MEGAMORFOSE

The development of an architectural prototype for an amphibious transformation in Setúbal

O desenvolvimento de um protótipo arquitectónico para uma transformação anfíbia em Setúbal

David Da Silva Brandão Matos

Dissertação apresentada ao Instituto Superior Manuel Teixeira Gomes para cumprimento dos requisitos necessários à obtenção do grau de Mestre em Arquitetura, realizada sob a orientação científica do Professor Doutor José Manuel Pinto de Carvalho.

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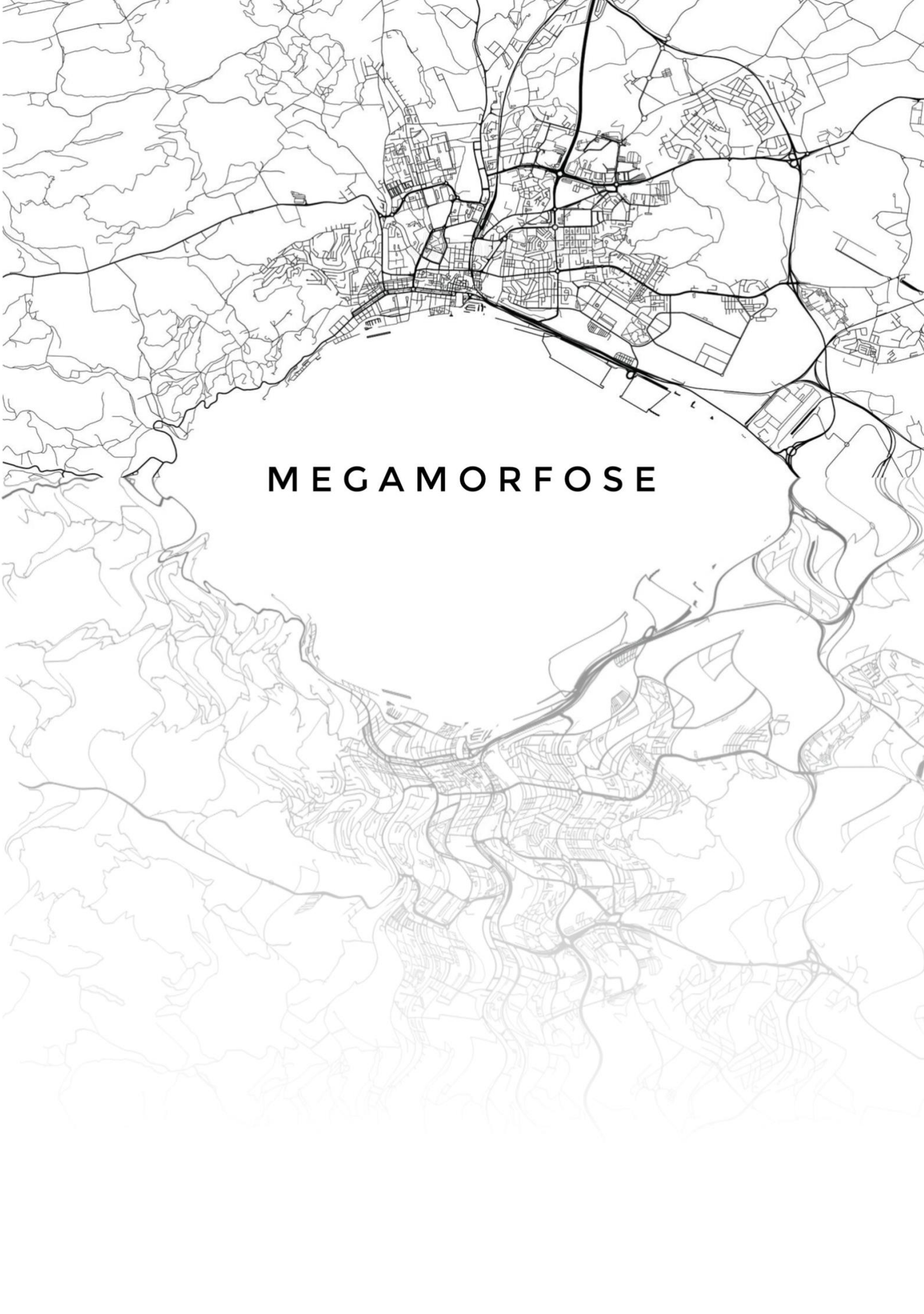
Presidente: Professor Doutor Luís António Guizado de Gouveia Durão, professor associado do ISMAT;
Professor orientador: Professor Doutor José Manuel Pinto de Carvalho, professor auxiliar do ISMAT;
Arguente: Professor Doutor Rogério Paulo Vieira de Almeida, professor auxiliar da Faculdade de Arquitetura da Universidade de Lisboa.


MEGAMORFOSE

Whenever humanity seems condemned to heaviness, I think I should fly like Perseus into a different space. I don't mean escaping into dreams or into the irrational. I mean that I have to change my approach, look at the world from a different perspective, with a different logic and with fresh method of cognition and verification.

- (Calvino, 1988)

RESUMO

Com o forte progresso económico e tecnológico desde a revolução industrial, uma transformação radical das estruturas industriais, sociais e urbanas instalou-se de forma resoluta nas cidades portuguesas e concretamente na cidade de Setúbal. Como resultado, a cidade transformou-se numa metrópole inserida num campo de complexa tensão entre política, cultura, história e sociedade, bem como economia. O desenvolvimento da cidade de Setúbal está intimamente ligado à nova vida urbana, recentemente influenciada por uma pandemia global e futuramente afetada por efeitos das mudanças climáticas e da subida do nível das águas do mar, fenómenos que irão provocar uma mudança radical da cidade. O objetivo deste trabalho académico centra-se na problemática dos efeitos espectáveis no estuário do rio Sado, enquanto elemento arquitectónico, bem como na questão da sua regeneração urbana e ecológica. O trabalho, desenvolvido através de uma metodologia de research through design, visa encontrar uma resposta arquitectónica para a problemática identificada, reconhecendo uma ligação territorial indelével entre a cidade de Setúbal e o Estuário do Sado.

Ao longo da investigação proposta, será desenvolvida e testada uma solução megaestrutural, flutuante, para a regeneração e prevenção deste lugar; um estudo que, mais tarde, poderá ser tomado em conta quando do estudo de outras áreas urbanas, com características semelhantes, em todo mundo.

Desde logo, a opção por uma solução megaestrutural flutuante surge também como convicta rejeição de outras ações tais como barragens hidroelétricas, diques ou quaisquer outros processos que ameacem de forma radical e negativa os ecossistemas estuarinos, procurando-se deste modo desenvolver uma solução flexível, modular, autónoma, e em equilíbrio com a estrutura cultural e natural.

Palavras-chave
Setúbal; megaestrutura flutuante; consequências climáticas; research through design

ABSTRACT

With the strong economic and technological progress since the industrial revolution, a radical transformation of industrial, social, and urban structures was resolutely installed in Portuguese cities and specifically in the city of Setúbal. As a result, the city has become a metropolis inserted in a field of complex tension between politics, culture, history, and society, as well as the economy. The development of the city of Setúbal is closely linked to the new urban life, recently influenced by a global pandemic and in the future affected by the effects of climate change and rising sea levels, phenomena that will bring about a radical change in the city. The objective of this academic work focuses on the issue of the expected effects on the estuary of the River Sado, as an architectural element, as well as on the question of its urban and ecological regeneration. The work, developed through research through design methodology, aims to find an architectural answer to the identified problem, recognizing an indelible territorial link between the city of Setúbal and the Sado Estuary.

During the proposed investigation, a mega-structural, floating solution will be developed and tested for the regeneration and prevention of this site; a study that can later be taken into account when studying other urban areas with similar characteristics around the world.

From the outset, the option for a floating megastructural solution also appears as a convinced rejection of other actions such as hydroelectric dams, dykes or any other processes that radically and negatively threaten estuarine ecosystems, thus seeking to develop a flexible, modular solution, autonomous, and in balance with the cultural and natural structure.

Key words
Setubal; floating megastructure; climate consequences; research through design

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EXORDIUM

The following dissertation is a product of the architecture master program of the Instituto Superior Manuel Teixeira Gomes in Portimão. An institute located in a port city and an estuary. A combination which subsequently lead to the theme of this dissertation, where the study site, the Port

City of Setubal, was suggested during the last year of the master program and where the motivation arises from the conviction that we need a critical and constructive look at the reality of current architectural practice and, at the same time, contribute to the elaboration of proposals that could become models of practical alternatives and even contribute to a methodological future in architectural intervention.

critical complex habitat

The City of Setubal, born from the Sado estuary but which today, paradoxically, is closed in on itself. The relationship with its waterfront shows us a long history of political influences, changes in riverside territories, in social and economic dynamics.

With regard to this dissertation the main consideration in terms of problem, is linked to the upcoming sea level rise (SLR) in the next 25 years. From 1994 to 2020, 29 trillion tons of ice melted, which already affected the average global sea level rise by 3.5 cm (EIB Group Carbon Footprint Report, 2018). This trend will continue and affect 800 million people, living in 570 cities all over the world. According to the IPCC report from 2021, major cities like Miami, Guangzhou, or New York are exposed to coastal flooding. An observable process which already began in 2010, but it's Kolkata, Mumbai and Dhaka that have the highest number of people at risk from coastal inundation. The report foresees a population between 11 and 14 million people being affected. Not excluded, the Sado Estuary and its City of Setubal, which will be the chosen site study and one of the most affected scenarios in Portugal.

nexus

The current different approaches by the affected cities encompass different models. To mention two of the most important cases while The Chinese government responds with their Sponge City Concept (SCC)[1], a combination of heavy engineering interventions, environmental and people-based strategies, hand in hand with the relocation of millions of people. The City of New York follows a more passive strategy by using concepts like 'retreat, accommodation and protection'.[2] This approach focuses on converting specific affected areas into water-based areas, strengthen existing waterfront constructions and the application of nature-based 'dikes'. Synoptically a complex problem linked to other related developments like population growth, economic activity, lifestyle, energy use, land use, consumption, and rapidly evolving technology. These consequences automatically enhance the complexity.

[1] Zevenbergen, 2018. *Transitioning to Sponge Cities: Challenges and Opportunities to Address Urban Water Problems in China*.

[2] Government of New York, 2020. *Waterfront Revitalization Program.* New York City Panel on Climate Change 2020.

protocol

How would we react if we were consciously aware that everything, we know will change fundamentally in less than a couple of decades? A rhetorical question that considers accepting changes as a natural consequence of time, whether the presence of the human species generates changes or not. The present research explores how to possibly adapt to changes in form of a response, which approaches the question of acquiring some level of control while facing inevitable changes. An apparent paradox that we try to deal through the search for architectural answers, conceptually defined by a central characteristic: flexibility as the fundamental attitude of nature to adapt to changing circumstances: accepting that 'flexibility is an ability to respond to human or non-human-caused changes' (Schneider & Till, 2007, pp. 157-160). This choice is not something unheard, as architects have already included or even focused on for over a century[3] (Alkhansaria, 2018, pp.120-133). On the other hand, the multiplicity of these past approaches linked to the subject of flexibility, turned this notion into an ambiguous and complicated process[4] caused by a variety of wrongly used 'solutions' (Abley, 2008, pp.7-9).

How should we react, or what should we response to these complex problems? I propose to understand, that in times of rapid economic, technological or demographic change, existing structures, from the scale of a building to the design of cities[5], a reassessment of the term flexibility should happen constantly.

Faced with this scenario, it seems indisputable that it has become crucial to understand the capacities of buildings to transform a negative environmental impact into a positive one, which leads to assert that accepting flexibility as a central strategy of the architectural design process should be an act linked to the present mindset of the architectural profession.

the evaluating architect

Considering the problematic of the City of Setúbal, a place naturally sensible to the SLR question, leads to the need to design an architectural answer to it. A dialogue between the problems and the hypothesis generating possibilities deserving serious considerations. The possible approach

[3] Richard Buckminster Fuller, technically not an architect, proposed in his book from 1969 called 'Utopia or oblivion : the prospects for humanity' to include several nature-based concepts and principles into the architectural paradigm.

[4] Kevin Lynch writes that "however frequently flexibility is invoked, its meaning remains unclear... No one knows quite how to attain it" (Lynch, K.,1984, pp. 167).

[5] The building sector accounts for 38 percent of the total waste production, 40 percent of the carbon dioxide (CO2) emissions and 50 percent of all natural resources used within construction (EIB 2015). In addition, fifty percent of investments in building construction in the Portugal are spent on partial demolition and adaptation of the existing buildings and 42 percent of new construction is due to the replacement of demolished buildings which do not have the capacity to be modified to accommodate new needs - How the climate crisis has changed perspectives on city design (Byrne, 2022).

to such complexity contemplates a systemic form in order to achieve a better adaptation between the respective estuaries, rivers and their urban areas.

freedom and control

The initial research that led to the hypothesis and supports this dissertation, took shape by the concept of an architectural system (as presented by Josep Montaner (2008). Since an early stage it became clear that the searched answer sought for more than the 'classical' development of an architectural design, rather to start from an inquiry about the very nature of the architectural solution to be proposed. This path led to the consideration of a megastructure form or megaform[6] – a concept theoretical shaped by Fumihiko Maki[7], synthesized by Ralph Wilcoxen[8] and Reyner Banham, as the working hypothesis.

The megastructure, as an architectural system, evolved through the works of the Japanese Metabolist, and the explorations of Cedric Price, Archigram, Alison and Peter Smithson and Le Corbusier, and it is commonly considered as an essential precursor of the megastructural idea[9], within the context of post-war social and economic trends and impactful lifestyle changes (Zuddas, 2018, pp. 51).

Simultaneously, the concept of the city as a building[10] has appeared throughout history as an upholding perception. The compaction of urban functions generates the hypothesis of creating a multifunctional structure that brings together the various urban activities. A system that belongs to its society and acts as a complement to the existing urban landscape. The megastructure, like the city, is defined by its infinite expansibility, modularity, and freedom through its open structure (Maki, 1964, pp. 10). Space becomes a network of aggregates, of free organisation of habitat cells. Modularity, adaptability, self-assembly, community, and embracing the benefits of a possible floating structure to restate and complement the city of Setubal.

[6] Term introduced by Fumihiko Maki (Maki, 1964, pp. 6) which varies throughout the written work between megastructure and megaform.

[7] The megastructure is a large frame in which all the functions of a city or part of a city are housed (Maki, 1964, pp. 8).

[8] Linked to precepts like pre-fabrication, modularity, infinity growth and a long living main skeleton system that supports a flexible sub-system (Wilcoxon, 1968, pp.2).

[9] Kenzo Tange's Tokyo Bay Plan in 1960—an extension of his earlier Boston Harbour project at MIT—can also be seen as a post-war version of Le Corbusier's Algiers project. Corbusier's techno-utopia also had a strong influence on the 1960 Metabolist movement (Maki, 2008, pp. 187).

