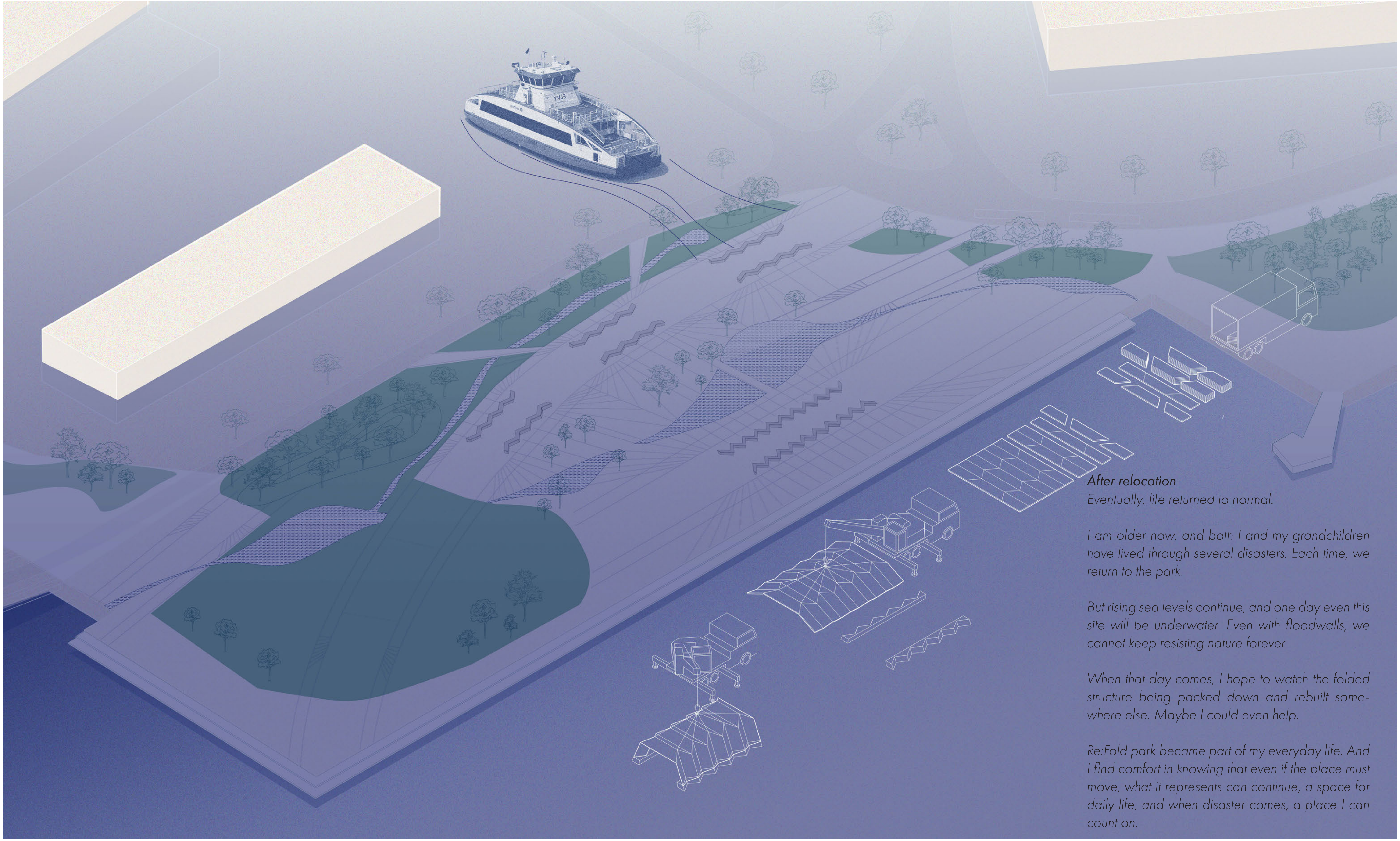
Before installation

I also remembered the site before the buildings and structures were installed—back when sea levels were low enough for this location to exist as it was. As a child, I used to play there, running along the zigzag foundations while my parents sat on them like benches. Back then, I didn't understand the logic behind the gutters or how the site had been prepared to manage water.

Now, watching the temporary roof shift and expand, I understood. What once felt like play and ordinary life had always been part of a larger system of preparedness.

Figure 41. Re:Fold park, Before installations of semi-permanent buildings.

Re:Fold park - Design implementation



After relocation

Eventually, life returned to normal.

I am older now, and both I and my grandchildren have lived through several disasters. Each time, we return to the park.

But rising sea levels continue, and one day even this site will be underwater. Even with floodwalls, we cannot keep resisting nature forever.

When that day comes, I hope to watch the folded structure being packed down and rebuilt somewhere else. Maybe I could even help.

Re:Fold park became part of my everyday life. And I find comfort in knowing that even if the place must move, what it represents can continue, a space for daily life, and when disaster comes, a place I can count on.

Figure 42. Re:Fold park, Disassemble and relocation of the elements due to sea level rise.

Re:Fold park - Design implementation

6.2 System

Re:Fold park is the result of integrating everyday urban life with disaster preparedness.

Next to the Göta Älv, visitors can enjoy views over the city and use the public park and open plazas freely. The site offers public toilets, drinking water, outdoor seating, as well as a café/restaurant and spaces for exhibitions and events. At the same time, under municipal management, the site also functions as a temporary safety point that can support individuals during crisis that disrupt normal societal functions. Here, there is to access reliable information, essential supplies and temporary support when needed.

The indoor spaces use the structure of the Muira-ori pattern, which is made to be installed on specific foundations and to be dismantled and raised elsewhere, see chapter Structure. The buildings have entrances mainly on the short sides and windows are placed to fit the functions of each facility. For instance, the exhibitions space with its roof windows creates a suitable space for exhibitions while also a private atmosphere for medical aid services. This also creates a spatial contrast to the more open environments, the reception and restaurant, where a connection to the surroundings is enhanced and connects with its public functions. Overall, the indoor spaces consist of rooms with flexible furnishments, allowing quick adaptation to the different needs.

Deployable roofs are installed on the site with similar Miura-ori pattern as the modules made for the buildings, the difference is that an additional V-pattern is added. The shape is closer of an arch such as the Yoshimura pattern produces and more like an arch-like cross section, each fold of in the cross section reduces the stress of the structure, see chapter 5.3. The flexible roofs are grounded on rails which allow the roof to be moved along the site while also following the deployment direction for the roof, allowing it to expand and retract. The roof offer protection from the weather but also creates new spatial rooms both between the other building but also outside the buildings. Other than this the roof is acting as entrance markings.

The site is also protected from flooding by deployable flood walls, using both the rigid plate structure and the Muira pattern structure. A long the flood line wall there are storage elements installed which have a dual use, acting both as a storage for the flood wall, protecting it from weather forces, while also providing seating on the outside. Three flood walls differ from the other. They are the flood arches and uses the same Miura pattern as the temporary roofs but, instead of extending biaxially over an area, these arches angularly around its pivots towards the ground. The architectural result is 45 degrees dome segment that can also be used for sheltered outdoor spaces or, when standing up, creates unique landmarks.

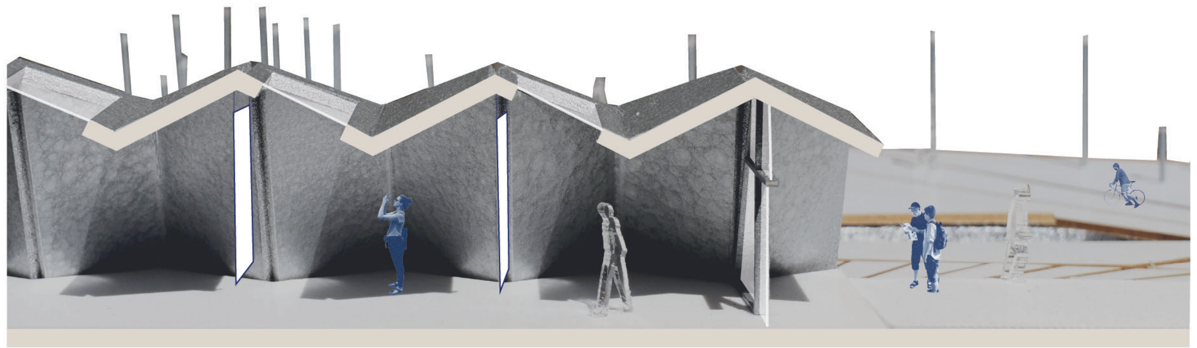


Figure 43. Section of the exhibition

Figure 44. Section of the headquarter.

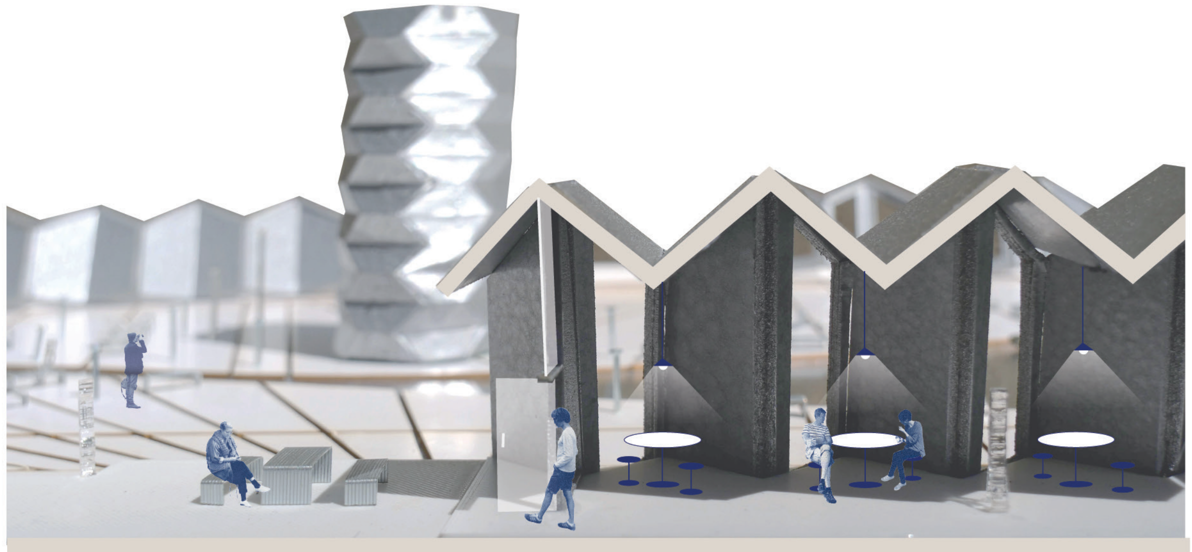


Figure 45. Section of the restaurant

Restaurant and Cafe / Meal distribution + Indoor gathering + Charge devices

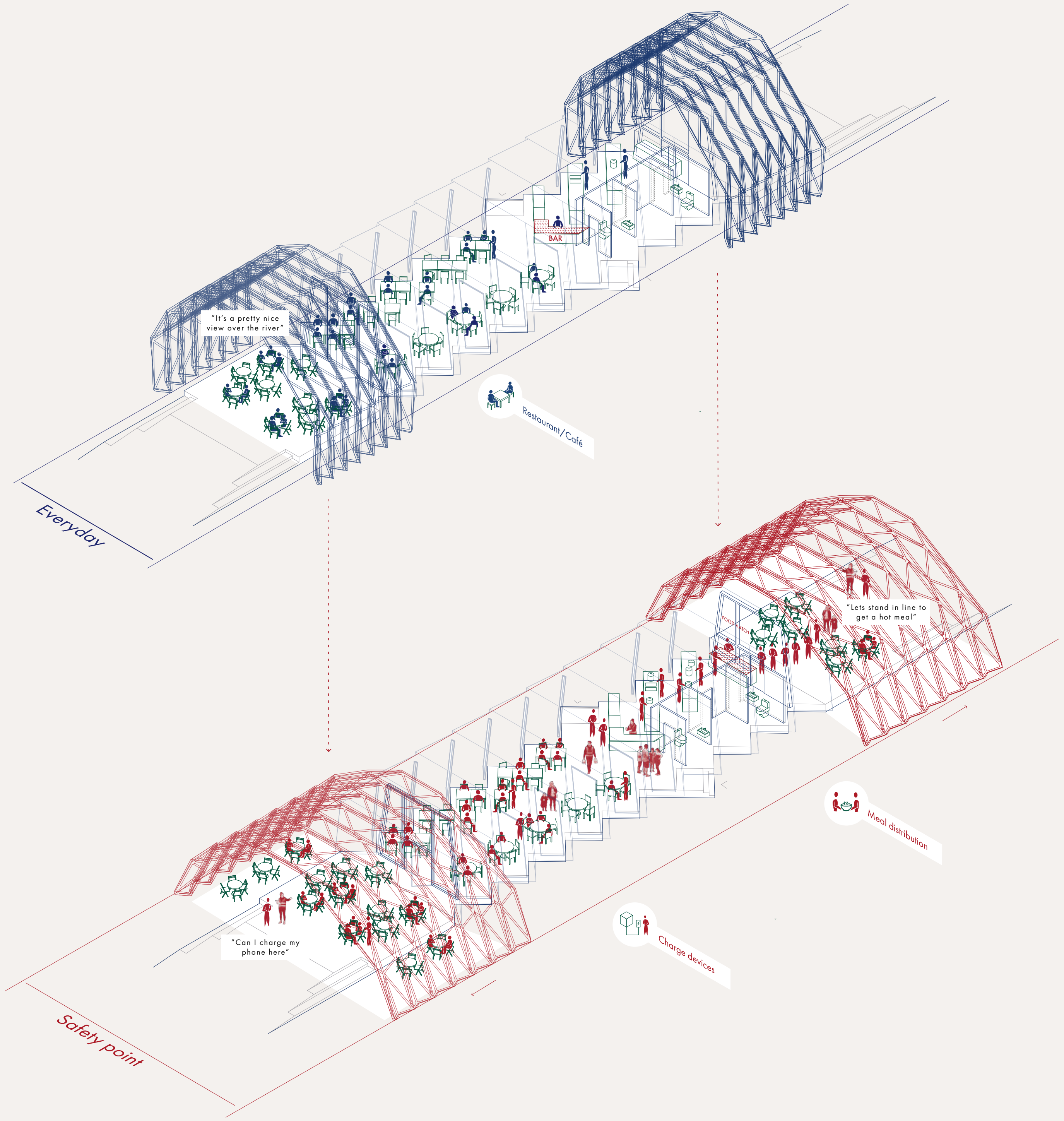


Figure 46. Conceptual idea of the dual use elements for the restau-rant/ Meal distribution building

Exhibition space/ Medical Aid

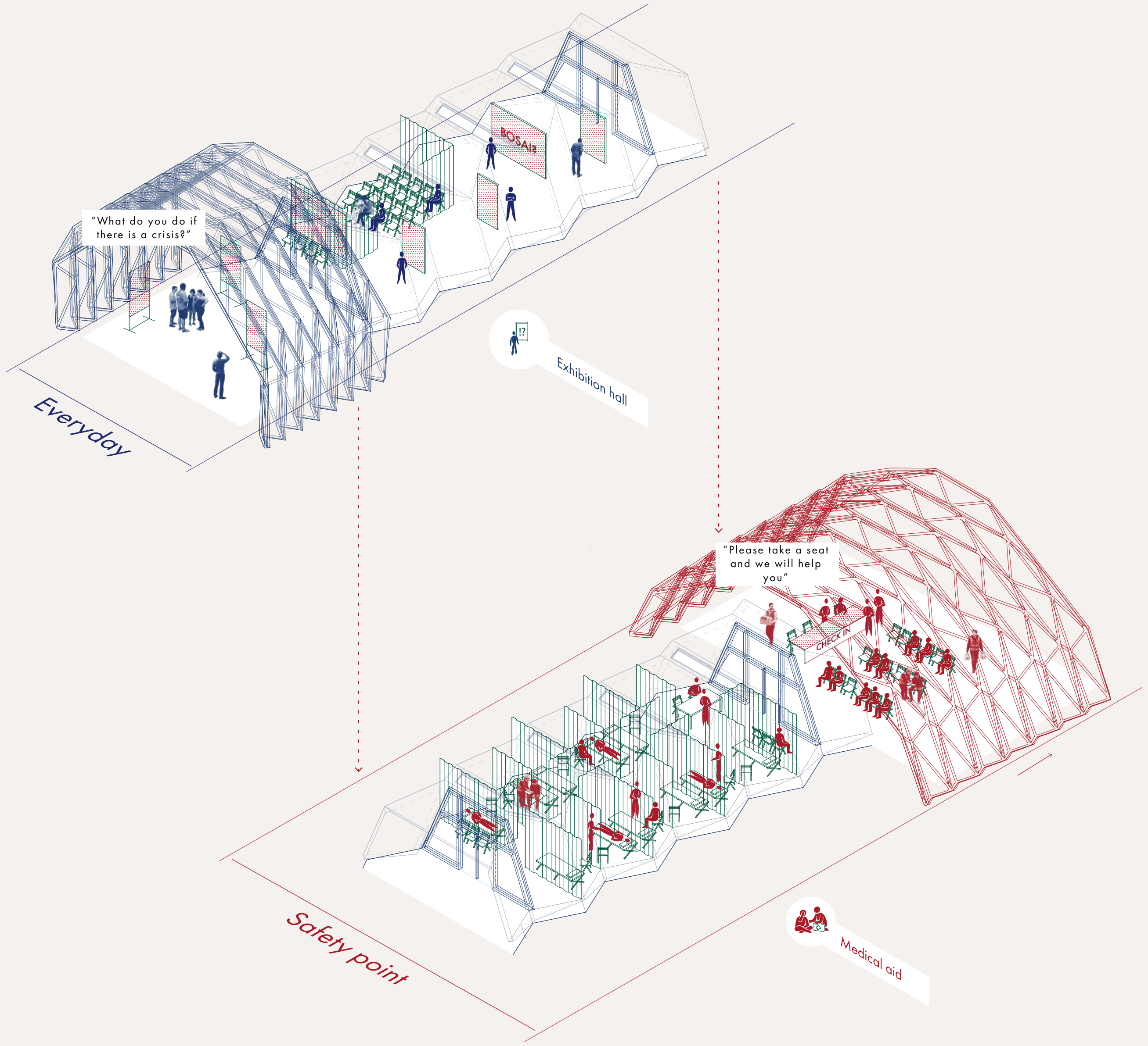


Figure 47. Conceptual idea of the dual use elements for the exhibition / Medical Aid building

Storage of supplies/ Distribution of supplies

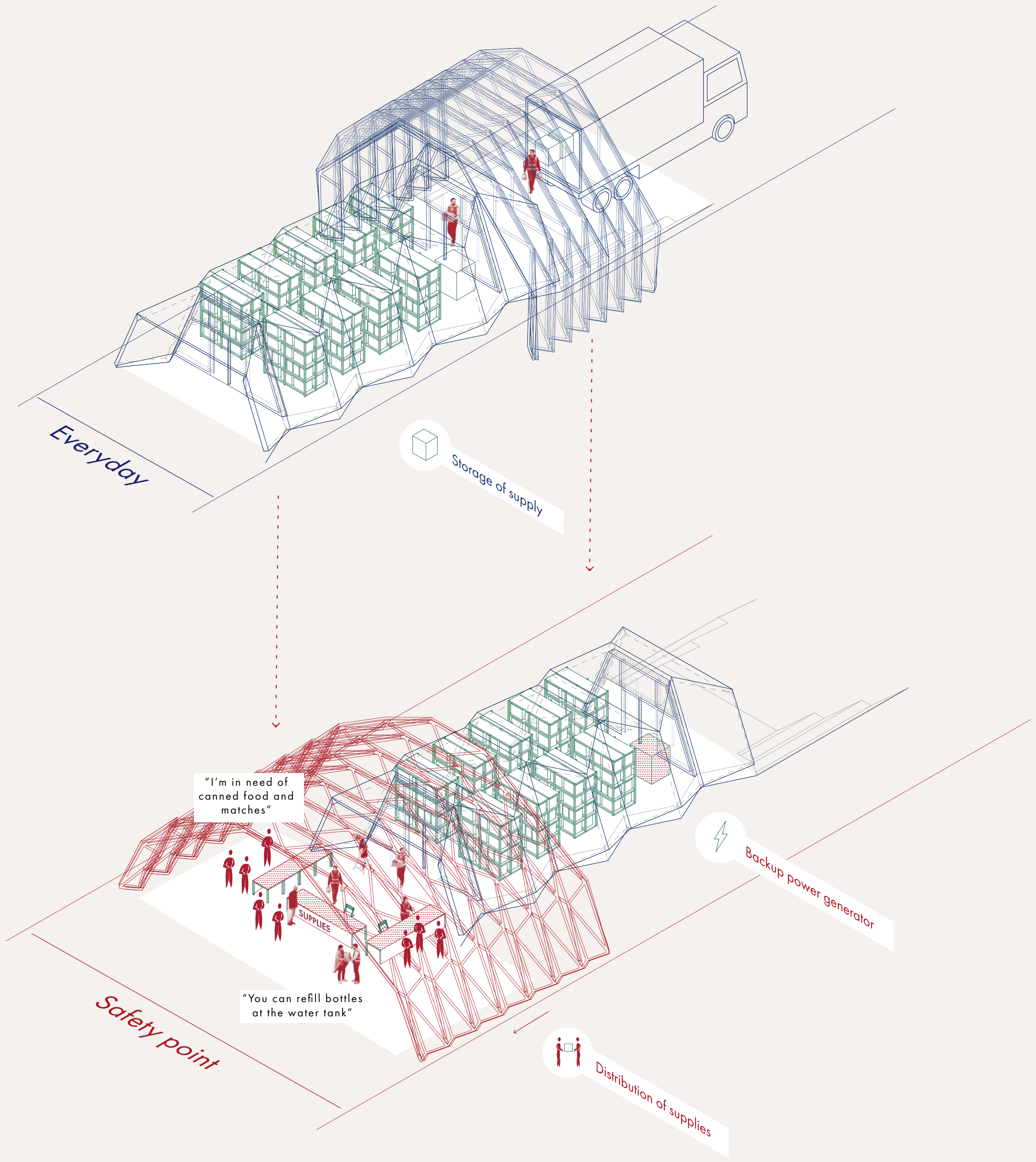


Figure 48 . Conceptual idea of the dual use elements for the Storage of supplies/ Distribution of supplies building