[10] In the book *De Re Aedificatoria* Leon B. Alberti theorized the existing relation between the spaces of each individual building and its city (Benevolo, 1971).

human complement system

This dissertation explores the use of megastructures, and its inherent transmutative capacity, as a combination of different tools and methods, like architectural and urban parametricism, the potential of self-assembly construction and precepts relinked to a possible circular economy approach in the architecture profession. resorting to the construction of an architectural prototype in order to evaluate it.

non-linear plausible reality

This process will be developed in parallel to the investigation of the different subjects directly linked to the problem, to the place, to the act of design and functional program, approaching and interrelating the natural habitat - The City.

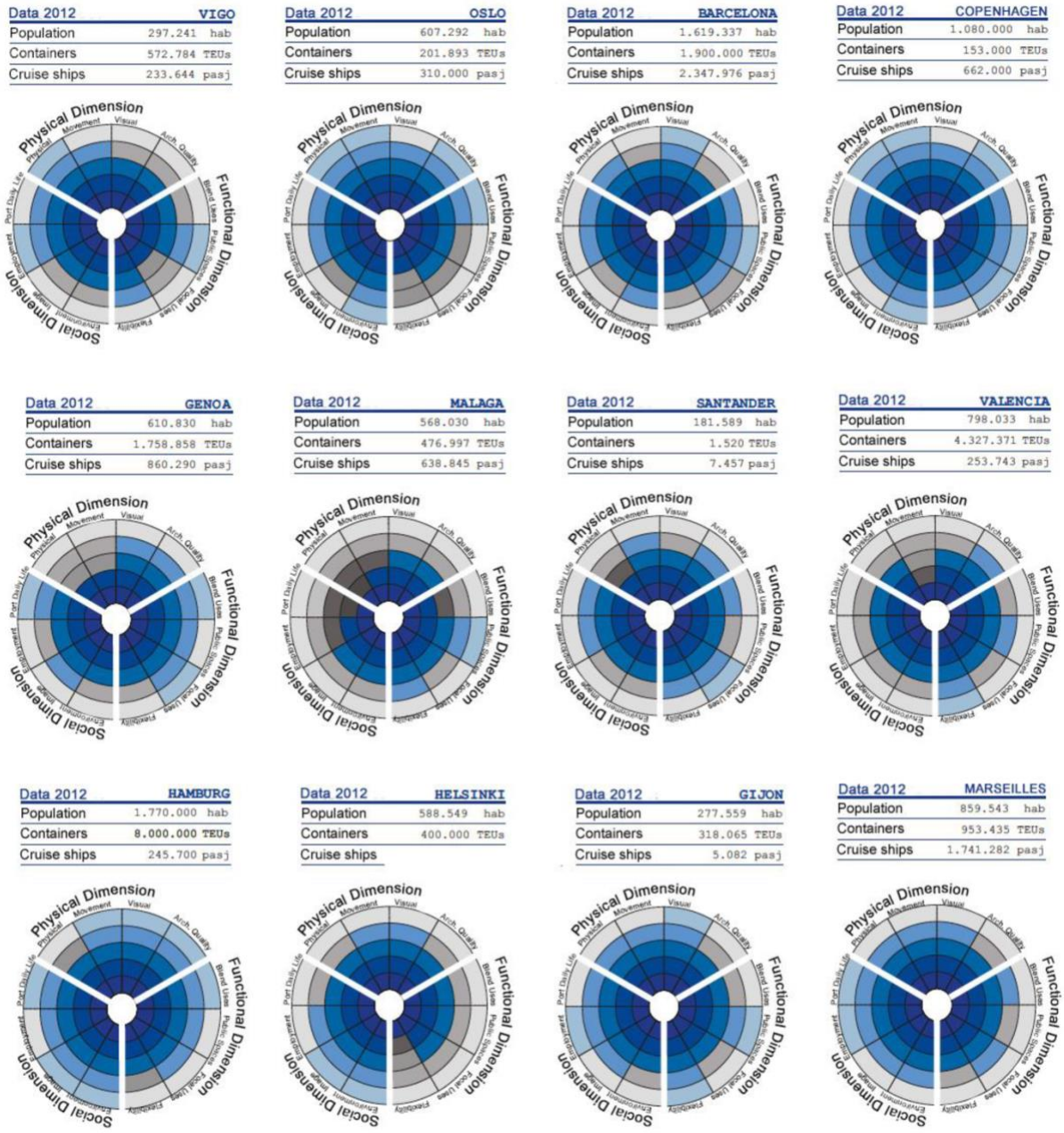
[CHAPTER I]

CRITICAL COMPLEX HABITAT

Waterfronts have always been a resource for the human settlements. Being a dynamic source of life, transformed into human complex habitats, resulting in areas of living, recreation, and exchange. Consequently, it also required a coastal area that involved port trade. With this evolution, the port areas began to grow, transforming the riverside landscape into port cities. The relation between the ports, cities and their waterfront are the topographical manifestation in terms economy, culture, and society as a whole. An equilibrium of linked dimensions that will face major changes in the next few decades in form of climate change consequences.

port city topography

During the last century, most of the ports cities have been detaching from its urban topography, in terms of social and functional dimension, caused by the evolution of industrialization (Hoyle, B.S., 1989). The traditionally relationship between port and port-related activities of their habitants has declined along with the integrated visibility of port activities inside its cities (Hein 2014, pp. 340). During the same period, the growth of the port physical dimension beyond its traditional urban context has led to an ascending importance of the port, both in terms of economic wealth as well as its negative environmental effects. Since the mid 20-century, cities like San Francisco, London, Rotterdam, and Hamburg had the need for an urban renewal and revitalization, maintain or even increasing its port`s physical and functional dimension, including the social dimension.



[Figure nº 1, *Comparative visual analysis of port–city integration, analyzing the physical, functional, and social dimension of different cities from 2012*, Andrade et al., 2020.]

The revitalization process began in the USA, which led to some examples in the process of transforming port spaces, which quickly reached Europe in the 1980s and Asia in the 1990s (Andrade et al.,2020, pp. 23). The strategies still concentrated on an economic objective and the results are still debatable. Alternatively, an urban revitalization process is often used in events of great worldwide visibility, such as the City of Barcelona with the 1992 Olympic Games and Lisbon, in the Parque das

Nações area following EXPO 98, which created the path to strategies creating a new linear waterfront center of the city.[11]

broken waterfronts

Waterfronts can often be observed as a fractal[12] interface between land and sea (Salingeros, 2003). The waterfront establishes a specific limit or border between the solid and fluid space. Maritime commerce, tourism and recreation bring people to the estuary, where it is possible to interact sensorially with the water and even benefit from the healing properties of visual and physical interactions. The waterfront provides a direction of visual and psychological freedom, a freedom that should consider more when we define the human habitat (Salingeros, 2003, pp. 2-21). The metabolism of waterfront cities mimics parasitical behavior. The cities use food, energy, and other resources from surrounding areas and proliferate by taking up productive land. The imported resources are used and changed into material waste, CO2, heat, and wastewater. These resource streams are not used productively (de Graaf, 2012, pp. 17). An impact that requires natural dynamics to adapt to this change and evolution in the form of what we call 'climate change', which more profoundly includes more than just one consequence.

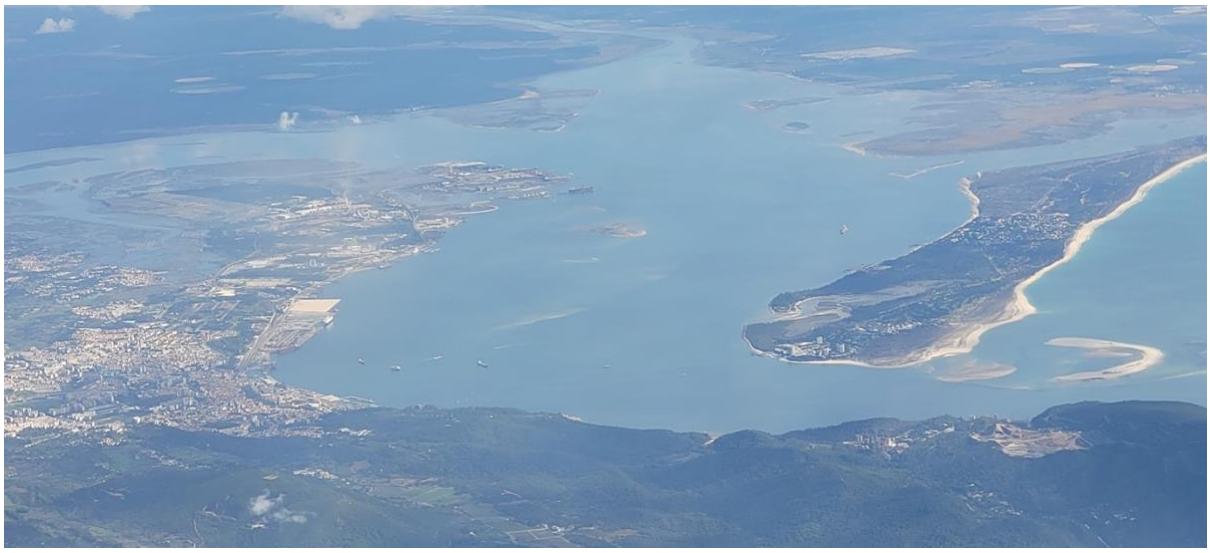
transforming estuary

The Sado estuary and the evolution of its natural and cultural landscape consist of a wide valley that extends to the North, sheltered from the sea by the elevation of the mountain Arrábida and exposed to the South, the city of Setúbal which enjoys a privileged situation, at the mouth of this estuary that allows the natural contact with the Atlantic Sea. A natural shell, wedged to the West in a steep topography, at the end of a fertile area, sheltered from the North and developing along a coastline, facing a Tróia, which protects the whole from the southwestern storms. With a population of 121,185 inhabitants and a total area of 230km2. The influence of Lisbon's closely located metropolitan area encouraged the implementation of different infrastructures, created a unique

[11] Pinto de Carvalho, J.M. (2022, October 7th). *Presentation during class.* Instituto Superior Manuel Teixeira Gomes, Portimão. A class about Lisbon´s waterfront evolution. Since the 80´s, the City of Lisbon is showing objectives and initiatives, launched critically by several architects at that time, to restructure and revitalize the waterfront of the city. Only after the announced of the EXPO 1998, a stronger interest raised towards that idea (politically and economically) which turned the waterfront in less than 20 years into a new linear city centre. A process that still evolves, starting from the Parque das Nações reaching Belém and growing.

[12] The word 'fractal' is a term coined by the mathematician Benoît Mandelbrot in 1975 which describes certain natural or artificial structures or geometric patterns and means broken, convoluted, perforated, bent, or folded, depending upon the mathematical situation. Nikos Salingeros develops the idea of an edge in a geographical sense and applies geometrical analysis to the general morphology of coastal cities. He considers the coast as a fractal line, with special mathematical properties. Those natural fractal properties are in turn reflected in traditional urban fabric (Salingeros, 2003).

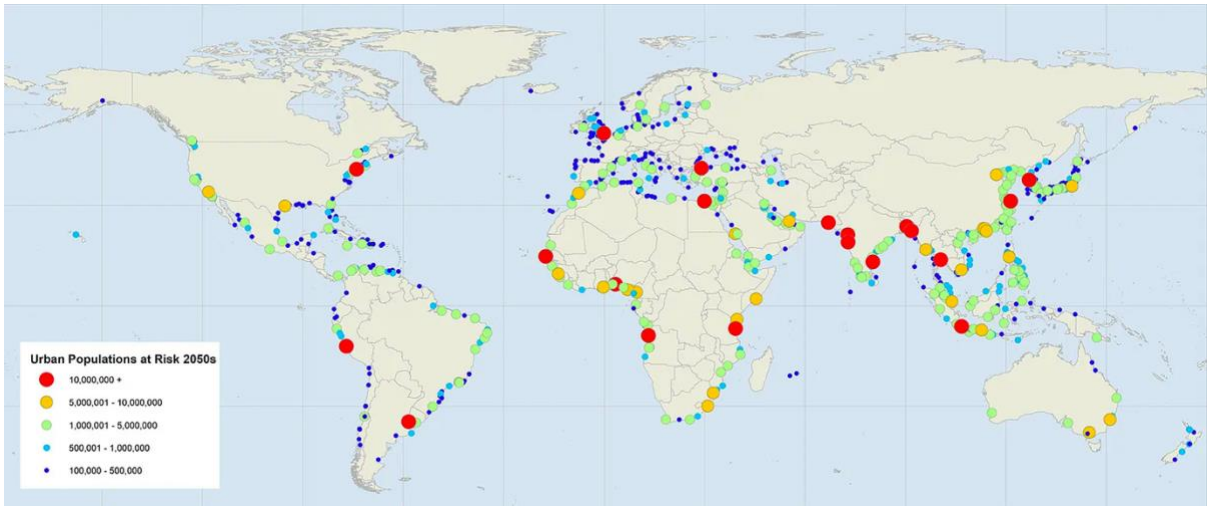
situation due to its proximity, and gave national importance to its port and maritime industry (Silva, 2009).



[Figure nº 2, *Aerial view of the Sado estuary*, Pinto de Carvalho, J.M, 2022.]

The increased scale of the industrialization processes transformed the city and its surroundings. It promoted the establishment of numerous canning factories towards the East of the railroad, which constituted the image of Setúbal. In the first quarter of this century, the establishment of two other industries of considerable dimensions, cement, and fertilizers, led to more port investments, the promotion of public works, and the construction of some financial districts, which are all constantly focused on the waterfront (Cabral, 2015, pp. 30). A waterfront that will face natural changes in terms of consequences of climate change effects - the rise of the average global sea level (SLR). During the last decade, the yearly IPCC reports constantly alert the significantly amplified risks in coastal cities. Coastal settlements are susceptible to climate risks such as sea level rise, storm surges, erosion, and saltwater intrusion. Since 1900 the international sea level has risen 20 centimeters faster than in the past 2.800 years.[13] It is now growing at eight of 3.5 millimeters per year and accelerating (IPCC Report, 2021). Curiously the reasons are not only the rise of the sea level but also the sinking of land. Due to the disruption of sediment flows, the severe decay of estuarine and coastal areas leads to severe land subsidence and deterioration, consequently leading to sea level rise above the land level (DeConto & Pollard, 2016). Depending on the tides, winds and atmospheric pressure patterns, as well as the ocean circulation, which presents high volatility in the case of the Sado estuary, the consequence will be multitudinous.

[13] Mooney, C. (2016). *Research on the global sea level rise*. Washington Post



[Figure nº 3, *World map of cities at risk from a sea level rise of 0.5 meters by 2050*, IPCC Report, 2021.]

The city of Setúbal but also the peninsula of Troía, at the national level, has the most significant number of residents and buildings in areas considered vulnerable to rising sea levels. It is estimated that around 38,000 inhabitants and 3000 buildings[14] will be affected by this phenomenon by 2050 and 59,600 by 2100 (Antunes, Rocha & Catita, 2017, pp. 15), which can be considered an urgent, complex problem. This is a common problem that affects not only the city but many other waterfront cities as well, making the response to this complex problem a possible prototype for future research and applications.