Public toilets/ Temporary pot-holes toilets

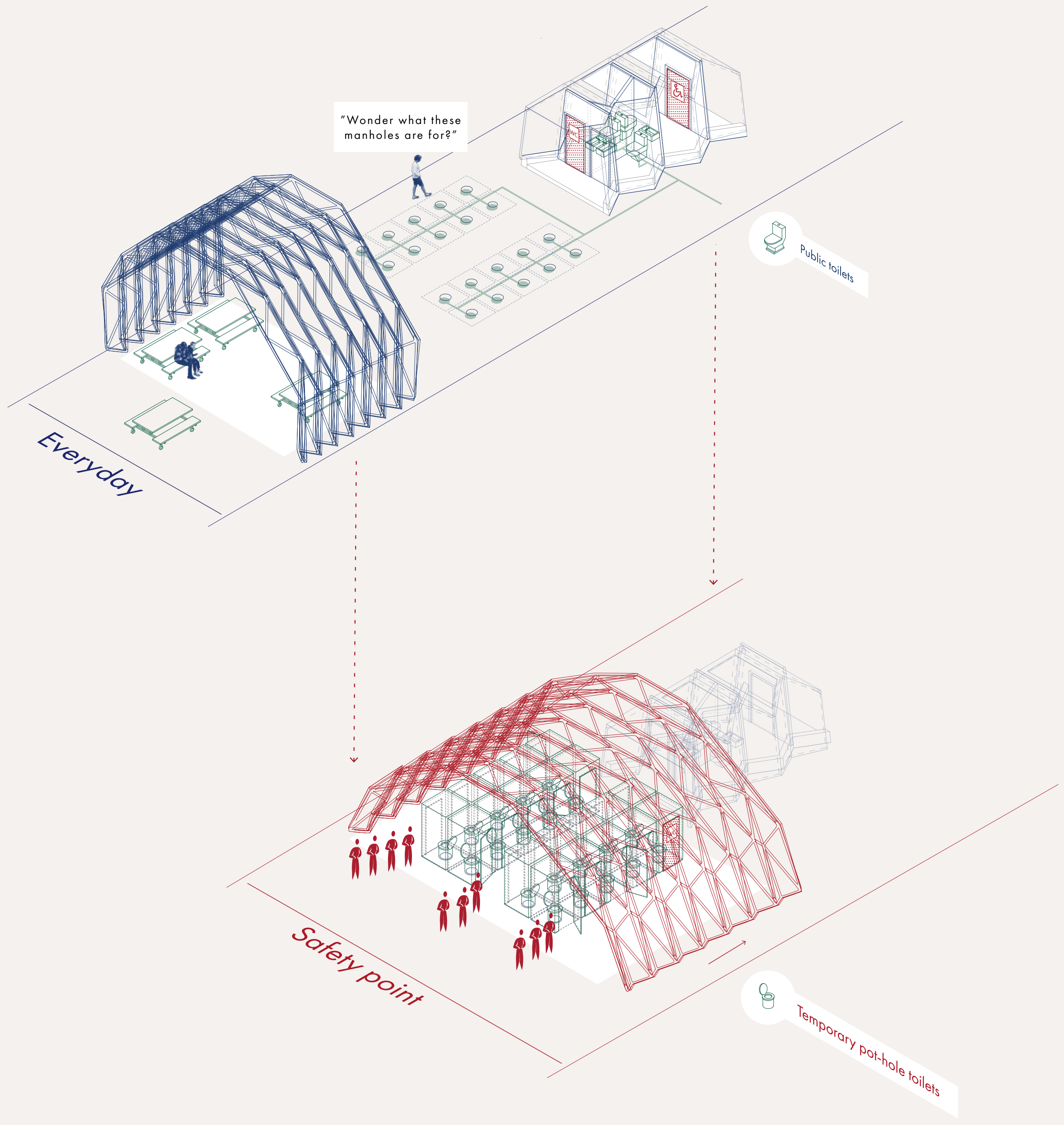


Figure 49 . Conceptual idea of the dual use elements for the pubic toilets/ Temporary pot-holes toilets

Reception/ Information and logistic hub

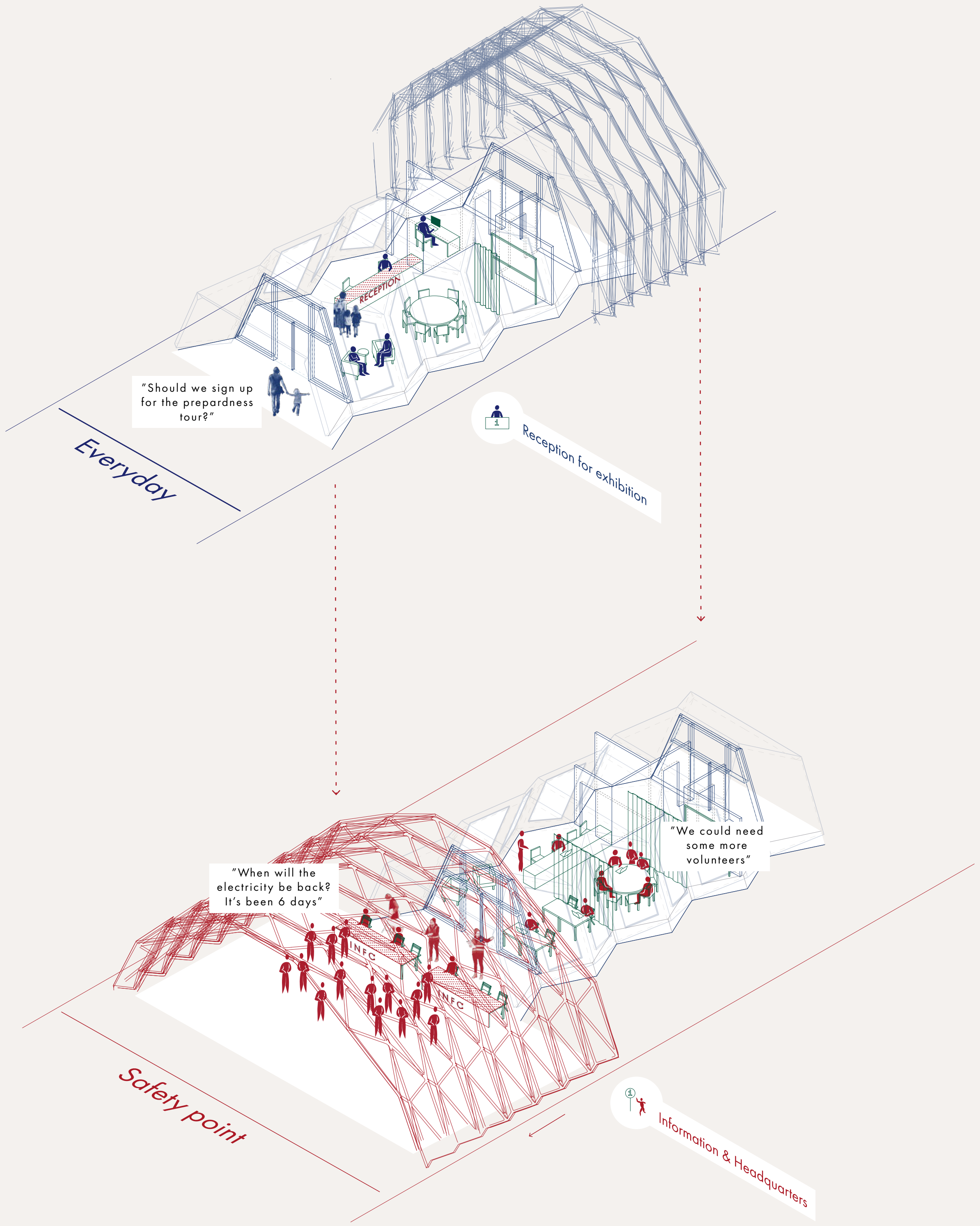


Figure 50 . Conceptual idea of the dual use elements for the reception / Information and logistic hub building

Benches/ Flood walls

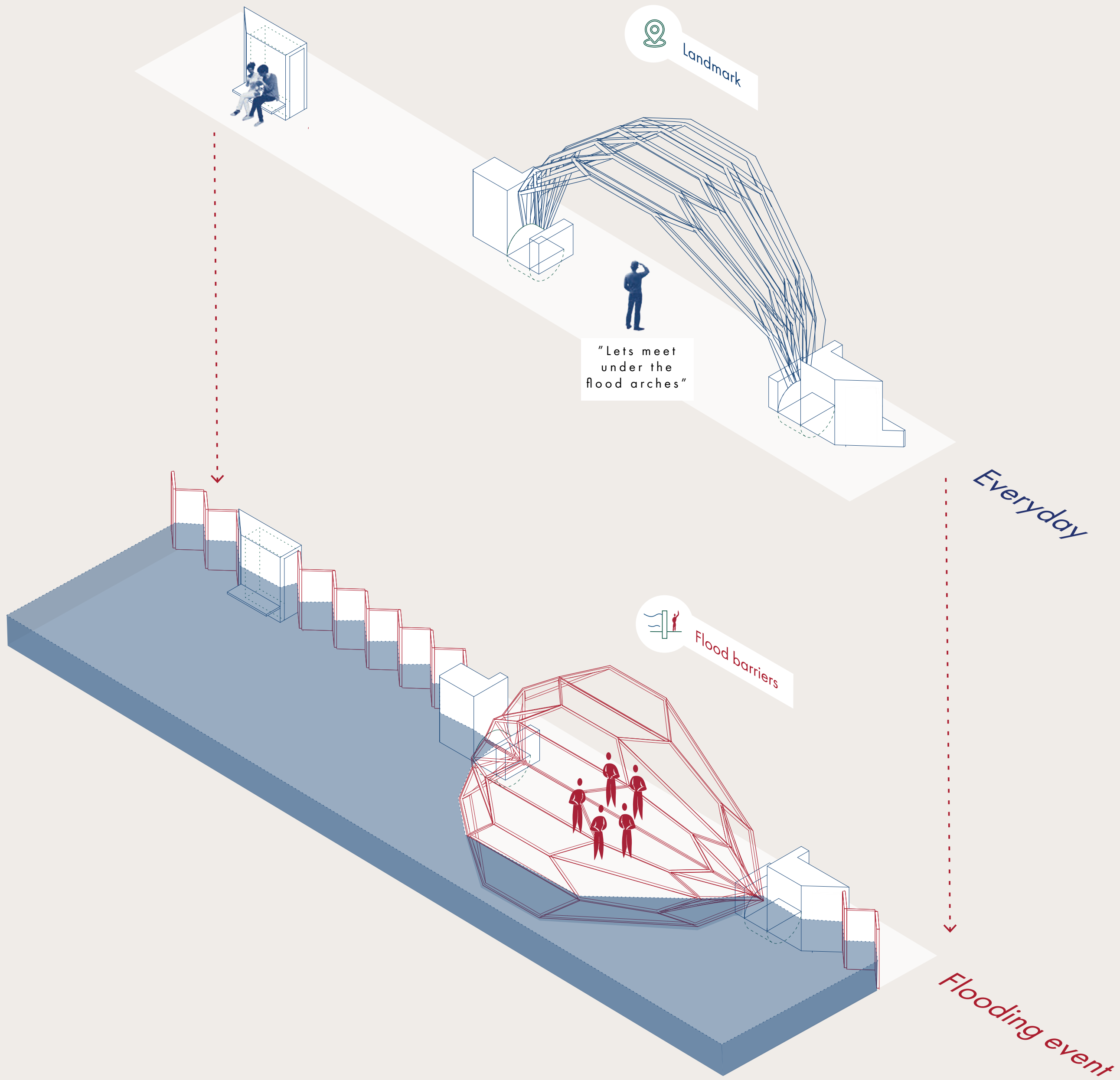


Figure 51 . Conceptual idea of the dual use elements for the benches / flood barriers

6.3 Temporary roof deployment model

Figure 52 . Packaged mode

Figure 53 . Deployment process

Figure 54 . Deployed mode

Re:Fold park - Design implementation

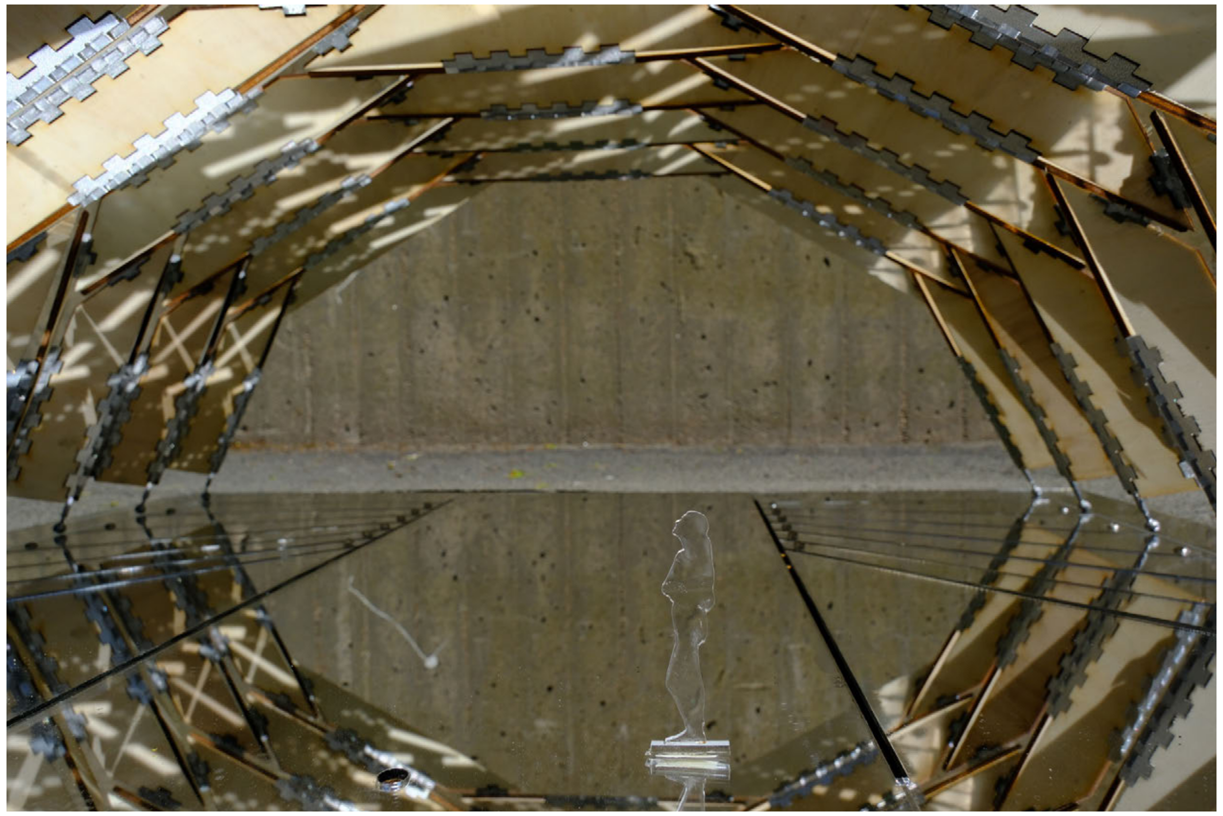


Figure 55 . Interior perspective of model

A final temporary roof deployment model was created to further challenge the scale, structural behaviour, and mechanism of the deployable system. The panels were laser cut, while the hinges were 3D-printed. The model can successfully transition back and forth between its packaged and deployed modes, as shown in Figures 52–54, while the architectural spatial result can be seen in Figure 56 and in Appendix B.

As stated in Chapter 5.3, the additional folds in the cross-sections allow the structure to span further by increasing its geometric depth and stiffness. This makes the roof not only a technical deployment system, but also an architectural element with spatial and experiential qualities. The temporary roof therefore has the potential to also define a clear architectural atmosphere, rather than simply acting as a protective canopy.

The physical model once again demonstrated that the mechanism works and that the system could potentially be scaled up even further. It also showed how the relationship between structure, movement, and spatial expression is central to the thesis.

6.4 Installation and disassembly process

The permanent buildings are based on the Miura-ori folding seen in figure 24c) and are designed in a way to promote easy installation. The size is regulated so the biggest size of a panels still can be stored and transported in a truck. The idea is to transport the panels to the site where they are arranged flat on the ground.

Then all edge joints are installed on the upper side of the panels. To reduce the weight of the wall components and at the same time provide a sufficient indoor climate the wall consists of a structural aluminium frame with PIR insulation with indoor cladding.

The next step is to lift the whole structure on the mountain folds of the roof to allow the fold behaviour of the structure. The crane lifts the structure to the foundation where it is installed and the latching element get attached to the building to lock it in this state. An final outer layer of insulation and façade panels are installed to prevent the cold bridges between the hinges along the folding lines.

Dismantlable latching elements are used to lock the structure in place. With that the whole building can be dismantled by reversing the installation process. The latching elements are visible and take up space which are intentionally design. It tells a story about how it can be dismantled by making the bolts visible. Explaining to the visitor that while this building is rigid it can still move when needed. An illustration of the process can be seen in figure 56.

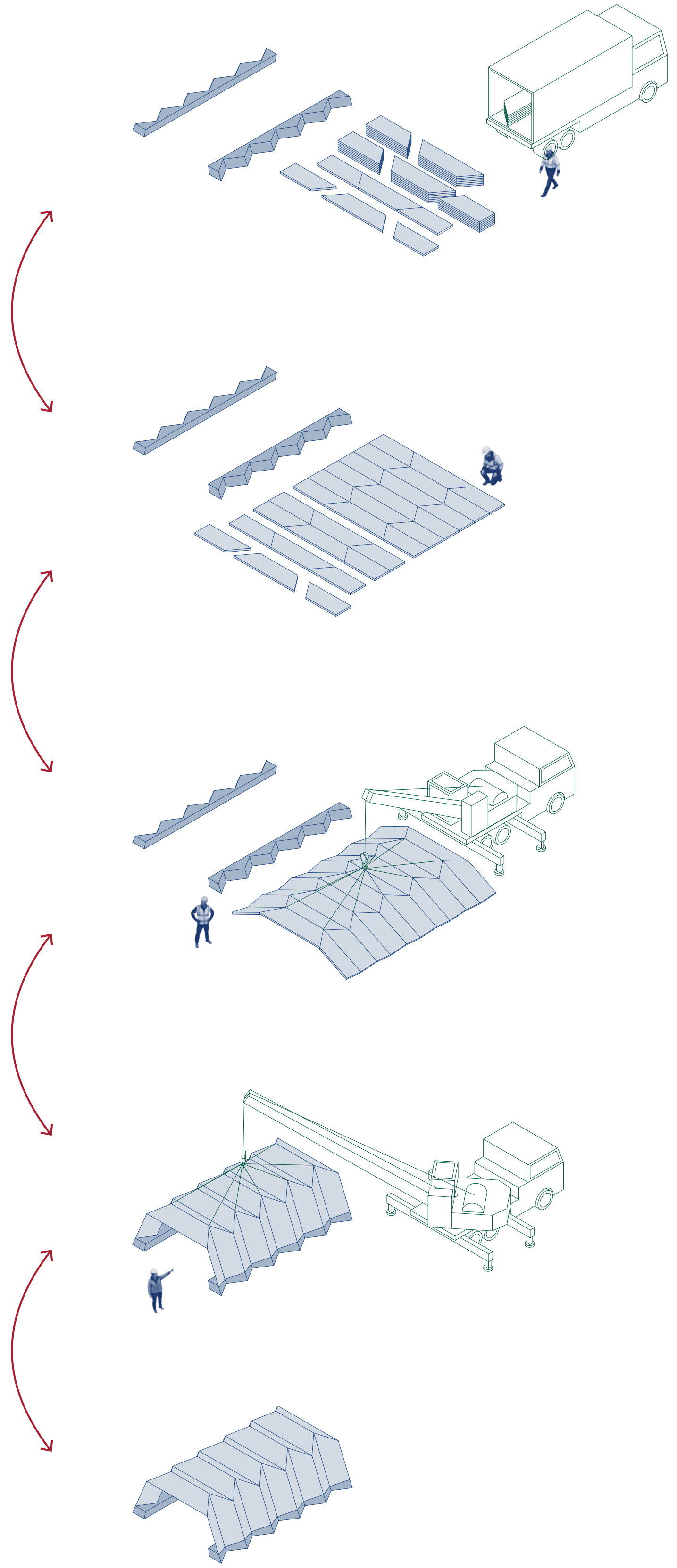


Figure 56 . Illustration of installation and disassembly process.