[14] The Setubal Judicial Court, Municipal Market, Police Station, Schools, Security, Port Administrations, etc. – Roughly most of the buildings from the waterfront till the Avenida Luísa Todi (Antunes, Rocha & Catita, 2017)

[Figure nº 4, *Map of the Sado estuary showing affected areas by a sea level rise of 0.5 meters by 2050*, Author, 2022.]

conclusion

The transformation of port cities and its waterfronts are constantly linked to decisions implying strategies. These strategies can be temporarily successful or not but in terms of time rigid towards change and flexibility. The consequences of the SLR, will bring major changes to port and waterfront cities all over the world. In the case of the City of Setubal and its estuary, numerous problems, linked to the consequences of this intense industrialization, become more evident. Many places that once lived intensely along the estuarine coast are now partially obsolete territories with an undefined function, belonging to a community which seeks to re-discover its estuary as an essential element of this city. The need for decision and strategies linked to these consequences are urgent and diverse. But will they be flexible?

This dissertation is about an investigation through design where this problematic is approached from a central premise: to find a flexible, modular, and adaptable architectural response - a proposal able to develop according to known and foreseen conditions, and to change, also, according to the buoyancy of the decision-making strategies adopted over time. The present

dissertation verse about research by design where this problem is approached from a central premise: to build a flexible, modular, and adaptable architectural answer - a proposal capable of developing according to the known and foreseen conditions, and of change, also, depending on the buoyancy of the decision-making strategies adopted over time.

[CHAPTER II]

HYPOTHESIS

The hypothesis already mentioned in the introduction emerges as a result of various factors and linked in a macro level to the restatement of the city as a response to the existing problems. The consequences of climate change, consequently leading to rising sea levels, which threatens most of the waterfront cities, shows the inflexibility and lack of proper sustainability, in order to response to these complex problems.

. The object should not be seen as a reform, reinterpretation or as the city of the future, but to produce possibilities that lead to serious deliberations. Consequently, and further explained it leads to the importance of flexibility in architecture, using design as research methodology it generated the hypothesis to explore the use of a floating megastructure.

Can a flexible architectural system, in from of a floating megastructure, positively catalyse the consequences of the SLR affecting the Port City of Setúbal, but also provide reversibility if needed?

[CHAPTER III]

NEXUS

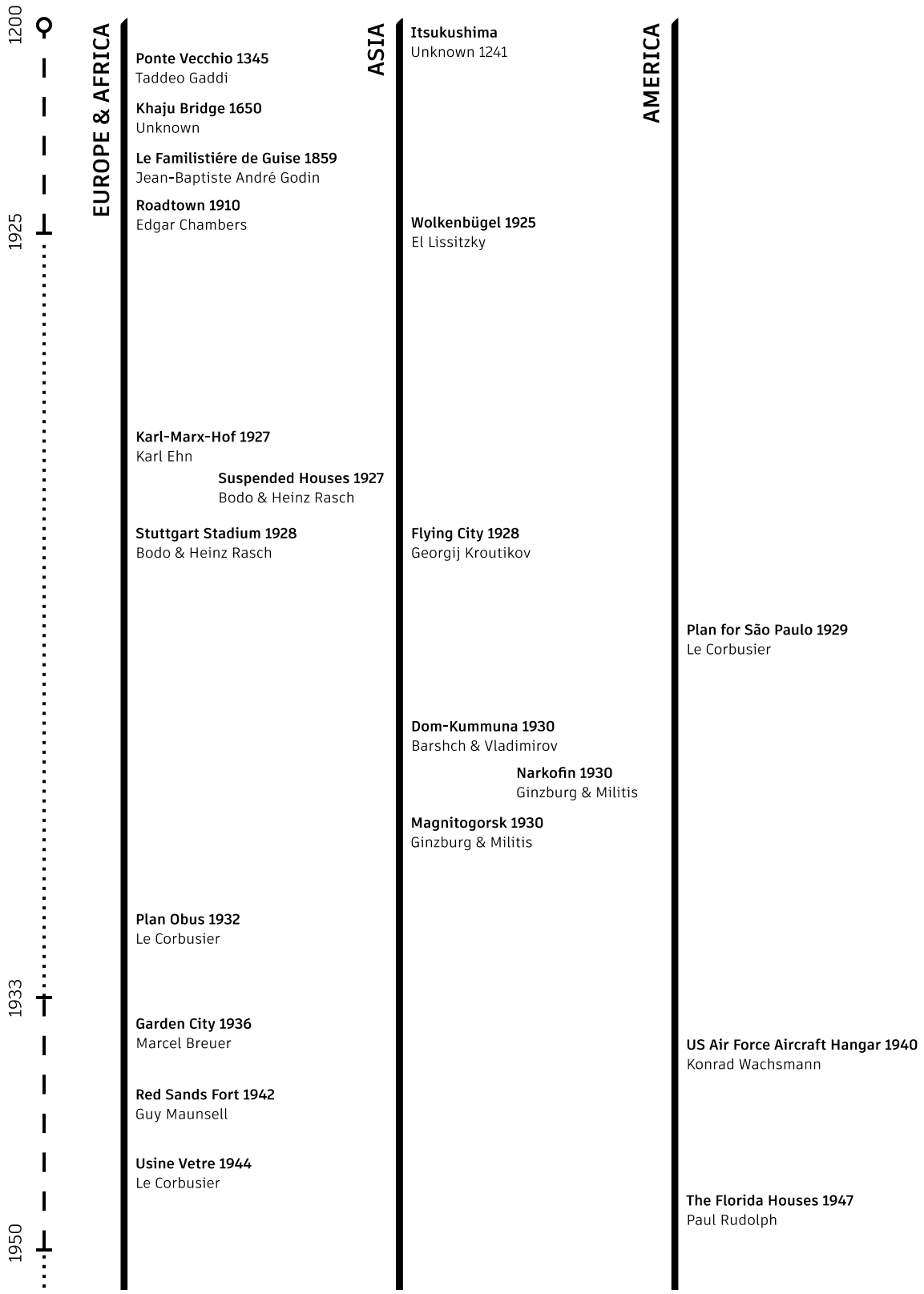
This chapter concentrates on the current level of knowledge and strategies related to the approach of the mentioned problem, leading us to a certain degree of state of art. The aim is to provide a context for new research and allows to build upon existing knowledge and to identify gaps in understanding that can be addressed in future studies.

From a wide selection of consult cases, two case studies were selected in order to provide valuable insights and conclusions in relation between the problem and response. Since there are no realized case studies linked to the specific hypothesis, besides floating domestic and industrial architecture, the decision was made to choose two moments whose study proved to be particularly valuable and directly applicable to the research project. The decision for theoretical frameworks,

which refers to the intellectual constructs, conceptual models and theories that guide the practice of architecture and provides several advantages. One advantage is that it can help to guide the research process by providing a structure for the study and a way to organize the data that is collected. This can make the research more efficient and effective which passes through a phase of testing within the existence of an experimental space. It can help to revaluate the hypothesis and create conclusions for further research.

It is important to mention that the analysis happened in non-linear different periods during process of this dissertation.

During this research, an inventory of about 150 realised and non-realised cases of past references was made. These references present different range of scale, functions and a distant relation to space/time and even if there is no direct link established between each one and the project/hypothesis developed, their presence is felt in a continuous subliminal dimension.


1200
1925
1933
1950
EUROPE & AFRICA
ASIA
AMERICA
Ponte Vecchio 1345
Taddeo Gaddi
Khaju Bridge 1650
Unknown
Le Familistiére de Guise 1859
Jean-Baptiste André Godin
Roadtown 1910
Edgar Chambers
Itsukushima
Unknown 1241
Wolkenbügel 1925
El Lissitzky
Karl-Marx-Hof 1927
Karl Ehn
Suspended Houses 1927
Bodo & Heinz Rasch
Stuttgart Stadium 1928
Bodo & Heinz Rasch
Flying City 1928
Georgij Kroutikov
Plan for São Paulo 1929
Le Corbusier
Dom-Kummuna 1930
Barshch & Vladimirov
Narkofin 1930
Ginzburg & Militis
Magnitogorsk 1930
Ginzburg & Militis
Plan Obus 1932
Le Corbusier
Garden City 1936
Marcel Breuer
US Air Force Aircraft Hangar 1940
Konrad Wachsmann
Red Sands Fort 1942
Guy Maunsell
Usine Vetre 1944
Le Corbusier
The Florida Houses 1947
Paul Rudolph