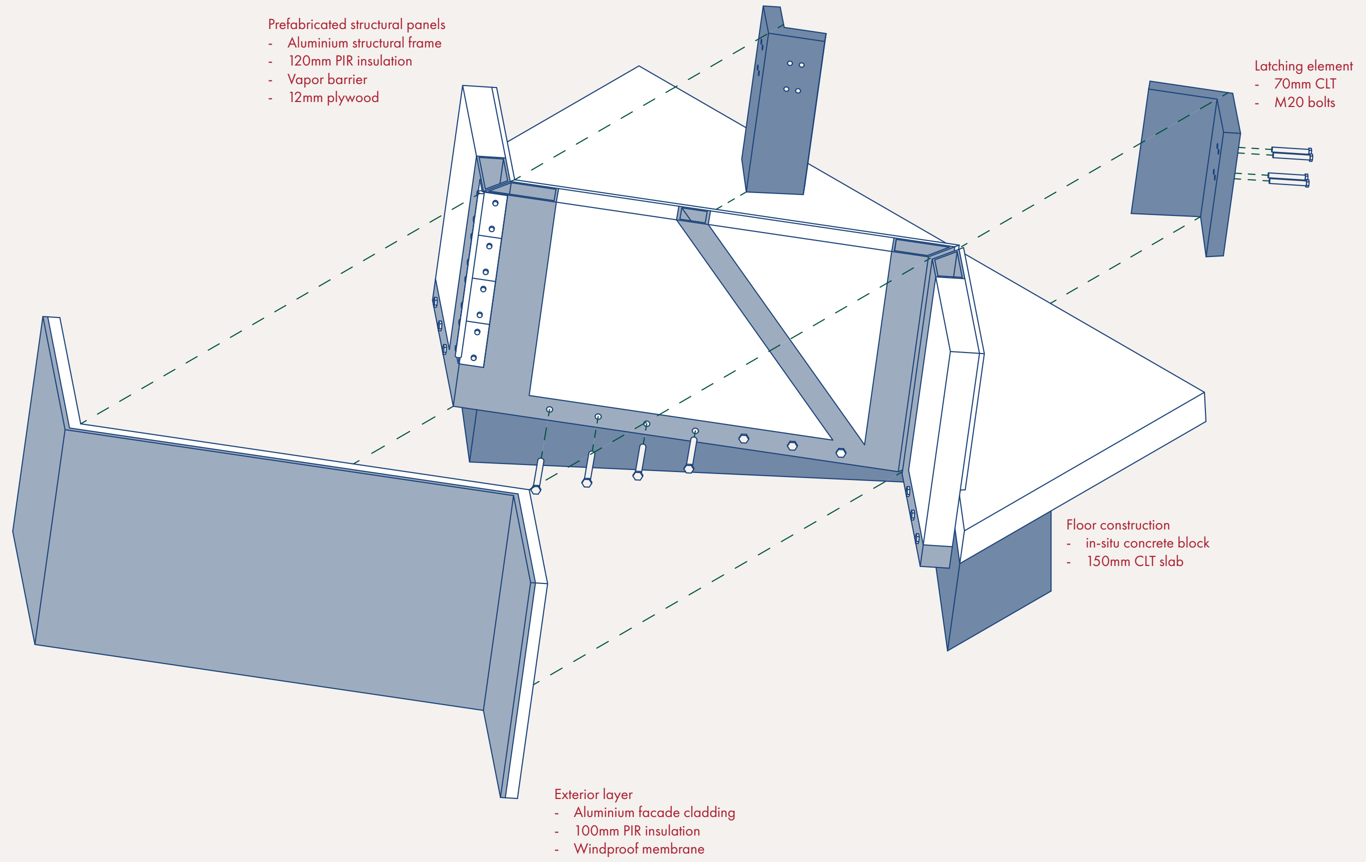


Figure 57 . Illustration of wall to foundation connection detail

Foundation is part of the permanent strategies where the idea is to cast the foundation for the permanent buildings beforehand. When not in use as structural foundation it will act as benches offering seating areas in the park. When the site shift modes the foundation will remove its bench material and be used as a structural foundation where the prefabricated panels are installed into the sides of foundation. Similar principles where the wall segments are installed on the side of the ground foundation is used on the St Loup Chapel in Pompaples, however they instead install the wall on a timber bearing plate that lay on top of a concrete block (2010).

Discussion & Conclusion

7.1 Discussion

How can an adaptive public shelter, for everyday life and disaster events, be designed through temporary and permanent architectural theories?

This proposal showcases an example of how a public shelter, for everyday life and disaster events, could be designed through temporary and permanent architectural theories.

Referring to chapter x, the project touches the aspects in different ways. Institutional permanence and temporality, which are mostly controlled by regulation and laws controlled by the municipality or the government, tend to restrict innovative and experimental architecture. Through the speculative nature of the thesis, it challenges the regulations of permanent buildings to also have the temporary properties of being designed for disassembly. On the other hand, we as architect have more power regarding the other three aspects, which explains the focus on the cultural, functional, and technical permanence and temporality.

The design has handled the cultural aspect for both permanent and temporary architecture in a similar way. The idea is to create a place with identity that can provide a rememberable experience to the visitor, in both the long term, slow nomad movement and short term, transformer cycle (see chapter concept for the safe place/ the shelter"). Through permanent functions such as open recreational areas, restaurant and exhibition space, the design wants to satisfy the long-term experience through recreational memories, social meetings and intellectual stimulation. While the short-term experience is expressed mainly through disaster situation, when the functions for the whole site changes, it could also include non-disaster temporary public events such as fairs or festivals etc. Events like this are encouraged and should be organized by the municipalities or third parties and increase the place to form a strong and meaningful relationship to the public. On the other hand, there is a risk that the design would be criticized due to its abnormal appearance and high cost that is a consequence of a unique structure. If that would be the case, the design could have a very short life span and fail its goal to stay relevant through centuries. However, only time can tell what will happen and the public need to be able to interact with the site to truly know what kind of relationships that could be made. As architect we can "only" try to create spaces that supports these activity and interaction. Further development of the project could be to invite the public to discuss its potential and weakness.

The Functional permanence and temporality have also worked closely together in the design. Flexible layouts inside the buildings and adaptive outdoor space provide different long-term layouts which focuses on the everyday life and disaster life. The temporary functions from disaster situations have influenced the everyday, both for the long-term needs but also short term. For instance, the temporary and flexible roof structure with its rail system allow for a wide number of outdoor configurations and, together with the temporary toilettes, it could meet needs for temporary larger masses and events. The concept of dual-purpose makes the design relevant through several scenarios and since this was an early design choice, it influenced the overall layout and guided the design towards an unexpected path that otherwise likely would not be considered.

Even though the technical aspect for permanent and temporary architecture lies on the opposite spectrum, see chapter 4.3, they have successfully been combined through the choice of material and structural system. Technical permanence is applied to the ground and foundation, by using concrete foundations that will stay in place for several scenarios. Technical temporality is applied by designing the semi-permanent panels to be light weight solution which allows easy installation and disassembly. One can question the material choice and argue that a more sustainable material such as wood could have been used. However, the other purposes must be considered. For example, CLT would have been incredible heavy compared to the aluminium frame, which would have complicated the installation, especially when the panels transition between the flat installation and the folded state, see figure 31. The light weight also makes it possible to reduce the use of heavy machinery. Durability is of importance as well, considering conditions the design is supposed to withstand. Because of the complex time scenarios, which asked for both flexible structures and more permanent buildings, it was not possible to only use technical permanence or temporality, but a combination.

How can speculative scenario thinking regarding future climate influence the architectural requirements for a public space?

Through speculative scenario thinking, this research challenges the building norms. By introducing speculative scenarios for future climate disasters, the design proposal suddenly needs to satisfy a new range of design criteria that would not normally be a part of the brief. In this case it was speculated that the increased climate disasters would come in cycles, augmenting for the functions on the site to shift. Additionally, the longer-term scenario showcased a proposed nomad-structure due to the rising sea level. Speculative scenario planning creates a new world where architecture can act upon and adds another way of how it can relate to a shifting climate and uncertain futures.

A disadvantage of the speculative scenario planning is that it is not possible to know for certain if, when or how the future climate scenarios will take place and how that will affect society. However, as stated previously in chapter 2.1, the main purpose of speculative design is not too necessary solve the issue itself but to instead promote discussion. In this case, how architects when designing could consider the impact of natural disasters and design to mitigate the loss. Other than that, even if the disaster scenarios would not happened, an investment of a public space is highly valuable if

How can structures shifting between different configurations, be designed for a public space?

Regarding on how to shift between configurations this thesis has put the focus on deployable architecture through folded structures. This has affected the design of the proposal immensely. The deployment motion and range affected both the ground and the space between the buildings. The hinges and connection between the plate are critical and much attention was given to those elements. Consequently, the method of using prototypes is essential. Without having both digital and physical prototypes to test the concept it would not have been possible to properly understand the folding motion, panel tolerance, importance of edge joints etc. The prototypes also confirmed the theory from the literature that the edge joints would be a critical detail, see chapter 5.3. Even though it is a time consuming and costly method, prototyping as a method has therefore been proven to be highly effective and essential for the project to create a deeper understanding for its structure.

While this thesis manages to solve how to integrate the joints for a deployable structure, it did not manage, due to time restrictions, to investigate the water tightness in the edges through prototypes in depth and is therefore relevant for future investigations.

Regarding the use of the Muira-ori pattern for the structure and its impact on the architecture, it cannot be ignored how much it has affected the design. The pattern creates architectural qualities through space, light and rhythm. At the same it creates an effective folded structure where the modular structure simplifies repair work and installation. It could be criticized if a folded structure is the most suitable structure for the semi-permanent buildings. The structure is supposed to be manufactured beforehand, but the non-standard panels could be hard to repair or replace if the original manufacture is not available. Addressing the multiple folding lines, complications could appear on each folding line in regards of making it weather tight, which is also relevant for all folded structure in the design.

Another alternative could have been a more traditional beam pillar system which prioritize a DfD approach, Design for Disassembly. This could simplify the process and probably be economical beneficial. However, the building would then lose a lot of it character and coherence to the design concept.

While this thesis puts much focus on foldable structure there still lies great potential in other types of deployable structure that could work in the same context which could be further studied for in future work. Examples could be pneumatic structures that uses a completely different method where a membrane is filled with pressurized air to deploy a structure without any need for other supports.

While this thesis puts much focus on foldable structure there still lies great potential in other types of deployable structure that could work in the same context which could be further studied for in future work. Examples could be pneumatic structures that uses a completely different method where a membrane is filled with pressurized air to deploy a structure without any need for other supports.

Figure 58 . Exhibition space of the thesis

7.2 Conclusion

From the initial aim of gaining more awareness for how architecture can mitigate the growing threat of climate change, the thesis has connected and mixed multiple ideas and perspective to better grasp this complex subject. There are several approaches for advocating this issue, where this proposal hopes to give at least one new angle or, by presenting itself, further bring up the discussion about the role of architecture in an uncertain future.