1960

Vertical Cotton Mill 1952
Richard Buckminster Fuller

Hauptstadt Berlin 1957
Alison & Peter Smithson &
Peter Sigmuund

Medical Research Laboratories 1957
Louis Kahn

Villa Spatiale 1958
Yona Friedman

Tower Shaped Community 1958
Kiyonori Kikutake

Boston Port Urbanisation 1958
Kenzo Tange

Sky House 1958
Kiyonori Kikutake

New Babylon 1959
Constant Nieuwenhuys

Raumstadt 1959
Eckhard Schulze-Fielitz

Amsterdam Orphanage 1960
Aldo van Eyck

Tokyo Bay Project 1960
Kenzo Tange

Climatroffice 1960
Terry Farrell

Agricultural City 1960
Kisho Kurokawa

Intrapolis 1960
Walter Jones

Caen-Herouville 1961
Candilis & Josic & Woods

Kôtô Ward 1961
Kiyonori Kikutake

Noah's Arc 1961
Piet Bloom

Floating City 1961
Kisho Kurokawa

Bochum University 1962
Günther Domineg & Heilfried Huth

Marine City 1962
Kiyonori Kikutake

Fun Palace 1962
Cedric Price

Cluster in the Air 1962
Arata Isozaki

Römerberg Frankfurt 1963
Candilis & Josic & Woods

Tsukiji District Renovation 1963
Kenzo Tange

University College 1963
Giancarlo de Carlo

Venice Hospital 1964
Le Corbusier & Jullien de la Fuente

Housing Zigurat 1964
Leopold Gerstel

Sunset Mountain Park 1964
Cesar Pelli

Plan Pampus 1964
Joop Bakema

Cellules D´Habitation 1965
Pascal Hausmann

Yamanashi Culture Hall 1965
Kenzo Tange

Power Membrane 1965
Reyner Banham & François Dallegre

Teatro de la Ópera 1965
Maurizio Sacripanti

Ghandi Memorial Museum 1965
Charles Correa

Raumstadt Ragnitz 1966
Günther Domineg & Heilfried Huth

Sewoon Sangga 1966
Kim Swoo-geun

Habitat 67 1966
Moshe Safdie

Lungoteveri 1966
Franco Purini & Laura Thermes

Residence Connective Systems 1966
Kenzo Tange Students

Olivetti-Underwood Factory 1966
Louis Kahn

Centraal Baheer 1967
Hermann Hertzberger

Pavilion Hospital 1967
Arieh Sharon

Triton City 1967
Richard Buckminster Fuller

Holiday Machine 1967
Cristiano Toraldo

Floating Matrix 1967
Stanley Tigerman

Plug-in City 1968
Peter Cook

City of the Future 1968
Richard Buckminster Fuller

Tanguantiga Hospital 1968
João Filgueiras Lima

Monumento alla Partigiana 1968
Carlo Scarpa

Habita New York 1968
Moshe Safdie

Amsterdam Civic Center 1969
MSGSSV

Floating Metabonate 1969
Kisho Kurokawa

Continuous City 1969
Alan Boutwell & Michael Mitchell

University Madrid 1969
Paredes & Solís & Candilis

1970

Centre Pompidou 1970
Richard Rogers & Renzo Piano

Metastadt 1970
Richard J. Dietrich

Lausanne University 1971
Mario Botta

Centre Pompidou 1971
Moshe Safdie

Hexacube 1972
Georges Candilis & Anja Blomstedt

Mobile Hotel 1972
Gernot Nalbach

“Freie” University Berlin 1973
Candilis & Josic & Woods

Campus Arcavacata 1973
Vittorio Gregotti

Vienna University 1974
Günther Domineg & Heilfried Huth

Train Station Trenes 1974
Jozef Jankovic

Bela Vista Quarter Setubal 1975
Aldo Rossi

The City Clubs Milton Keynes 1976
Derek Walker Associates

Florence Office Buildings 1976
Leonrdo Savioli

Center of Visual Arts 1978
Norman Foster

Lloyd`s of London 1978
Richard Rogers

Hampstead House 1979
Wendy Foster & Norman Foster

Bridge of Houses 1979
Steven Holl

1980

Center Police Station Belgrad 1983
Spasoje Krunic

Berlin Wall Housing 1986
Morphosis Architects

Government Offices 1970
Alison & Peter Smithson

Expo Tower & Takara Beautilion 1970
Kisho Kurokawa

Responsive House 1971
Arata Isozaki

Nakagin Tower 1972
Kisho Kurokawa

Shahestan Pahlavi Tehran 1972
Louis Kahn

Weir City 1973
Kazimir Lucheskoy

Pilgrim Accommodation Muna 1974
Kenzo Tange

Aquapolis 1975
Kiyonori Kikutake

University of Hamadan 1977
Candilis & Mandala

Habitat Puerto Rico 1970
Moshe Safdie

Ontario Place 1971
Eberhard Zeidler

Ontario Place 1971
Eberhard Zeidler

Banco Cordoba Offices 1975
Miguel Angel Roca

Antarctica City 1979
Amancio Williams

Plan Tietê 1980
Paulo Mendes da Rocha

Hydropolis 1982
Vittorio Giorgini

Beach Resort Miami 1985
John Johansen

2000

AZM Offices 1987
Laurens Bisscheroux

Module Octet 1991
Vitorio Giorgini

RiverCrane 1993
Vitorio Giorgini

Chemische Fabrik Cologne 1998
Bernd & Hilla Becher

Swis Pavillon Expo 2002
Peter Zumthor

Silodam 2003
MVRDV

Tokyo International Forum 1989
Richard Rogers

Kuala Lumpur Airport 1992-98
Kisho Kurokawa

Hyperbuilding Bangkok 1996
OMA

Port Terminal Yokohama 2002
Foreign Office Architects

Future Systems NASA 1982-1989
Jan Kaplicky & David Nixon

Edge of the City 1990
Steven Holl

Quaderns 1993
Andres Keller & Michael Mackauley

International Space Station 1998
NASA & ESA

Plan for Vigo University 2005
Paulo Mendes da Rocha

Santa Catarina Market 2005
Miralles & Tagliabue

Cancer Centre 2006
MVRDV

Center Police Station Belgrad 1983
Spasoje Krunic

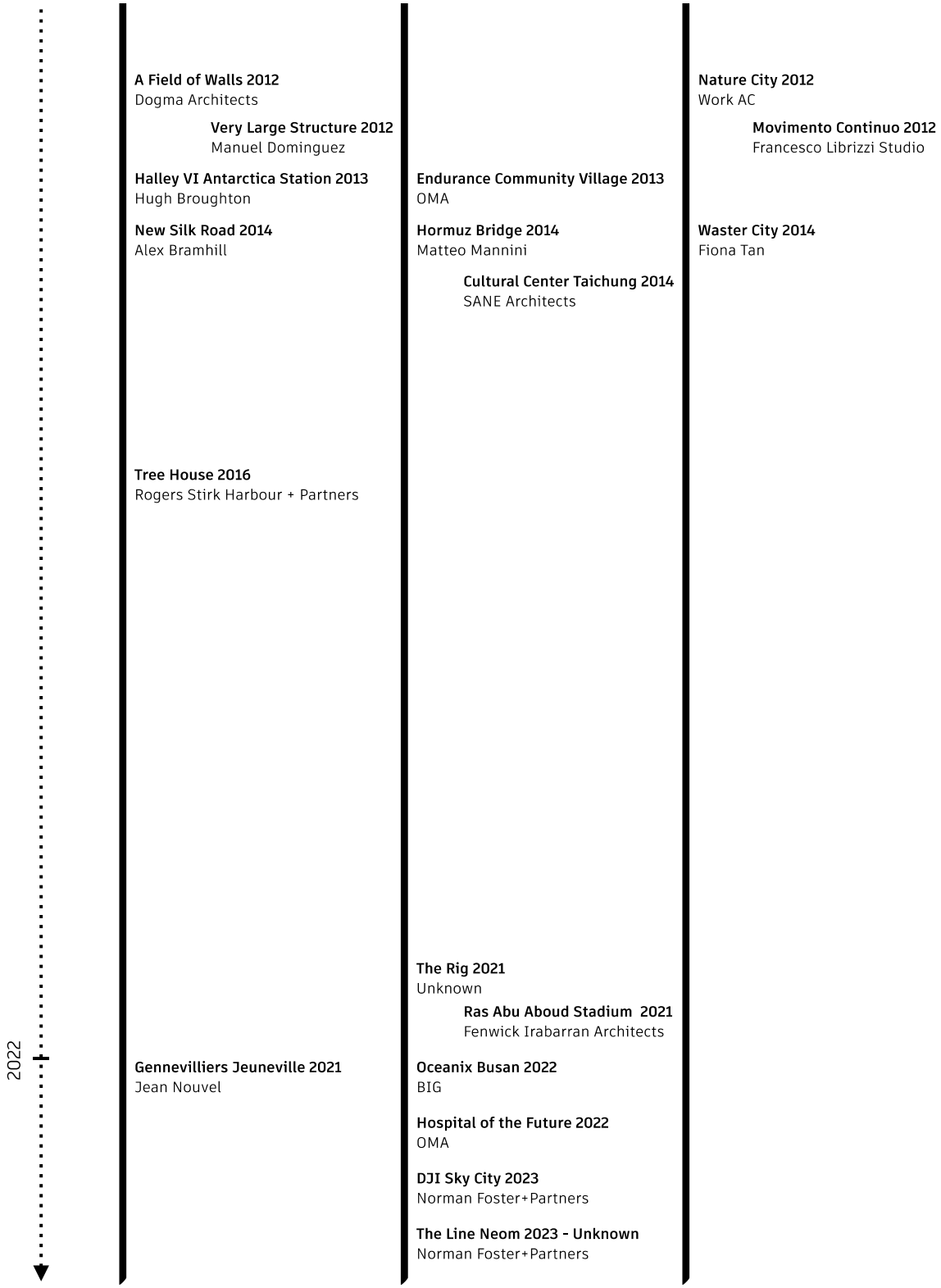
Tatami Mat Housing 1983
Glen Small & Shizuo Harada

2010

Rolex Learning Center 2010
SAANA

Port Terminal 2010
Carrilho da Graça

Metropolis II 2010
Chris Bruden



[Figure nº 5, Chronological *list of referential Projects*, Author , 2022]

linear waterfront centres: case studies

In port cities, their waterfront and port, originally functioned as the true linear centre (and image) of the city. Today we are witnessing a rehabilitation of this central role of the waterfront, even, or above all, when its harbour function has become obsolete or has disappeared for good. This rehabilitation shifts the traditional city centres towards their waterfronts creating new(true) linear centres[15] for a number of reasons. One reason is the redevelopment of old industrial areas that were previously located on the waterfront into mixed-use residential, commercial and recreational areas. Their development generated an increase of tourism and local economy which led to a high demand for waterfront property. Another reason can be explained by the proximity of the water element, which makes them desirable and qualitative places to live and work. During the last decade and considering the Portuguese context, cities such as Lisbon or Porto confirm this evolution, towards a new linear waterfront centre, incorporating the mentioned factors. On a global scale, cities such as New York City or Shanghai show that their waterfronts have undergone the same significant changes. In the past, waterfronts were seen as hubs for logistic, political and social activity. Economic growth, together with technological advances in maritime transport, notably the universal adaptation of the shipping container as a volumetric standard. The progressive increase in the size of merchant vessels, led to the need for larger or expanding ports which established distinct physical and functional dimensions to incorporate their port activities.[16] New harbour infrastructures are regularly built far from established urban areas, freeing up large waterfront areas previously off-limits to the city.

As a result, these cities began to revitalise their waterfronts, turning them into destinations for residential and commercial development, as well as recreational activities. Today, their waterfronts are an important part of the city's governance, economy and culture.

the big u

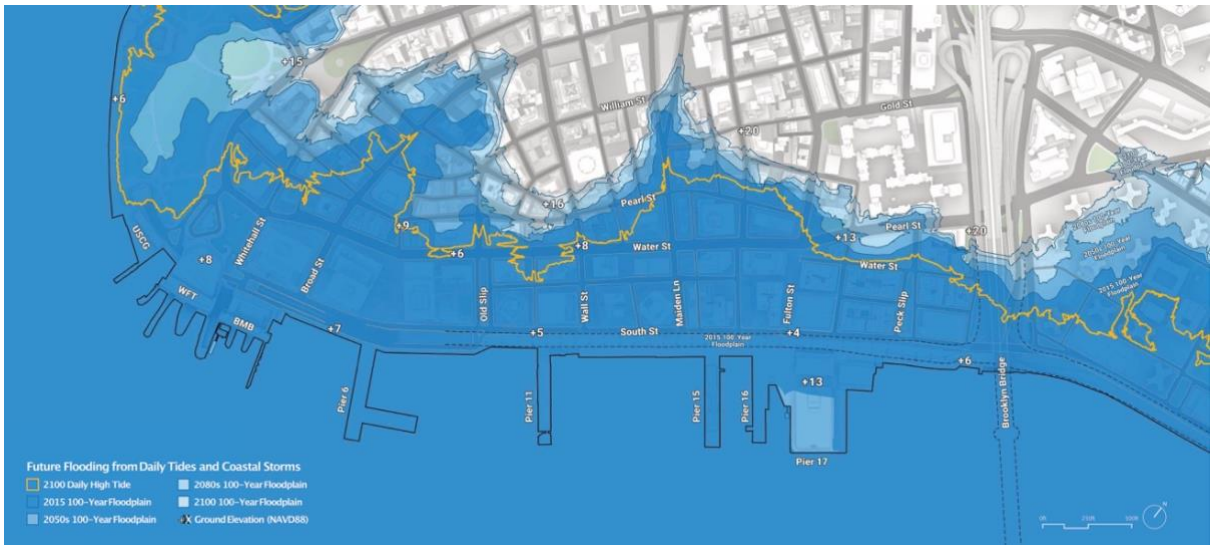
One strategy being used in New York City, is the implementation of a coastal protection system, known as the 'Big U'. In response to the threat of sea level rise this $500 million dollar project includes the construction of a series of seawalls, parks, and green spaces along the city's waterfronts

[15] Linear centres theory in urbanism is a concept that suggests that cities should be developed along a linear axis, rather than a central point. The theory proposed by the urban planner Constantinos Doxiadis in his book 'Ekistics' in the 1960s. Doxiadis argued that linear centres would be more efficient, as they would reduce the need for long commutes and would make it easier for people to access the services they need. Additionally, linear centres would also promote the development of smaller, more sustainable communities, rather than the sprawling urban areas that often result from a focus on a single central point. (Rezende, 2016, pp.252)

[16] Hoyle research is based on the evolution between global port cities, analyzing the functional, physical, and social dimension between the port and their urban habitat. He compared the European/American to Asian approach referring to the fact that modern western port terminals shift from the urban core in order to free initial port areas from their functional and physical dimension in order to redevelop it for urban use. In contrast, Asian port cities concentrates on expanding and including their port with the respective city (Hoyle, 1989, pp. 429–435).

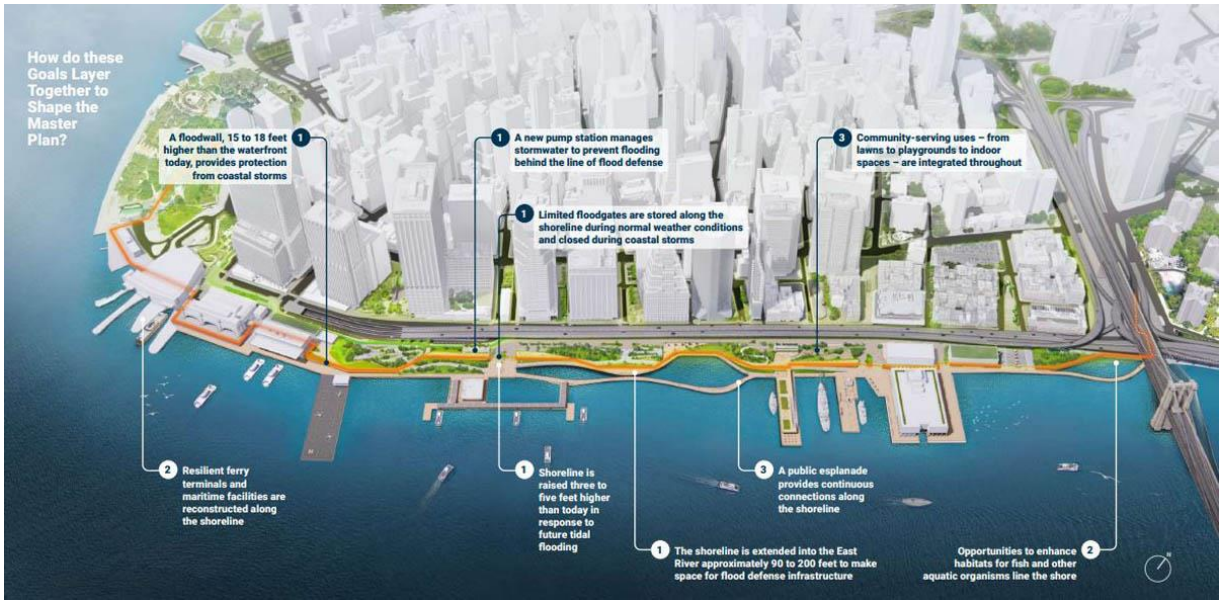
in lower Manhattan and Brooklyn. The project aims to protect the city`s waterfront, while providing new public spaces for residents. The plan is designed to create a 10-mile-long protective barrier around the southern tip of Manhattan, which is one of the most vulnerable areas in the city to coastal flooding. It includes the creation of a series of interconnected parks and public spaces along the waterfront that will act as natural barriers and absorb storm water. The strategy includes the construction of new seawalls, dikes, and other coastal defences, as well as the strengthening of existing infrastructure such as subways lines and roads.[17]

The Big U includes 'green infrastructure' elements, such as the creation of wetlands, rain gardens, and other natural areas that can absorb excess water and reduce the impact of flooding. The use of 'grey infrastructure' such as underground water storage tanks and drainage tunnels to better manage stormwater complements the plan. Concepts such as 'retreat, accommodation and protection' include a focus on making the area more resilient by elevating buildings and other structures, installing flood-proofing measures, and educating the public about the risks of sea level rise and the steps that can be taken to prepare for and adapt to its effects.[18]



[17] Government of New York, 2021. *NYC Comprehensive Waterfront Plan*

[18] Government of New York, 2020. *Waterfront Revitalization Program.* New York City Panel on Climate Change 2020.



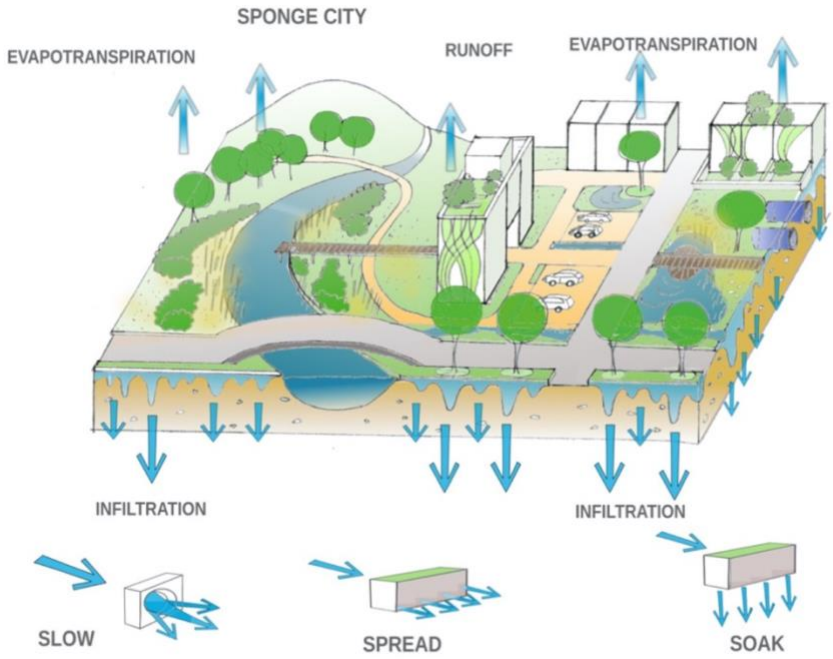
[Figure nº 6, *Map of New York´s Financial District vulnerable areas by a sea level rise*, Government of New York /Author, 2021.*;* Figure nº 7, *3D Model of NYC Comprehensive Waterfront Plan applied in the Financial District*, Government of New York , 2021]

sponge city

The city of Shanghai has adopted the Sponge City Programme (SCP)[19], which was released by the Chinese government in 2014 to design cities that adapt to the global sea level rise and other consequences of climate change. The strategy aims to transform traditional urban areas into 'sponge cities' by creating urban environments that can absorb and store large amounts of water, reducing the amount of runoff and the potential for flooding. This is achieved by incorporating green infrastructure such as rain gardens, green roofs, permeable pavements, and retention ponds into the urban landscape. These features help to reduce the amount of runoff, recharge groundwater, and improve water quality. In addition, the programme promotes the use of low-impact development techniques and encourages the integration of water management into urban planning and design. The Sponge City program is currently being implemented in 24 pilot cities across China, with plans to expand to other cities in the future. The aim of the programme is to create more resilient, sustainable, and liveable urban environments (Yin et al., 2022, pp. 4-8). In the specific case of Wuhan, it turned out to be inefficient, which caused the relocation of 23,000 people to new build part of the city. However, this experience should be understood as an ongoing research project. At this point, we can/should

[19] Zevenbergen, 2018. *Transitioning to Sponge Cities: Challenges and Opportunities to Address Urban Water Problems in China*.

learn from its hypothetical dimension as well as from the problems that have arisen during its implementation *in loco*.



[Figure nº 8, *Illustration of the applied techniques of the Sponge City concept*, Zevenbergen, 2018.]

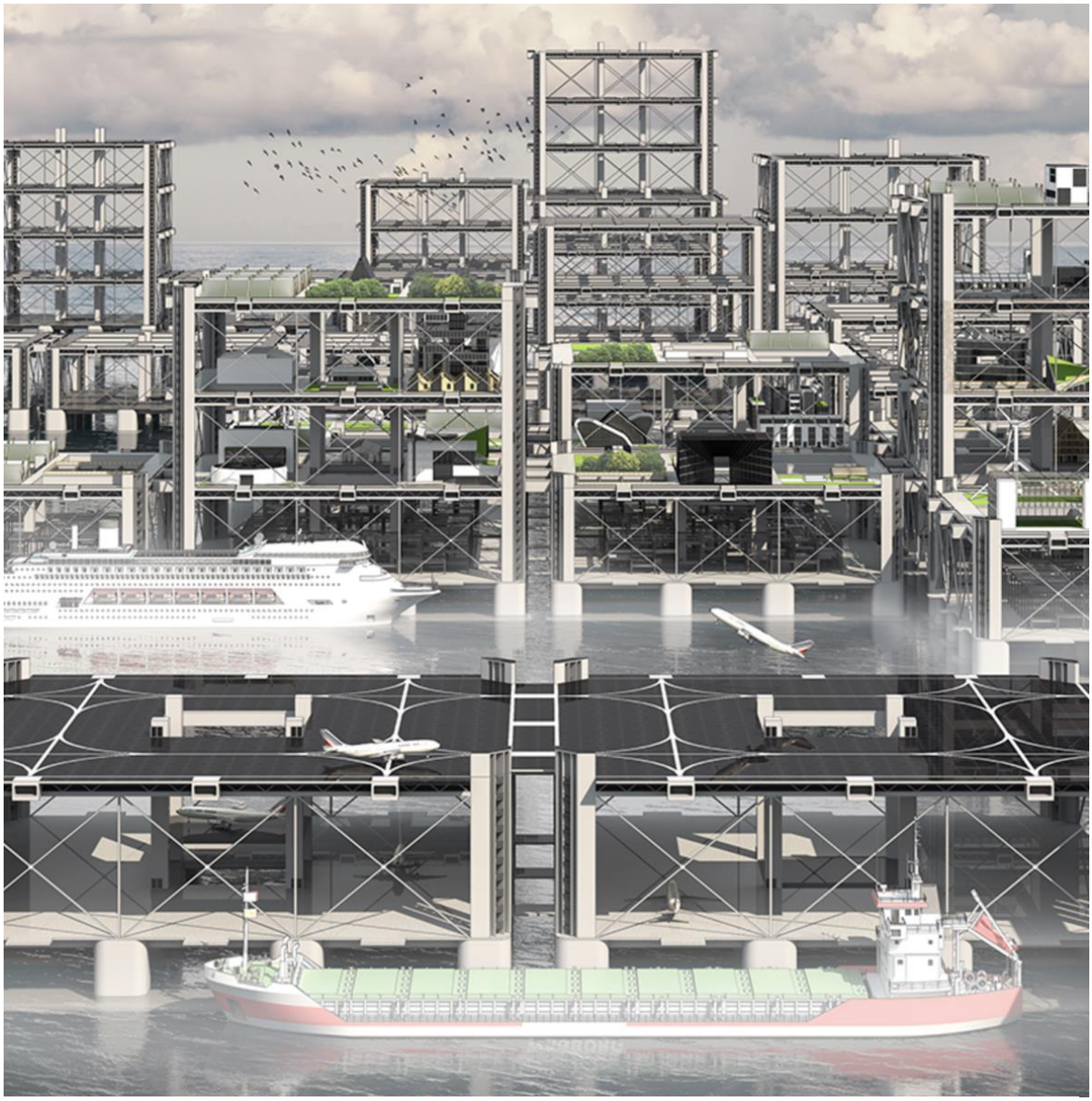
researching responses

The following case studies are based on strategies that can be considered as an alternative strategy to combat the effects of sea level rise. Specifically, case studies that use floating structures; a singular attribute that has the dual utility of contributing to the formalisation of the research working hypothesis and, at the same time, representing a series of prototypes that allow us to judge the merit of this concrete type of architectural response to the problem under study.

The first case study is the 'City of Nowhere' by architect Haoyu Wang.[20] The project was developed in 2019 as part of the master course at the MIT Department of Architecture. Inspired by the megastructure[21] architectonic system of the 1960s and 1970s, combines Constant Nieuwenhuys' *New Babylon* and the Japanese metabolism movement.

[20] MIT Spring Program, 2019. *City in Transition*, 2021..

[21] Megastructure as proposed by Reyner Banham in his eponymous work from 1976 - *Megastructure: Urban Futures of a recent past*



[Figure nº 9, *3D Model of the 'City of Nowhere',* Wang, 2019.]

The project is emerged while analysis of various examples of floating developments and megastructures, representing a wide range of ecosystems, population sizes and contexts. Wang's project revisits the idea of a megastructure but reframes it to address current issues of displacement and placelessness in contemporary society, to be used in different existing contexts. He argues that our ways of living and our social existence are becoming detached from fixed places, due to factors such as pervasive digital technology, social and environmental uncertainties. The design, taking Kiyonori Kikutake's 'Aquapolis' in 1975 as a clear reference, features a series of interconnected, artificial grounds that resemble drilling platforms rising out of the water. As the structures expand, they incorporate various functions such as material circulation, transport, construction sites and

energy networks, similar to the infrastructures of modern cities. The properties built on them are independent of their neighbours, symbolising the displacement and lack of a sense of place in contemporary society. The aim is to attract the attention of people beyond the architectural profession and to stimulate public awareness and debate about the changing world.

The 'City of Nowhere' was chosen at a late phase in the dissertation process for its analogous approach which led to similar conclusion in terms of architectural idea, presented further ahead.

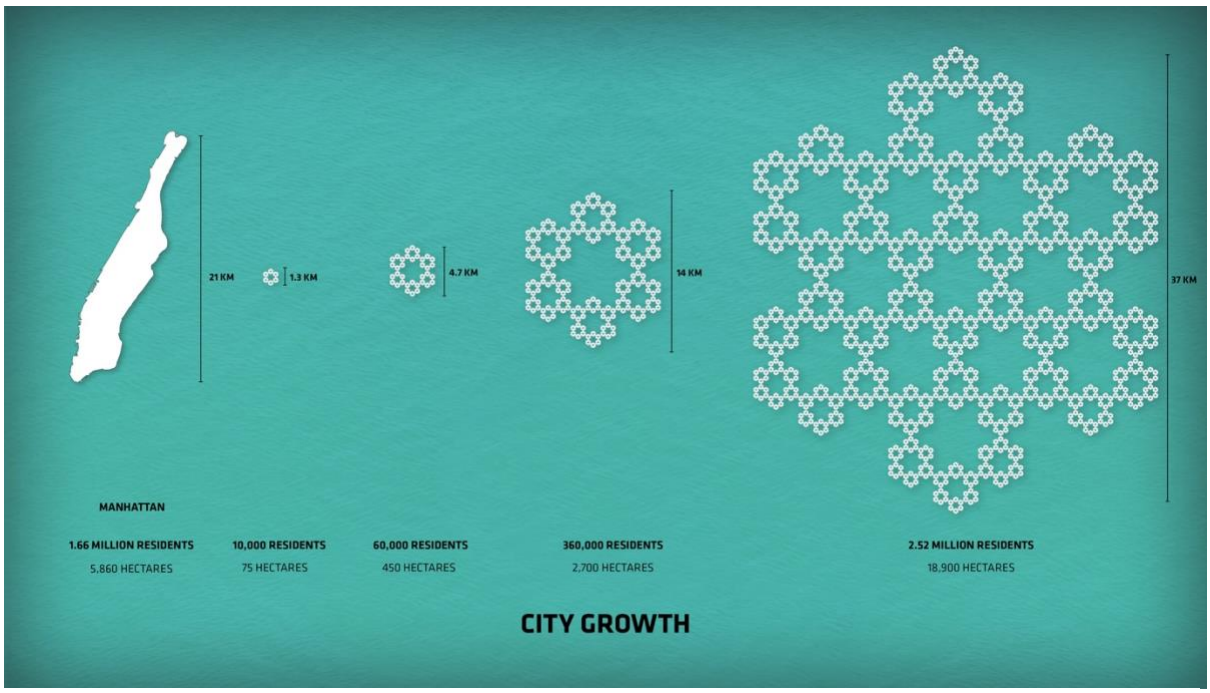
present future

The second case study shows a prototype by Bjarke Ingels Group (BIG), called 'Oceanix City'. It was chosen for its high level of development, flexibility and autonomy. The Danish architect and founder of BIG sought to address the challenges of global sea level rise when designing the prototype, which is will be implemented on the Bay of Busan, a city of the Republic of Korea. The project is at the intersection of architecture and marine engineering. The aim of the project is to face the rising sea without applying heavy intervention on the existing context.

[Figure nº 10, *3D Model – Aerial view of the Oceanix City* , BIG Architects, 2022.]

The 3 hectares collegiate neighbourhoods will accommodate a community of 12,000 people as an initial set-up. All modules are designed to be functional for living, research, and housing. Each neighbourhood, between three and four hectares, presents a mixed-use programme. Linked to land by connecting bridges, the floating platforms create protected blue lagoons that frame floating outposts for recreation, arts and performance (Oceanix Busan, 2022). The buildings, limited to 15-20 metres on each platform, feature a composition of terraces that contribute to indoor and outdoor

living, helping to dynamise the network of public spaces. Oceanix Busan will change organically over time adapting to the demands of society. The referred initial set-up consists of 3 platforms that have the potential to expand to more than 6-8 times its size as it evolves. Numerous productive outposts accompany the floating platforms with photovoltaic panels and greenhouses that can expand and contract over time according to the needs of Busan's users (Bjarke Ingels Group, 2022). The prototype to be realised has six integrated systems: zero waste and circular systems, closed water systems, food, net zero energy, innovative mobility and coastal habitat regeneration. These interconnected systems will generate 100% of the required operational energy on-site from floating and rooftop photovoltaic panels. Similarly, each neighbourhood will treat and replenish its water, reduce and recycle resources, and provide innovative urban agriculture (Bjarke Ingels Group, 2022). Besides these self-sustainable characteristics, the significant advantage is its 'scalability'.



[Figure nº 11, *Scheme of Oceanix City´s growth possibility,* BIG Architects, 2022.]

''It can continue to grow or increase depending on the demand", according to Collins Chen, co-founder of the Oceanix Busan. The prototype was planned to be realised as a resilient and sustainable floating community in 2023 but the recent pandemic and current political and economic factors delayed the construction process, and it remains unclear when the first prototype will reach Busan. But according to Katerina V. Berzgachina, UN-Habitat Director of Communications Chief of

Communications and Hwang Hyun-ki, spokesman for the metropolitan city of Busan, the construction is aiming its completion between 2025 and 2028.

Floating communities like Oceanix Busan have been in the collective imagination for decades and not only Hwang Hyun-ki compares the Busan project with the project of "NEOM", in Saudi Arabia, which will supposedly house a floating city on water called "Oxagon".

The presence of a coincidence of concepts refers to a situation where multiple researchers arrive at the same or similar conclusions or research projects. When multiple independent experts arrive at consistent outcomes, it strengthens the validity and reliability of the proposal or concept under consideration.

In July 2022, Carmelo Cascino, PhD in naval architecture, states in his presentation at the BIP "*Cidades de Acolhimento*" at the Instituto Superior Manuel Teixeira Gomes in Portimão, that it is universally accepted that the departure of humanity to colonise the oceans is not only an irreversible fact, but also that we are very close to achieving a technological level that makes this utopia feasible in a relatively short time.

conclusion

Major cities - such as New York City and Shanghai - are developed strategies in order to protect these new linear centres and to prevent the consequences of sea level rise. These strategies aim to combine engineering interventions and the use of green spaces in order to act sustainable for a certain period of time. Although they imply a high static impact on their communities and environment, they seem to be the current reliable approaches related to the problem.

Architectural research and prototypes show the availability and possibility of flexible floating alternatives which would be designed to be self-sustaining and independent. The example of BIG´s Oceanix Busan suggests that the more the architectural response is tested and developed, the more acceptance it generates in order to create more flexible alternatives to the existing problem.

[CHAPTER IV]

PROTOCOL

This thesis chapter explores the understanding of the word 'flexibility' by pursuing the hypothesis, considering the state of art and learning from the case studies. The aim is to establish a foundation for the response in form of an architectural idea.

flexibility

The word 'flexibility' initially came into architectural terminology in the mid twentieth century. Such as other thinkers of his contemporaries, Walter Gropius promoted the concept of accommodating change over time to the forefront in 1954.[22] The idea of flexibility in architecture refers to the ability of design to adapt to the changing needs of their users over time[23].

pre-design & post circularity

During the same period Louis Kahn's ideas about form established a different approach to flexibility but related to each other. Both emphasize the importance of designing buildings that can adapt to the changing needs and uses of their occupants. Kahn believed that form should emerge naturally from the building's intended purpose and function, rather than being imposed upon it. This idea of allowing the function to dictate the 'form', is the foundation of the flexible architectural approach (Kahn, 1955, pp 46-63).[24] Form should be seen as catalytic agent, able to become a property of society (Maki, 1964, pp.20-21) acting flexible according to the changes of space and time. Architects like Le Corbusier and Mies van der Rohe developed manifestos to provide quick response and adaptation, generating theories like the '*Wohnmaschinen*'[25] (Seelow, 2018, pp. 2-18). In 1956, Yona Friedman introduced the idea of mobile adaptive architecture[26], which proposed that architecture could react to social changes. This can generate reflections on how society perceive flexibility.

With the beginning of this millennium, French art critic and curator Nicolas Bourriaud, developed the theory of post-production[27]. A term that refers to the process of repurposing and remixing existing elements in contemporary art defining its culture. He contends that, in the age of the internet, culture is no longer primarily based on original production, rather on the repurposing of existing materials. Recycling and reusing are the fundamental laws of nature to achieve flexibility. characteristics that gave birth to the concept of circular economy. Based on nature's flexibility,

[22] "The architects have to conceive a building not as a monument, but as a receptacle for the flow of the life which they are to serve, and that his conception should be flexible enough to create a background fit to absorb the dynamic features of our modern life."

[23] Through the last decades the term incorporated different approaches included but are not limited to modular, multi-functional or changing spaces, but also adaptable infra-structure systems that can adjust to different occupancy patterns and uses, reducing the need for costly retrofits in the future. More recent flexibility approaches are using smart technology, automation and integrated systems.

[24] In 1960 Louis Kahn's theoretical concerns began to focus on a concept which he called 'form', not meaning a building's three-dimensional shape, but the essence of its underlying type. " (2003, Fleming SP, PhD Thesis)

[25] *German term translated into' Constructional Kit' developed 1922 by Walter Gropius* (Petrs, 2020, pp. 27).

[26] At the *Congrès International d'Architecture Moderne Nº10 C*onference with his revolutionary pamphlet (Petrs, 2020, pp. 29).)