The civic purpose in this case, where disaster preparedness was the baseline for architectural design, allowed for a new type of project and typology. Expanding the perspective by using different time horizons through speculative scenario thinking, it brought new layers of aspects which influenced an experimental design process to take place. The outcome, informed by the various inputs, created a design with unique features that otherwise likely would not have been considered.

Speculative design has this opportunity of supporting otherwise time consuming and costly design activities and invent new type of projects instead of waiting for commission. It allows designer to push and test the limits of what architecture could bring to the table without the pressure from industry and its financial incentives. In this particular case, it brought new construction methods that influenced the entire architecture, creating new spatial experiences and even more importantly highlighting the civic purpose of architecture.

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8.2 Figures

All pictures and Illustrations are own by the authors if nothing else is stated.

Figure 3. Cook, P. (2011). Island City [Airbrush and colour pencils on paper]. Gallery Espace. URL: https://galleryespace.com/artwork/island-city/

8.3 AI appendix

Artificial intelligence has been used for following:

- As a tool for finding references
- Creating and adjusting cut-out people for illustrations. Cut-out people from skalgubbar.se have been used for this purpose.
- To find synonyms for words given its context.

The prompted results have been thoroughly revised and verified. Artificial intelligence have not been used to generate text.
Example prompts:

" Give examples of relevant references, literature, articles projects for [insert subject]"

" Change outfit and change pose for this cutout [insert cutout people]"

" What is another word for [insert word] for the context of [insert context]"

Appendix A - Japan study trip

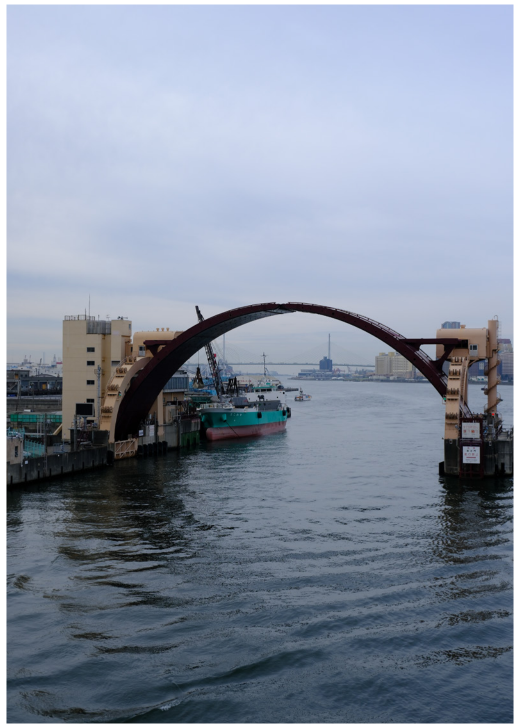


Figure A.1. One of five river sluice gates, Osaka.

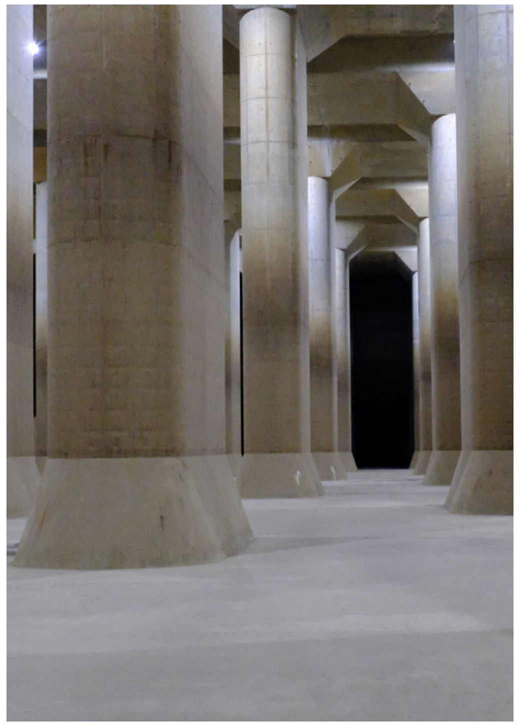


Figure A.2. G-cans, Pressure-controlled tank or "the underground shrine" , Kasukabe.

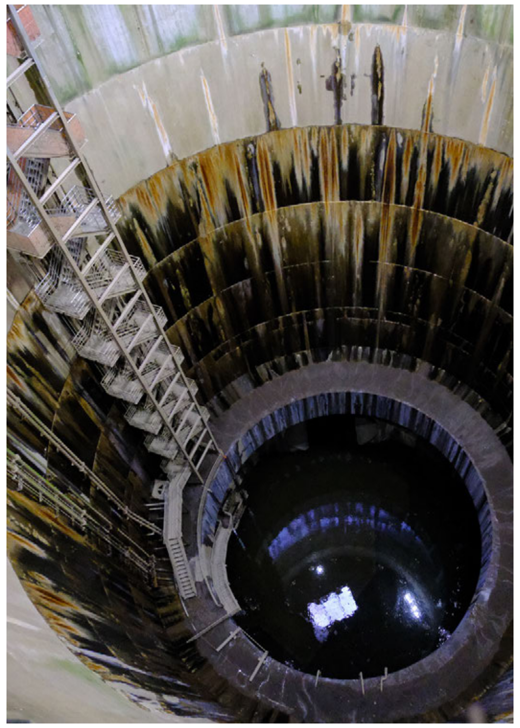


Figure A.3. One of the five water banks which is connected to the pressure-controlled tank,

Figure A.4. Apartment complex acting as a fire wall to protect the park, Higashi-Shirahige.

Figure A.5. Emergency water station, connected to a water tank underground, Ueno park.

Figure A.6. Solar- and wind-powered street light, Tokyo Rinkai Disaster Prevention Park .

Figure A.7. Speakers used to broadcast information during times of crisis, Ueno park

Figure A.8. One of many signs directing people to a designated evacuation area.

Figure A.9. Entrance area to the Kyoto Imperial Palace, An open space that is used for disaster

Figure A.10. Embankment design prepared for flooding situations, Sumida river

Figure A.11. Open space surrounded by necessities in neighboorhood park, Higashi-Shirahige.

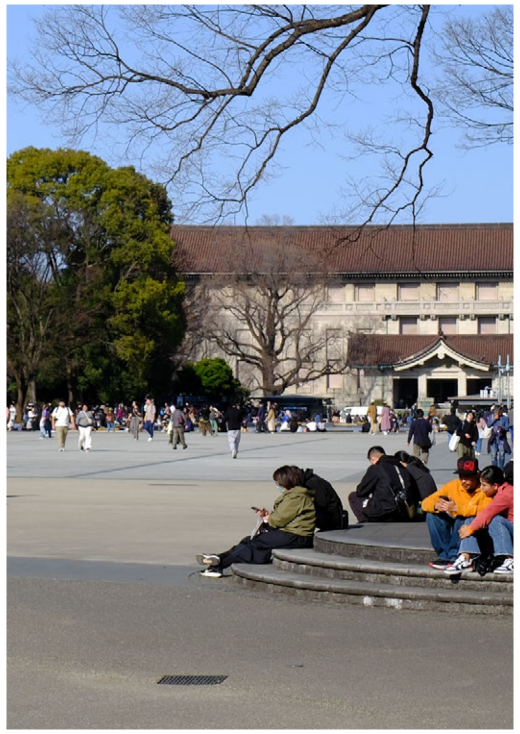


Figure A.12. Public buildings often work with the government to provide temporary accommodation. Tokyo national museum, Ueno park.

Figure A.13. Guided disaster prevention tour, Tokyo Rinkai Disaster Prevention Park

Figure A.14. Examples of disaster relief supplies, Tokyo Rinkai Disaster Prevention Park

Figure A.15. Examples of disaster relief supplies, Tokyo Rinkai Disaster Prevention Park

Figure A.16. Examples of disaster relief supplies and how everyday items can be used, Tokyo Rinkai Disaster Prevention Park

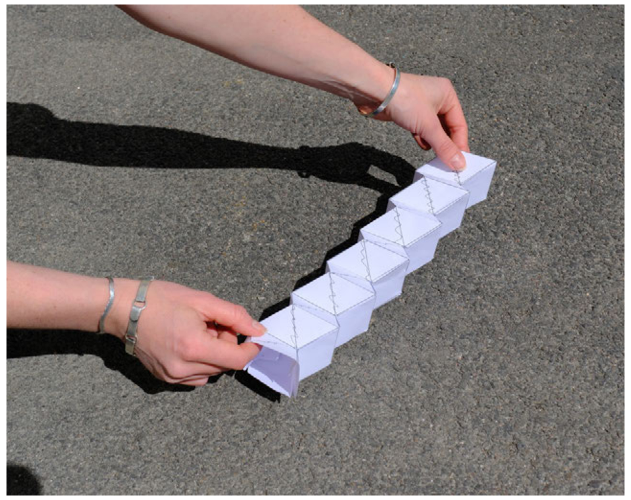
Figure A.17. Bensches able to transform for cooking, Kasai- Rinkai Park.

Figure A.17. Pavilions meant to be wrapped with fabric to create tent like structures, Kasai- Rinkai Park.

Figure A.19 Potholes for temporary toilets, Higashi-Shirahige.

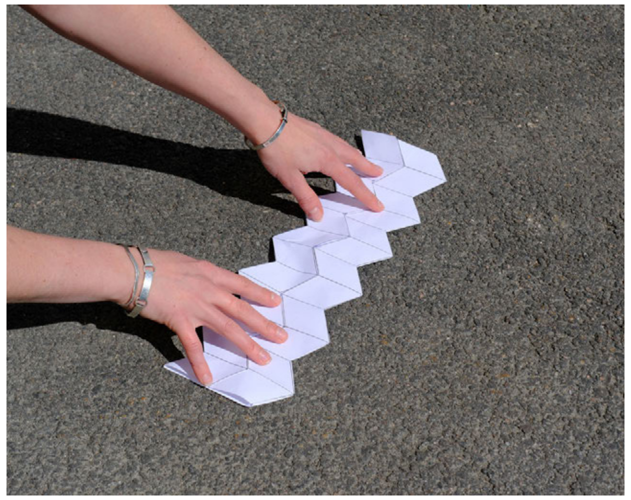
Figure A.20 .Public drinking fountain, Higashi-Shirahige.