[27] The theory of post-production is an attempt to understand how the digital age has affected the way we create, consume, and understand art and culture and how humans as producers are responding to a constant changing context (Bourriaud, 2002, pp.10).

circular economy explores strategies applicable in urban environments, from architecture and construction materials to energy production, waste management and food production, as well as the processes and operations of a constantly adapting construction. The circular economy concept is much more complex, presenting multiple ramifications involving paradigm shifts in urban environment's` design and functions which are still not fully explored. Such theories (i.e. Kahn, Friedman, etc.) serve the entire design process (i.e. Bourriaud), helping to define the architectural idea. The interconnection between these two aspects plays a important role in shaping the outcome of the architectural response.

conclusion

The existence and link between the design process and the architectural idea are of equally important in order to work with interdisciplinary theories, related to each other. They highlight the importance of flexibility incorporated in our contemporary society. The need to design a sustainable world, by limiting produced resources and acting according to the needs of the society where architecture has always responded in spirit of time.

[CHAPTER V]

THE BIPOLAR ARCHITECT[28]

Throughout this dissertation, the use of research by design as the methodology emphasises the iterative and collaborative process of designing, aiming to produce reliable research results. In the following chapter, we will explore the relationship between research by design and other design precepts and processes, including flexibility, parametricism and mathematical chaos.

complex evaluation

The paradigm that starts how architecture deals with a problem, leads to two fundamental reflections: How do we perceive or define the problem[29] and how do we respond to it.

In the thesis case the definition of the problems itself follows the premise of 'wicked' problems as discussed by Rittel & Webber (1973). Wicked Problems synthesizes something that seems to fit perfectly in the architect's mental process by accurately describing the type of problems that the researcher-designer faces.

[28] According to the research of Gardner Murphy (1962), the cognitive process would be bipolar; that is, it is influenced not only by the external world but also by the internal needs of the individual (Bohemia, et al, 2012)

[29] Wrong-structured problems cannot lead to solutions that require clarifying and redefining any existing problem (Rowe, 1992, pp.19).

Wicked problems are described as complex, open-ended and systemic problems that are difficult to define, solve or even understand. (Danish Design Centre, 2023)

From the perspective of architectural design, wicked problems are characterized by multiple, interdependent factors, incomplete information, and conflicting values and interests. linked to social, political and environmental constant changes which make them resistant to linear problem-solving approaches. Karl Mannheim's theory of utopia and ideology states that utopian thinking is a necessary aspect of social change. According to Mannheim utopian ideas criticize the existing social structures and institutions from which it seeks to distance itself by offering an ideal community. It follows that utopia has a strong connection to reality, which is generated by a crisis situation in which the untenability of the old situation manifests itself as an objective contradiction (Mannheim, 1929, pp. 169-173)

The research by design method, uses the design process as a tool for investigating and addressing complex issues. It is an approach to design, that emphasises the importance of an iterative and reflective process of inquiry and experimentation, creating an experimental interface. It turns out to be particularly useful for addressing wicked problems by allowing architects to explore multiple design alternatives, test their feasibility, and evaluate their potential impact. Design thinking consists of concentrating on methods and establishing a mindset to help designers understand their mental mechanisms. Architect Jones C. J. observes two design methods in practice: black box and glass box. The black box approach happens when complex, wrong-defined problems and solutions appear within the designer’s mind. The glass box approach is achieved when a problem is defined , and the response is understood in terms of the problem. The glass box approach involves a planned sequence of logical steps in contrast to the black-box approach, where all design steps are internal to the designer and not open to the rational or empirical process (Jones C. J. , 1992 in: Smith, Moore & Zhao, 2017, pp. 398).

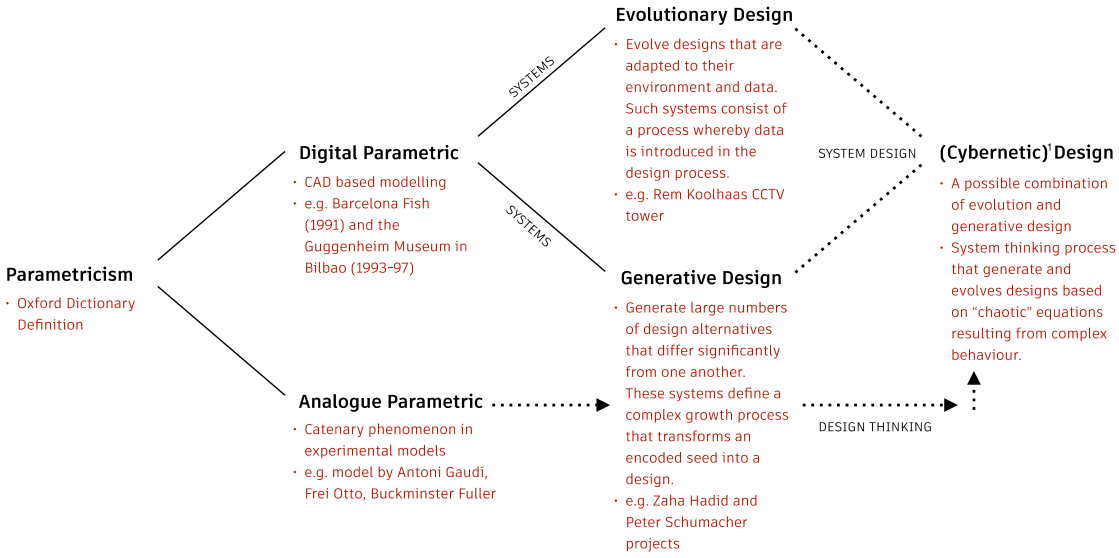
Architect and educator Jeremy Till argues that the design process is not a straightforward, linear process, but rather a complex and iterative one. He defends that the design process involves a constant back and forth between different stages, and that the designer's decisions are influenced by a number of factors, including context, constraints and intuition. Embracing contingency and flexibility, having in mind a utopian uncertainty and ambiguity, rather than a linear ideological process. Jeremy Till argumentation of the design process is recurringly linked to the idea that a building should not be seen as a fixed object, but rather as a 'field of operation' that can be configured in different ways to be socially and structurally responsive. He believes that flexibility should be an integral part of the design process from the outset, rather than an add-on or afterthought (Till & Schneider, 2005).

chaos and order

Since the early 1990s, the computational approach to design, known as parametricism, has become a prominent complementary design technique (Rowe 2017, pp. 11–15). The term parametricism[30] refers to the use of parameters[31] and algorithms to generate and manipulate design elements and forms. It allows architects to create complex, responsive and highly customised designs that can adapt to specific site conditions, user needs and performance criteria. Simultaneously and iteratively, the test procedures are applied to the generated multiple possibilities or prototypes until the performative and formal requirements are achieved. In my opinion, the combination of research by design and parametricism can lead to solutions that respond to the specific needs and context of a project. It allows architects to explore a wide range of possibilities and find the optimal solution, rather than being restricted to a single preconceived idea.

[30] The term parametric originated in mathematics, but there is some debate as to when designers first began to use the word. In 2005, David Gerber, credits in his doctoral thesis 'Parametric Practice', Maurice Ruiter as the first user of the term in a 1988 paper entitled ʻParametric Designʻ. However, in 2006 Robert Stiles argues that the true origin of parametric design is dated several decades earlier, in the writings of architect Luigi Moretti in the 1940s (Bucci and Mulazzani, 2000, pp.21).

[31] Simple parameters are used to describe relation between base points and the surface based on these points. This method attempts to create a graph hierarchy where the location, shape and size of some objects depend on the basic elements.



[Figure nº 12, *Graph of the general evolution of parametricism and possible interpretation by author for a complementary tool combining research by design as methodology,* Author, 2022.]

Most of the applied algorithms in parametricism are linked to linear simple equations with logic outcomes[32], in order to generate designs, which turns the process still static.[33] Substituting these simple equations with mathematical chaotic algorithms can help to explore complex behaviour and include it the design process. Complex and chaotic systems give rise to simples behaviour and simultaneously, hold the laws of universality (Gleick, 1987, pp.304). A superficial study of many of Islamic and western cities, helps to understand the chaotic nature behind its structure and morphology which is the result of a deep underlying structure (Hamouche, 2009, pp. 217-238). From Islamic cities, characterized by their irregularity to partially planned cities like Serda´s Barcelona, show this phenomenon. Another possible example is the difference between the planned[34] square[35] and the generated plaza[36]. The square was designed before it existed, but the plaza is designed after it exists. Conversely to the square, the plaza emerges as compounded spatial result based on a formal

[32] Logic based professions and even some mathematicians had overlooked complex systems and their chaotic behavior because of the lack to explore disorderly systems (Gleick, 1987, pp.76).

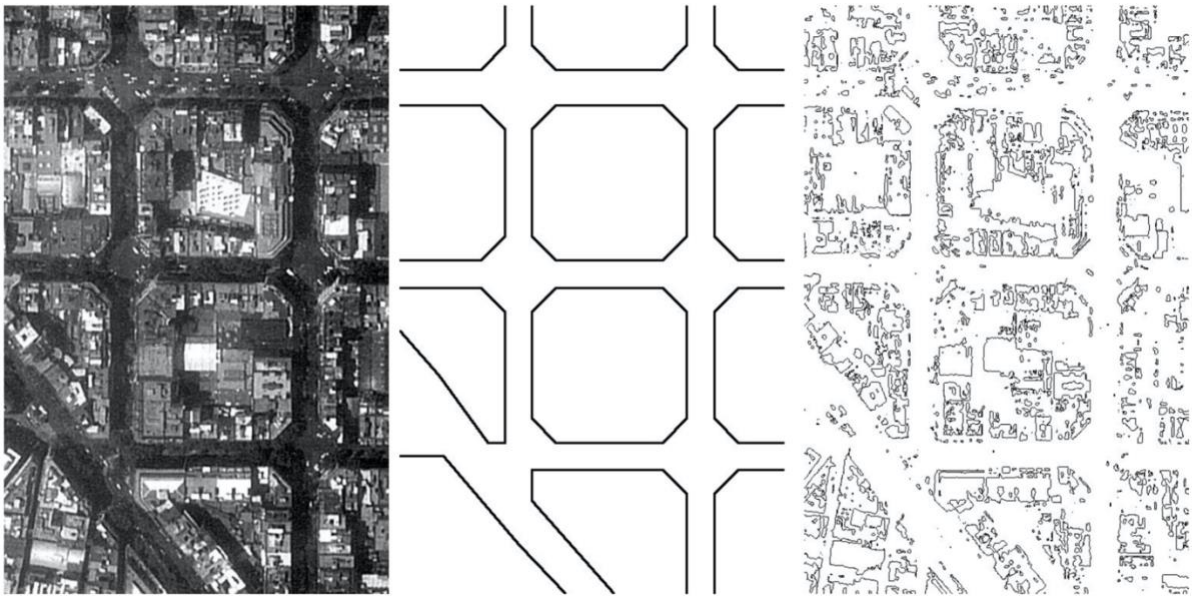
[33] Many things in nature don't act this way. Whenever parts of a system interfere, or cooperate, or compete, there are nonlinear chaotic interactions going on. Most of everyday life is nonlinear (Storgratz, 2015, pp.8-9).

[34] refers to the intentional and systematic pre-design

[35] translated by the author - refers to the Portuguese word *praça*

[36] translated by the author - refers to the Portuguese word *largo*

layout with geometric and structured patterns applied in the city. This process is the essential law of mathematical chaos.



[Figure nº 13, The analysis of the urban structure of a region in Barcelona, Spain: the aerial view from the 90´s (left); the geometric synthesis(middle); the inner complexity and chaos of the living space inserted in the urban structure , Rubinowicz P., 2000.]

conclusion

In conclusion, architectural design solutions are negotiated between problem description and response. In this thesis, the 'design' is a task that involves defining a description of a problem and then generating and searching amongst alternatives to find a solution that satisfies the problem. 'Parameter' has been described as any measurable factor that defines a system or defining its limits. The combination of research by design methodology and parametricism can help to design the city as a result of applied order through mathematical chaotic mindset. Chaos and order interact and come together to constitute the balanced of the urban fabric.

[CHAPTER VI]

FREEDOM AND CONTROL

The concept of flexibility already established strong roots in architectural theories and models. Hierarchising control while allowing freedom is i.e., a structuralist stance that involve setting certain parameters or constraints that guide the design and construction process, while still allowing

flexibility within these parameters.[37] Structuralism, as a design philosophy, emphasises the importance of an underlying structures, systems and its transition to practice.[38]

serving the servants

John Habraken's distinction of three autonomous layers: building, subdivisions and furnishings (Lopes & Correia, 2017, pp. 89-108) was influenced by Gerrit Rietveld's Schroeder House's substantial flexibility and the Dutch structuralist tradition of Aldo Van Eyck, Piet Blom and Herman Hertzberger. The proposals distinguished permanent ''hard core'' and flexible and changing interiors. Similarly, the megastructure is defined by an extensive system in which all city or district functions are incorporated, an anthropogenic landscape, independently from its scale. Reyner Banham accompanied the evolution of the megastructure in his own critically way. Banham himself avoided defining his terms in his monograph on megastructures. Instead, he provided the definitions of Fumihiko Maki's (Rouillard et al., 2018, pp.37) introductory chapter from Investigations in Collective Form of 1964[39] and a definition by Ralph Wilcoxen from his 1968.[40]. Reyner Banham points out the four key concepts of Megastructure by referring to Ralph Wilcoxon's definition on Megastructure in the book, A Short Bibliography on Megastructures (Banham, 1976, pp.8).
Wilcoxon's definition of Megastructure is described as (Wilcoxon, 1968, pp.2):

- Constructed of modular units;
- Capable of great or even 'unlimited' extension;
- A structural framework into which smaller structural units (for example, rooms, houses, or small buildings of other sorts) can be built – or even 'plugged-in' or 'clipped-on' after having been prefabricated elsewhere;
- A structural framework expected to have a useful life much longer than that of the smaller

[37] For example, a building project may be guided by certain sustainability principles, such as the use of renewable energy sources, the reduction of waste and pollution, and the promotion of biodiversity.!

[38] The structuralists, such as TeamX, etc., used the different hierarchies of spaces in a building as a guide to defining its spatial structure and, ultimately, to defining its form. Louis Khan, contemporaneously, speaks of spaces that serve and spaces that are served.

[39] The megastructure is," says Maki, "a large space structure that houses a city or part of a city. […] In a sense, it is a man-made contribution to the landscape. She's like the big hill on which the Italian cities were erected." (Van der Ley & Richter, 2008) Fumihiko Maki describes the megastructure is a large frame in which all the functions of a city or part of a city are housed. Composed of several independent systems can expand or contract and move into ever new states of equilibrium. A structure that permits the greatest efficiency and flexibility with the smallest organizational structure (Maki, 1964, pp.11).

[40] The model of megastructure was distinguished by four major characteristics according to Wilcoxon. It is 1) constructed of modular units; 2) capable of great or even 'unlimited' extension; 3) a structural framework into which smaller structural units (for example, rooms, houses, or small buildings of other sorts) can be built—or even 'plugged-in 'or 'clipped-on 'after having been prefabricated elsewhere; 4) a structural framework expected to have a useful life much longer than that of the smaller units which it might support." (Rouillard et al., 2018, pp. 37)

units which it might support

This type of framework allows the structure to adapt to the individual wishes of its residents, even as those wishes change with time Banham mentions that Wilcoxon's definition is invaluable because its emphasis is not only on the distinct hierarchy of structural frameworks, "dominating frame" and "subordinate accommodations," but also on the different characteristics of the two: "permanent" and "transient" (Banham, 1976, p.9).