Appendix B - Prototypes and representation models



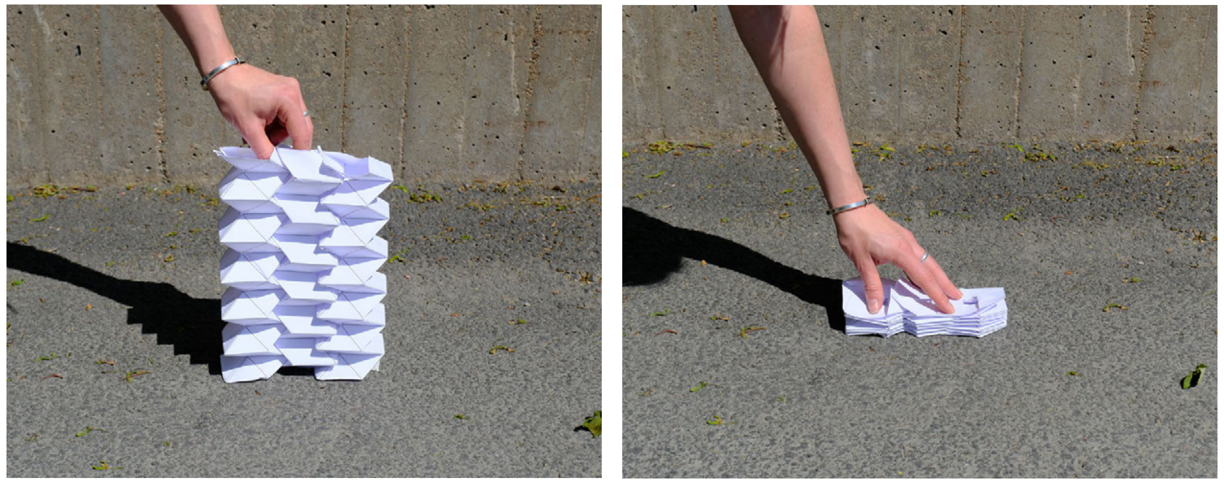
a)

b)

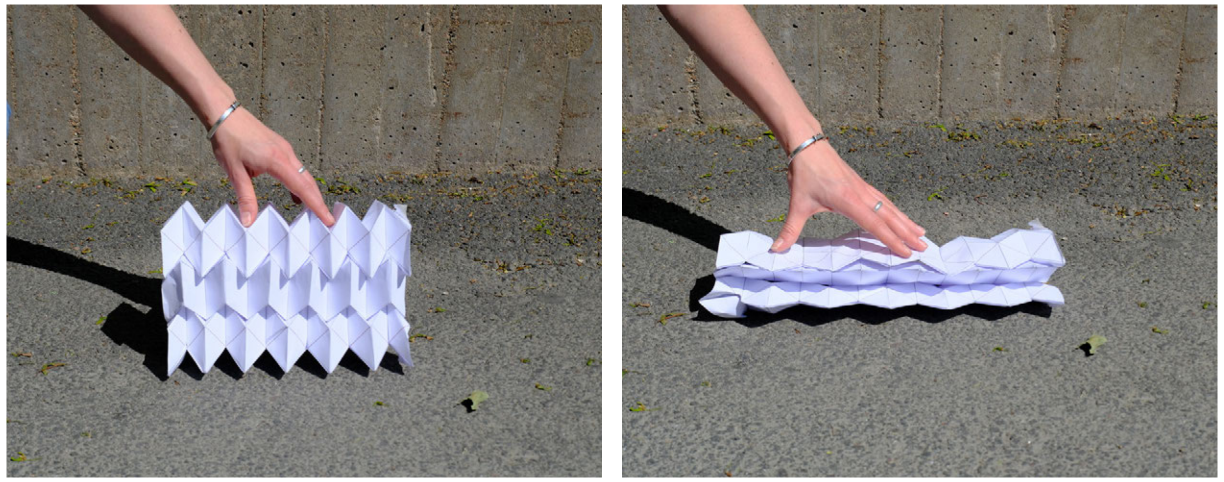


c)

Figure B.1. Physixal Miura- ori tube configuration

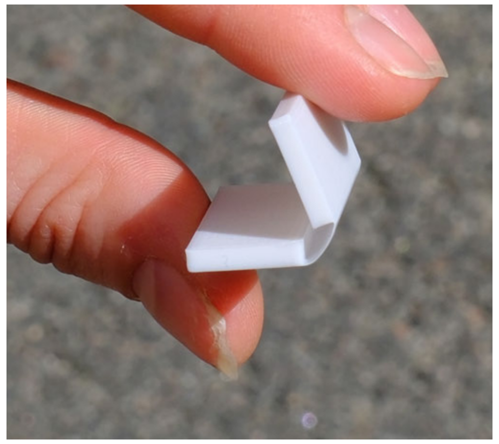


a)

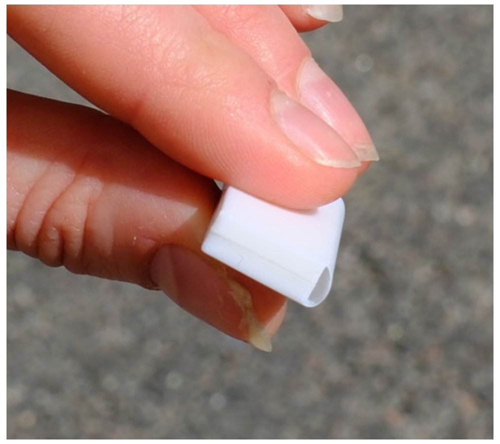


b)

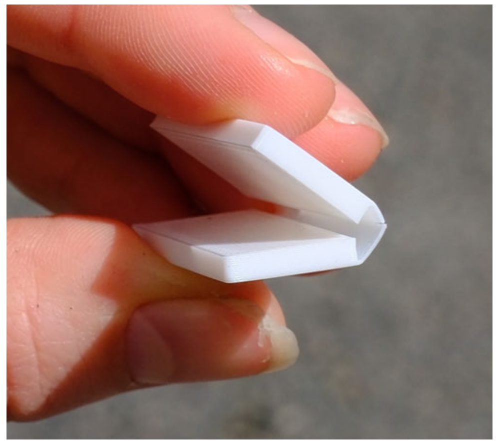
Figure B.2. Several Miura-ori tubes connected to each other



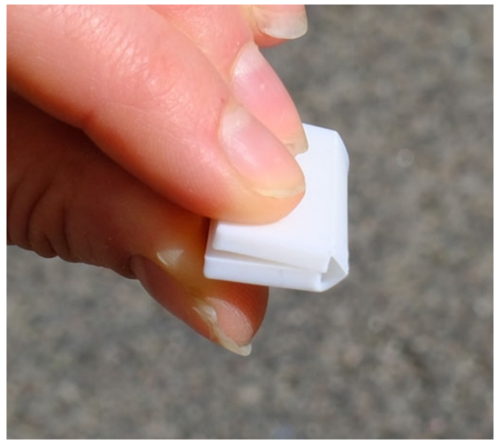
a) 1mm hinge thickness



b) 1mm hinge thickness



c) 2mm hinge thickness



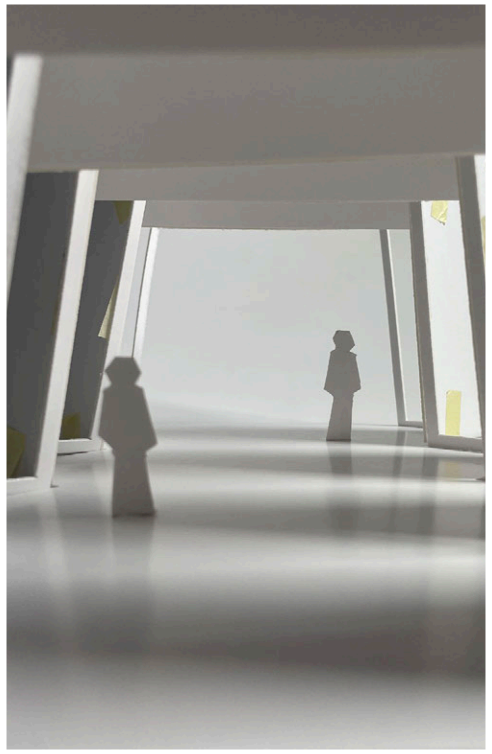
d) 2mm hinge thickness

Figure B.3 Living hinge prototype with different hinge thickness

Figure B.4 Miura-ori folding with living hinge prototype.

a).

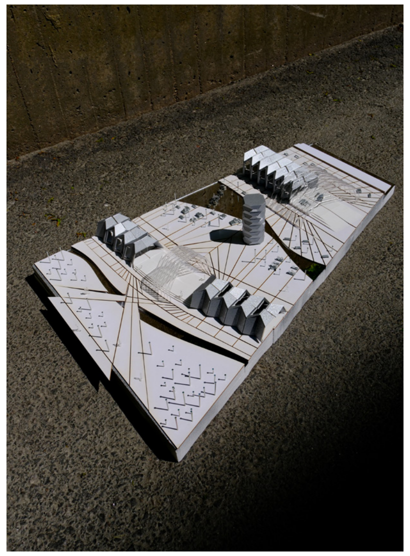
b).



c).

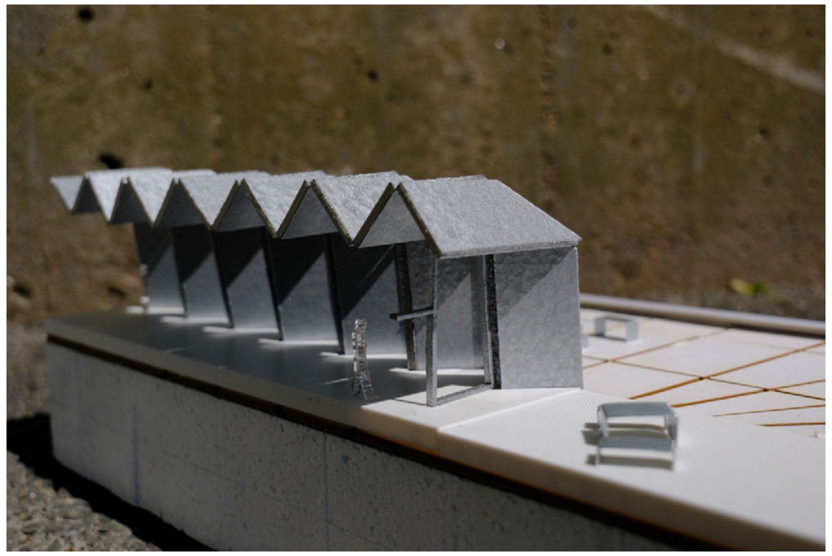
d).