Learning from Structuralism and megastructures can help to design distinct but complex spaces, solid but adaptable (Lopes & Correia, 2017, pp.66-71). Both concepts represent a departure from traditional architectural and urban planning practices, which tend to prioritize stability, permanence, and fixed structures over flexibility and adaptability.[41]

The ideal form is a multipurpose guiding system, which can achieve functional equilibrium in the long term.[42]

Giving a megastructure a floating property enhanced these key-features significantly which will be evaluated in further chapter.

intelligent ville dérivée

During the 1950s and 1960s, Constant Nieuwenhuys, not an architect but a plastic artist, developed 'New Babylon'. An idea of a constantly evolving, mobile and autonomous city built from prefabricated modules. 'New Babylon' is seen as a continuation of and response to the theories and practice of the avant-garde group called 'CoBra', and the International Situationism movement. A tentative not to create architecture rather than creating communities.[43] In his text Diagram of Utopia, Anthony Vidler describes New Babylon as "clever use of already-known architectural parts in order to fabricate a new unknown. Vidler explains recognizable influences by Chernikov's or Leonidov's constructivist ideal cities, 'megastructures' of van Eyck, Bakema, Woods, Yona Friedman and even Alison and Peter Smithsons mat-buildings (Vidler, 2000, pp. 83-89). Ignoring the political and economic

[41] British architect Cedric Price whose work investigated how architecture might promote social change through its adaptiveness, collaborated with theatre producer Joan Littlewood, for the project of the Fun Palace, in 1961-1976. It was sought to integrate concepts of social participation and improvisation with technological interchangeability to produce a highly responsive environment. Price conceived the project in terms of process, with a core design principle committed to indeterminacy, thereby embracing the nascent fields of cybernetics, computer technologies, and game theory (Mathews, 2005, pp. 73-91). Price as fully convinced about the flexibility, took himself part in the campaign for pro-demolition of the Inter-Action Center in London. Exchange increases the range of possibilities of an object or structure, for it allows it to support more than a single value. The architect understands exchange as the capacity to confront, relate, and incorporate other objects, structures, and people in an interface, and therefore as a process of constant revision that assures the contingency and non-solidity of a building (Vodanovic, 2007).

[42] The Plan Obus by Le Corbusier can be considered a precedent for this idea (Pinto de Carvalho, 2021, pp. 120).

[43] Recent Critique made by Norman Foster in the 2023 Conference to Sustainable Housing

viability, New Babylon was confronted by problems of insufficient technical possibility, like an elf-reconfigurable modular system.

The fluctuations of society and technological progress have triggered the need for adaption, flexibility and reversibility to act controlled in space but free from constant and fast changes.[44] This need introduces the term ''intelligence'' or commonly 'smart' into architectural paradigm. Intelligence describes the ability to learn, understand and conclude. Applied to the city, it consists of digital tools which allow the optimisation of its functioning and sustainability, as well as of its 'inhabitants' quality of life and their relationship with each other and the city (Picon, 2015). In the intelligent city, some mechanisms for learning, understanding and reasoning are internalised, and they become intrinsic to the city itself, which allows a constant constructive automated evolution of the city, depending on the behaviour and changes of their community.

conclusion

The roots and evolution of the presented theories allow us to consider that design might begin with the conscious (or unconscious) attribution of values to parameters describing requirements of the design problem and the constraints that limit the range of possible design solutions (Schumacher, 2009).

The dissertation aims to investigate and develop an architectural prototype[45] in form of a prospective nature on the way, towards an amphibian shift.[46] The precept is flexibility, not evasion or manipulation. The option of a floating megastructure arises from the fact that this architectural typology is not only naturally highly resilient to sea-level change, but also because it offers flexible and responsive characteristics: Changing needs and patterns, adaptably[47], ability to transform and move and constantly interact with the community.[48]

[CHAPTER VII]

[44] This idea of an architecture in which time is built into form as memory has been a persistent theme throughout its history, but it was Sigfried Giedion in both Mechanization Takes Command (1948) and Space, Time, and Architecture who established these themes as the primary concern of twentieth-century architectural theory and design (Lynn, 1999, pp.11).

[45] The exploration of floating architectural prototypes can communicate the architectural idea and every prototype should be tested, verifying if the necessary conditions are valid in order to be applicable to the suggested architectural idea (Raisbeck & Kaji-O`Grady, 2005).

[46] Stefan Huebner (2020), the environmental historian at the National University of Singapore Research Institute, published an article in Cambridge Press where he assumes that the world and riverside urban centers are undergoing an 'amphibian transformation' that radically changes the idea of how we should think about future interventions.

[47] Characterization of flexibility in the context of housing (Schneider and Till, 2005, pp.1)

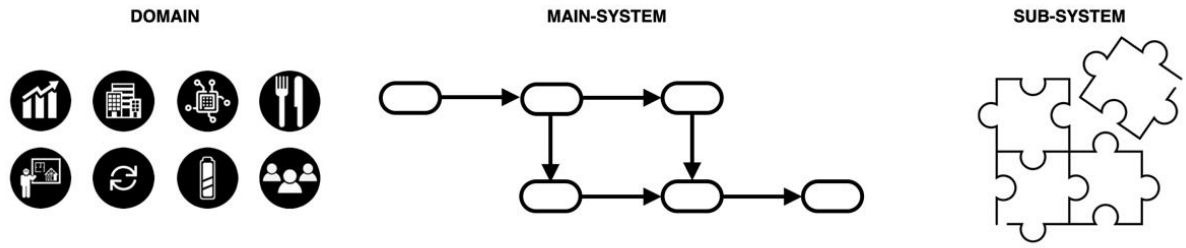
[48] Robert Kronenburg, Chair of Architecture at the School of Architecture, University of Liverpool, described flexible architecture as “buildings that are designed to respond easily to change throughout their lifetime,”(Kronenburg, 2013, pp.2)

HUMAN COMPLEMENT SYSTEM

Throughout history, models have been proposed that have been improved to support human needs, approaching and interacting with its natural habitat - the city.

Functionality and the importance of the community led to architectural ideas developed by French utopian socialism based on the study of Fourier and later Godin.[49] This ideal did not succeed, but the hypothesis of creating a multifunctional structure that brought together the various urban activities and acted as a complement to the existing urban or rural environment was indeed later explored by Le Corbusier (Dzwierzynska & Prokopska, 2017, pp.2-6). So called 'unbuilt' projects still allow us to learn from it, not as an ideology, but rather as the plausible utopia it is (Wigley, 1998, pp. 5).

The following architectural idea in the form of a floating megastructure creates a self-sustaining, dynamic system of integrated construction, densification and interconnection of all functions in space and a continuous adaptation to changes over time. A megastructure consists of several individual and independent systems that are interrelated and can grow and shrink. The nature of the relationships varies, but the contact must be dynamic, and the development or optimization must be continuous. An efficient classification system needs to be developed. The most efficient system would be the one with the least organizational structure.



[Figure nº 14, *Schematic classification of applied system within the megastructure,* Author, 2022.]

This ordering system should regulate the relationships between the systems and determine where physical connection points between the systems can arise, which would form the framework. An ideal system as a master form which, in the long run, constantly renews itself and is thus always in balance, without losing its aesthetics or order (Maki, 1964, pp. 11).

[49] Apollo Art Magazine. Stamp, 2013

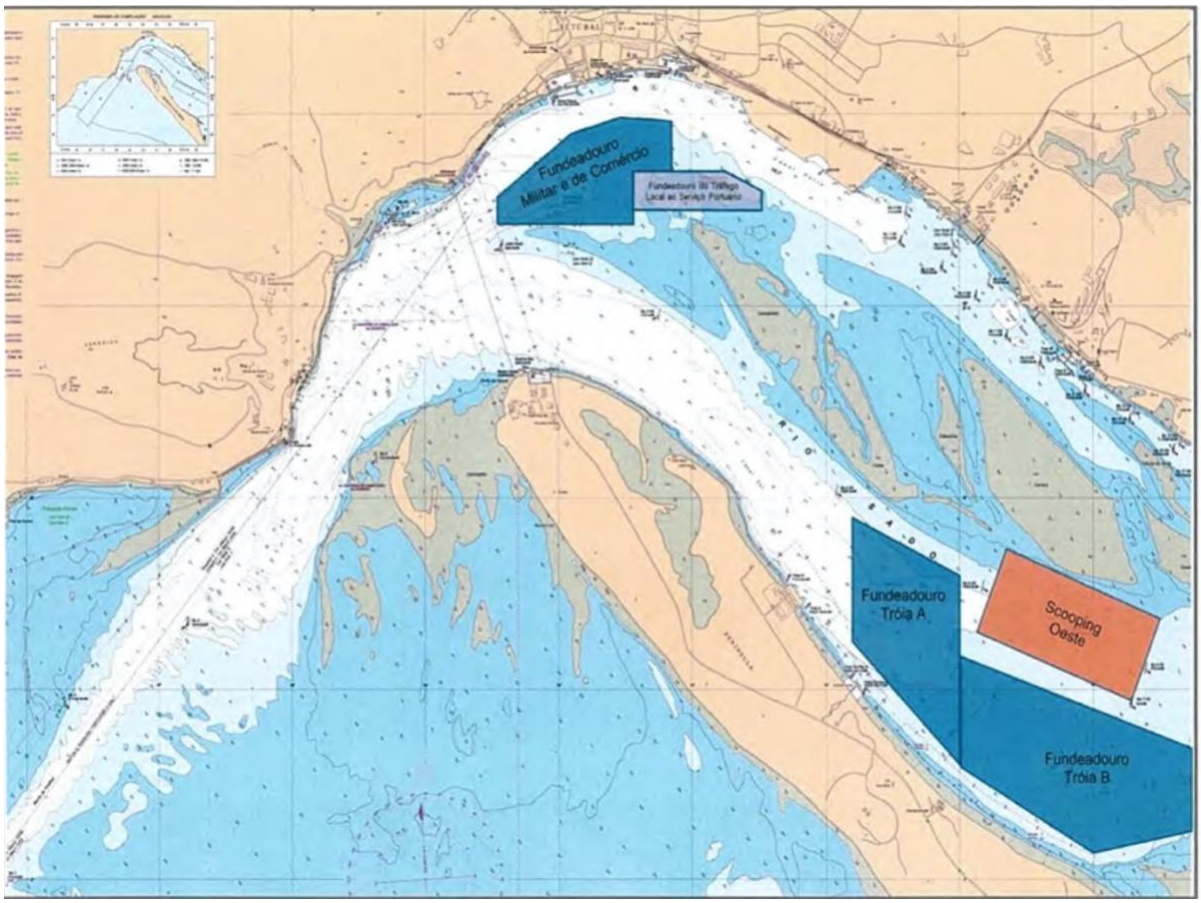
The floating megastructure, like the city, is defined by its infinite expandability, modularity and freedom through its open structure. Space becomes a network of aggregates, a free organisation of living cells. Modularity, adaptability, self-assembly, community and taking advantage of a floating structure to reinterpret and complement the city of Setubal were the basis of the design process.

With the environmental changes on one side and the social changes on the other side, the alternative of 'living on water' can bring the opportunity to start with a better understanding of adaptation and at the same time recognize the liquid territory as an asset.

system first

During the process of this research by design investigation it became clear to first established and design some of the cardinal rules of the system.

Find a set of rules that define~~s~~ the network of the floating megastructure, in order to promote connectivity and ability of increase and decrease of the network. This includes a wide spectrum of questions, from scale, volumetry to materiality, connectivity, mobility, etc. When designing a viable system that seats on water, characteristics based on the Sado estuary's natural and ecological properties should be harvested order to inform and evaluate the most promising solution. This includes hydrodynamics and existing ecosystems.

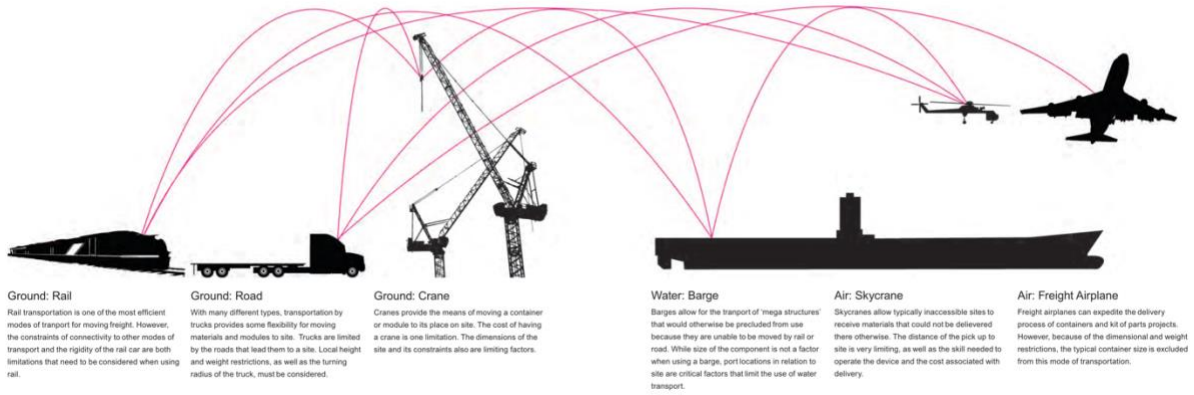


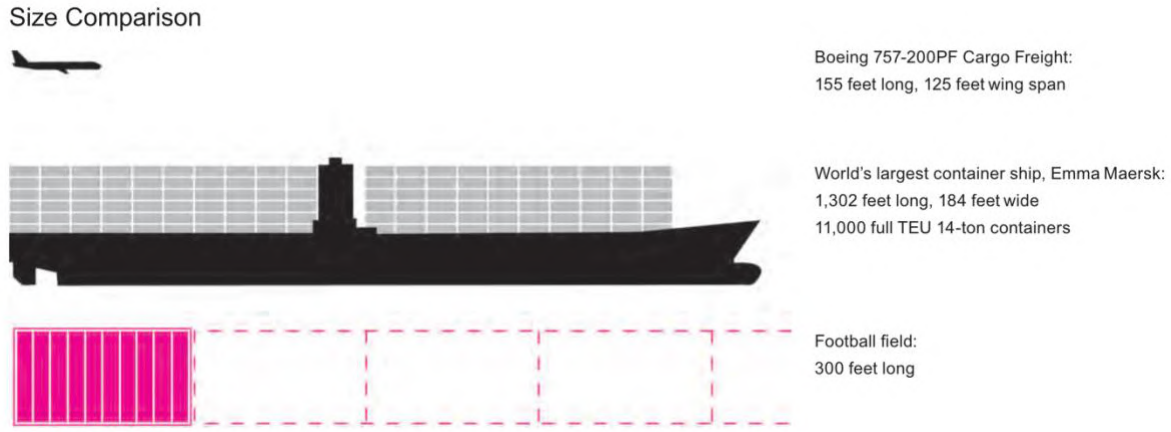
[Figure nº 15, *Nautic map of the Sado estuary ,* MARETEC, 2020.]

As part of a systemic process the logistic factors of the construction to the site (land or water) should be included as well, and, at the same time, be aware that they are constrained by several factors.