Figure B.5 Early interior models to explore light and spatial qualities

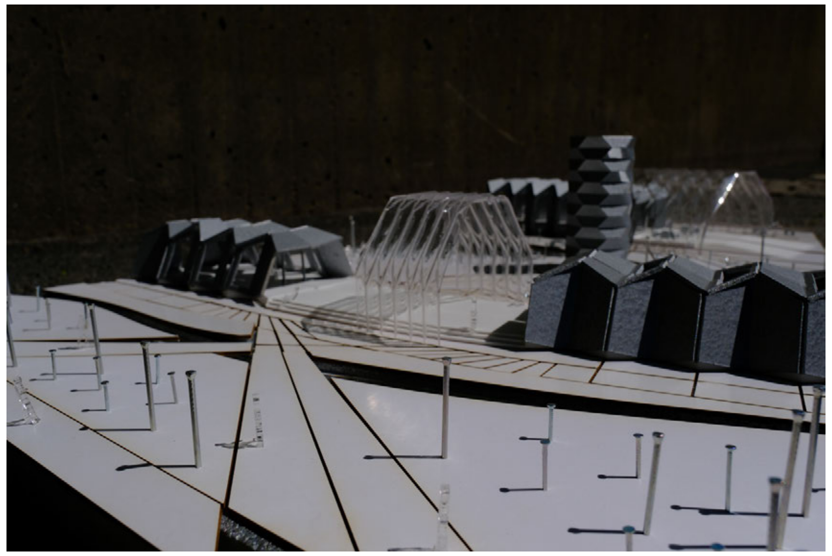


a) b)

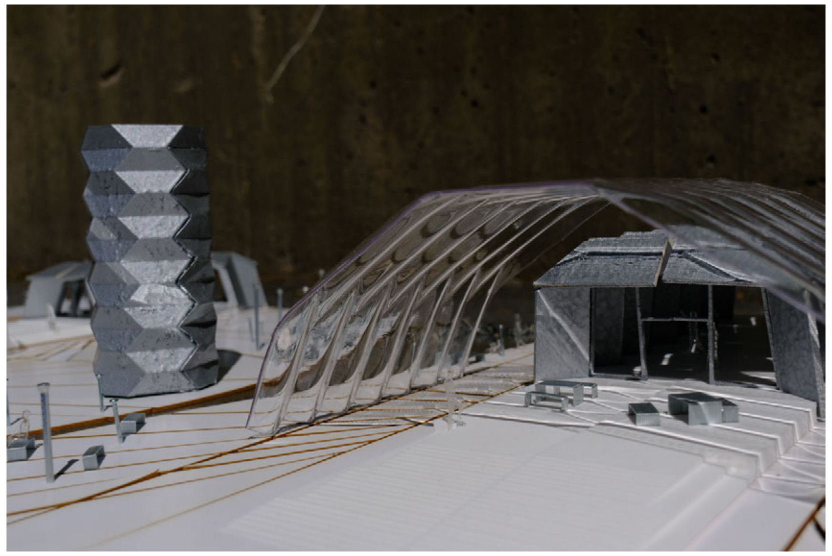
c)



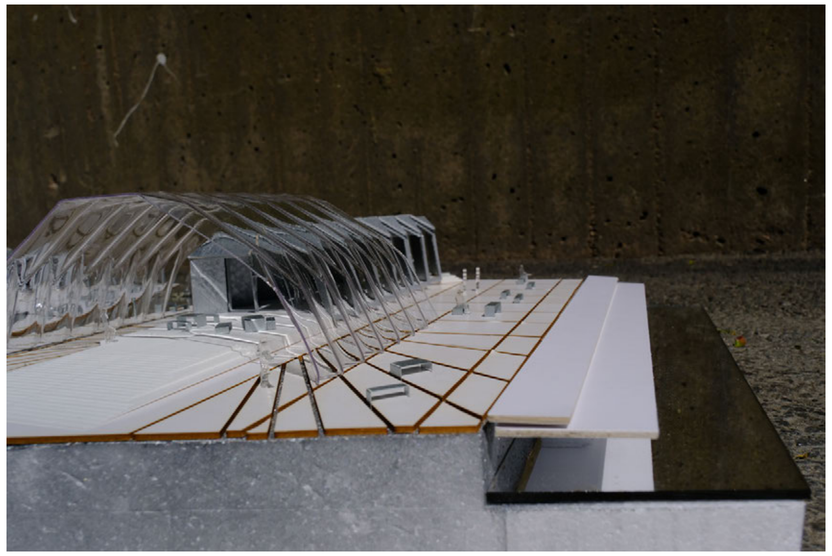
d)



e)



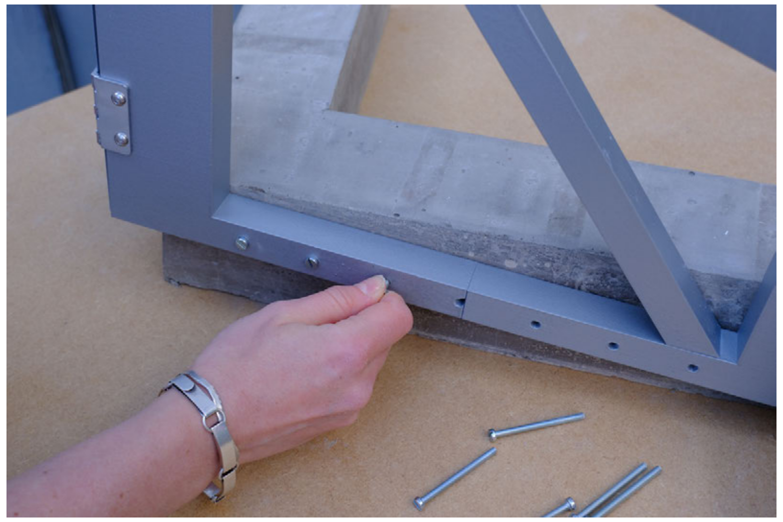
f)



g)

Figure B.6 Various photos of the 1:100 section model

a)



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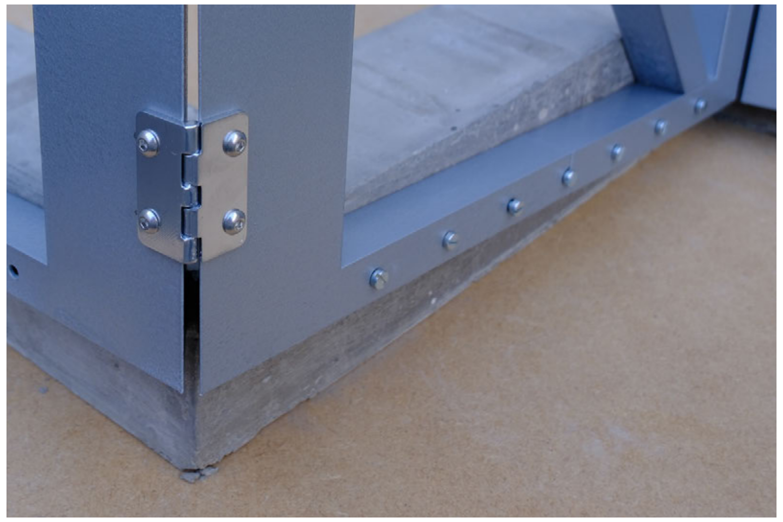
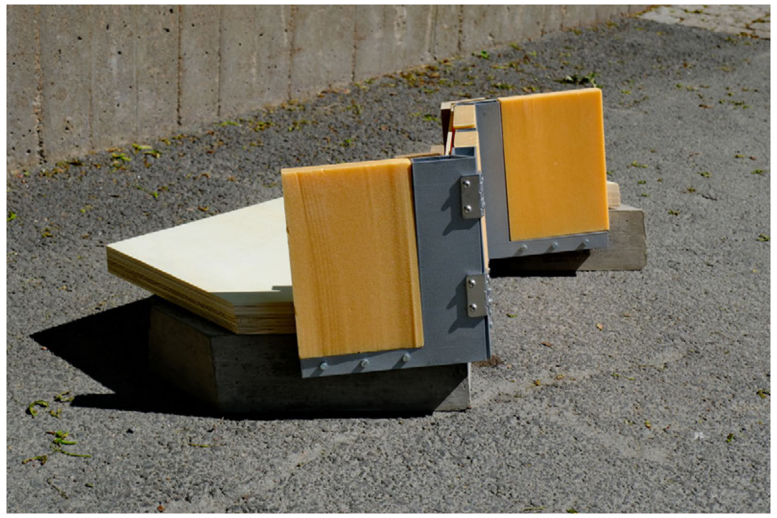


c)



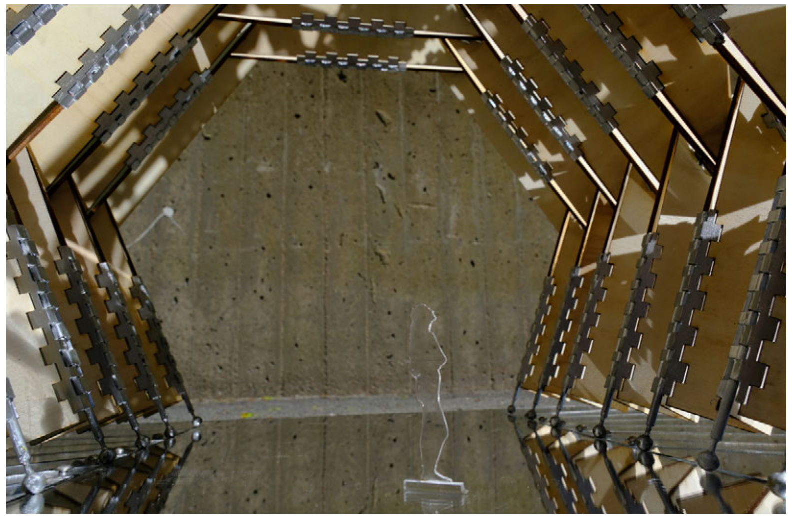
d)

e)

f)

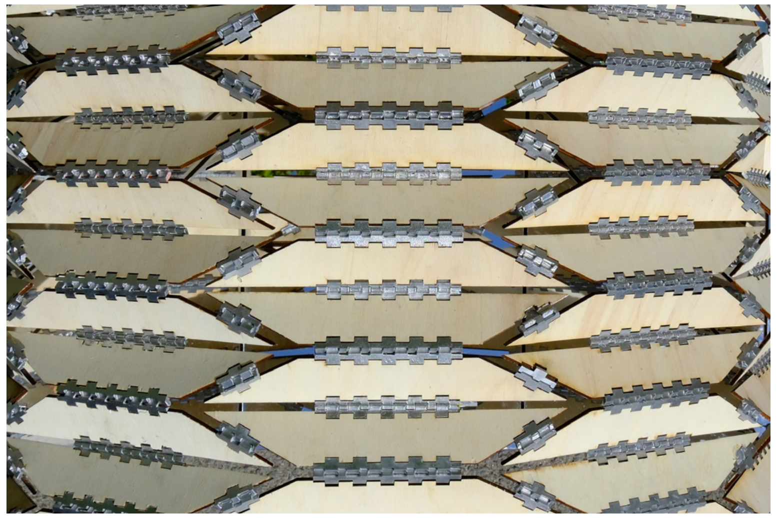
Figure B.7 Various photos of the 1:5 detail model

a)



b)

c)



d)

e)

Figure B.8 Various photos of the 1:25 rail model