ISO shipping containers are standardised high-capacity containers made of steel that enable goods to be loaded, transported, stored and unloaded quickly and easily. The relevant standards (e.g., dimensions, brackets, stack-ability) were agreed upon in a coordinated manner by the International Maritime Organisation (IMO) and are specified in ISO standard 668. Containers for air freight are standardised according to the International Civil Aviation Organisation (ICAO) standards and are subject to other rules. A common ISO container can be 2.4384 m wide, 2.591 m high and present a length of either 6.058 m (20 ft) or 12.192 m (40 ft). Adopted practically to all heavy transport, such as trains and road vehicles, designed to adapt instantly to the volume and weight of ISO containers. This inbuilt mobility is crucial for the development of metamorphic megastructure.

The objective is to create a modules and construction elements and methods, which adapts to these factors, take advantage of the worldwide logistic standards and infrastructure. This facilitates and reduces resources in many ways (Northeastern University, 2010).





[Figure nº 16, *Schematic representation of current container infrastructure and logistics,* Technical University of Delft, 2019.]

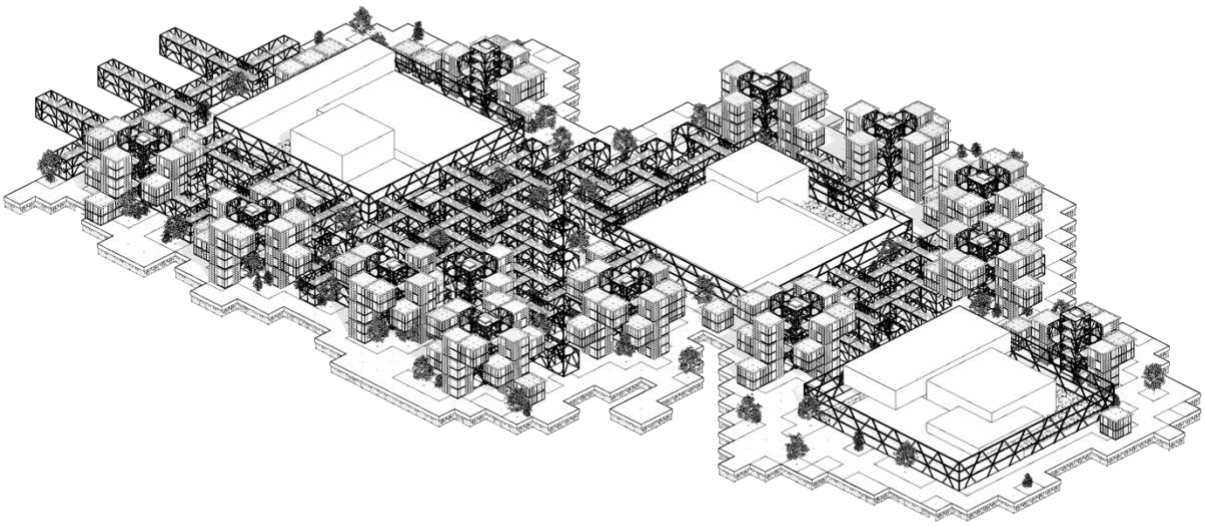
[PROTOTYPE]

The Sado estuary divides two important surrounding urban areas into two different parts. One is the peninsula of Setubal, the other, the peninsula Troía.

[Figure nº 17, *Conceptional representation of the floating megastructures constellation within the territory of the Sado estuary ,* Author, 2022.]

The main key of the proposed floating megastructure is to use the estuary as an urban element in order to merge these two urban areas. Considering that the estuary is not a border, but rather a connecting element of the territory, both waterfronts would take advantage of the floating megastructure and be able to establish more substantial mobility and possible future relationship and development.[50] If both cities begin to use this floating community as a passageway (physical and visually), they will start to accept it as a part of their daily life and connect with the existing land community (Adnan, 2017).

[50] Typically, the pre-industrial vernacular constructions can be described as made of economic principles, using locally available resources, with simple but effective construction methods. These are adjusted to the physical, social and cultural needs, as well as to the local climate, but also depict a strong resilience based in a morphological adaptability, by successive addition and transformation over time. The resulting forms are precise, in the sense that are directly reflecting the natural context, as well as the needs and life experiences originating them." (Lopes & Correia, 2017, pp. 59)



[Figure nº 18, *Axonometric projection of a possible quarter within the floating megastructure ,* Author, 2022.]

context/connect.exe

The Sado estuary forms a kind of an enormous lagoon that mixes fresh water from the river with salt water from the sea. Surrounded by dunes and ancient roman ruins, the *Caldeira de Troía* reveals a vast area of salt marshes at low tide, which is the chosen location for the connection of the new megastructure with solid land and the existing web of roads and paths. An artificial square, built as a persistent platform that helps to complete transition between the floating megastructure and the whole estuary region.

[Figure nº 19, *Constellation of initial quarters of the floating megastructure within the Caldeira de Troía, ,* Author, 2022.

The platform acts a form of narthex, helping to meet the infrastructural needs (water and land) of the surrounded area, by providing comprehensive south and east-west connection to the region, as a central hub, where the first parts of the floating megastructure will dock. The hub promotes the future amphibious functionality. In addition, the hub improves the accessibility between the peninsula and offers a direct journey with its surroundings, as it acts a public square and observation platform.

The reason for its permanence, even when the floating megastructure is no longer needed or moved to another location, is based on the meanings in memorials. The values of symbols and meanings in the architecture of commemoration reminds us of important events in human history, the merging of past realities with present worlds, largely created by architecture and place, as well as objects or even our own experiences.[51]

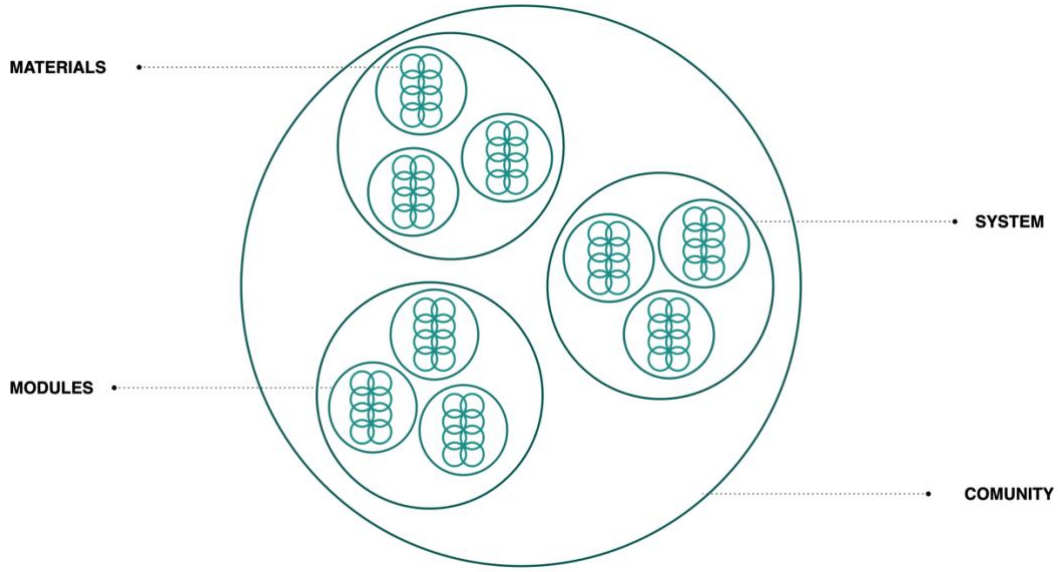
[Figure nº 20, *Constellation of the floating megastructure within the territory of the Sado estuary* , Author, 2022.

parametric urban complex

The whole system comprises six elements belonging to different categories: domestic, public, circulation and different structures. These units are designed to allow flexibility and adaptability, encouraging social interaction and activities between the living groups.

[51] As Peter Zumthor wrote in his book Thinking Architecture (2010), "Architecture is exposed to life. If its body is sensitive enough, it can assume a quality that bears witness to the reality of past life." (Zumthor, 1999, pp.24)

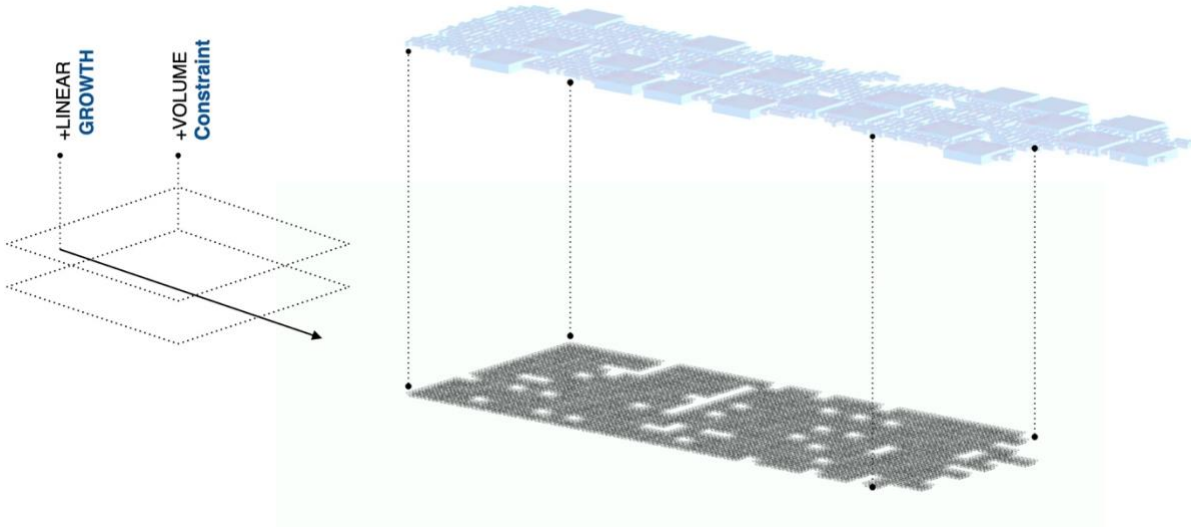
In order to establish a certain level of order in the urban complexity, the megastructure was constrained by different rules and definitions of aggregation and distribution.



[Figure nº 21, *Schematic representation of aggregational system within the project,* Author, 2022.]

The parametric aggregation rules are based upon controlled stochastic rules and chaotic evolution parameters. Enabling different types of possible connectivity, the floating megastructure can grow or decrease without the inactivity of the existing network, offering variety and connectivity (Menges & Dietrichs, 2013, pp.302).

The parametric composition is additionally constrained by a volumetric growth of 15-meter height and a linear growth with a width of 500 meters. It is to note that the concept of linear megastructures cannot be entirely separated from the context of linear urban development and its historical precedents pioneered by Arturo Soria y Mata's Ciudad de Lineal in Madrid in 1890s but based on the contemporary example of linear megastructures as in Paolo Soleri's Lean Linear City concept from 2010. Here the main objective is to assure a contextual relation to the estuary and the attached region, like the Island of Troía. Linear megastructures are therefore defined as "a compact form of linear urban development in a continuous built structure" (Tufek-Memisevic, 2019, pp.54-58). Everything works as a unified complete entity, for instance, in the new floating city, instead of a central transportation spine, the network acts as the spine, and the surrounding estuary acts as a dynamic entity and fundamental architectural element.



[Figure nº 22, *Axonometric graph of rules and constraints applied to the project,* Author, 2022.]

The initial definition of the system concentrates on the scale and volumetric design of the spaces which are divided in domestic nodes (meta-1.0), connectivity hubs (meta-1.2) and public cells (meta-2.0). These will be supported by a floating structure (meta-3.0) which complements and accompanies the system in form of a network. For reversibility and circularity reason of this system, the decision was made to only use 100% recyclable, which also aims to reflect the existing industrial, marine image of Setubal waterfront and intends to communicate throughout the proposed floating community. The objective is not to shock with a new imagine imposed, instead allowing an aesthetic transmission of this image and how people received this image.

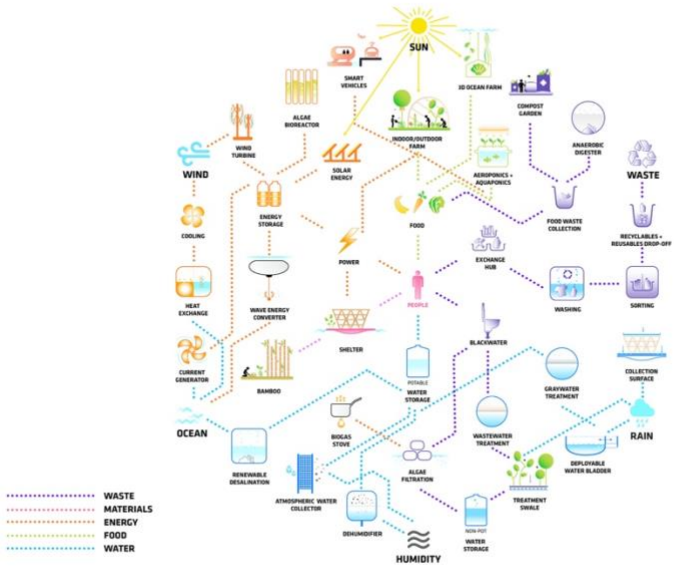
However, the fact that the sizing of these ISO modules responds to a use other than human habitation will lead to permanent compensation in order to ensure the best quality of life in the new city.

integral infrastructure

When considering the primary products and water obtainment, it is helpful to equip the network with aeroponic, aquaponic, hydroponic farms and water desalination plants (Kizilova, 2019). In order to produce energy in the autonomous structure, it is necessary to organise water, solar and wind energy accordingly. Integrating biogas plants, hydrobotanical ponds and waste recycling systems helps the network create an 'intelligent' habitat and increased liveability. Another component of the entire ecological cycle is productive management in terms of automation. With the help of sensors and A.I., the whole system can function independently at any stage if the adequate processing of the

obtained data is guaranteed (Picon, 2015, pp. 37-46). Water resources can also be involved in transport, logistics, and microclimate maintenance.

To guarantee the development of a complete ecosystem, supply, water and waste management are the 'dishonest' prerequisites. Therefore, advanced systems are introduced using indoor and outdoor farming to produce on-site food, mainly for a plant-based diet. Water treatment plants, rainwater harvesting, atmospheric water collection, renewable desalination facility, etc., are some methods for adequate water supply and drainage systems. As the infrastructure systems used at Oceanix Busan are already tested and applied (Bjarke Ingels Group, 2021), it will be taken advantage of this structure to install in the proposed floating network.



[Figure nº 23, , *Scheme of Oceanix City´s autonomous circular economy within the community,* BIG Architects, 2022.]

Waste control will be carried out in a closed circuit that includes sorting organic and inorganic waste, a recycling system, and treatments for reuse. Some of the waste will be used to make compost for the crops. Installations like anaerobic digesters, compost gardens, algae filtrations, and black and grey wastewater treatments provide a closed circuit to reduce water resources. Water infrastructure tubes are inserted inside the cybernetic steel structure, similar to the example of a floating domestic house by MOS Architects.[52] Equipped with sensors, which control the water/air balance inside the tubes and the hydrodynamics of the river outside the pipes, the sensors will communicate the perfect distribution along the whole infrastructure to let the cybernetic structure float perfectly, even with

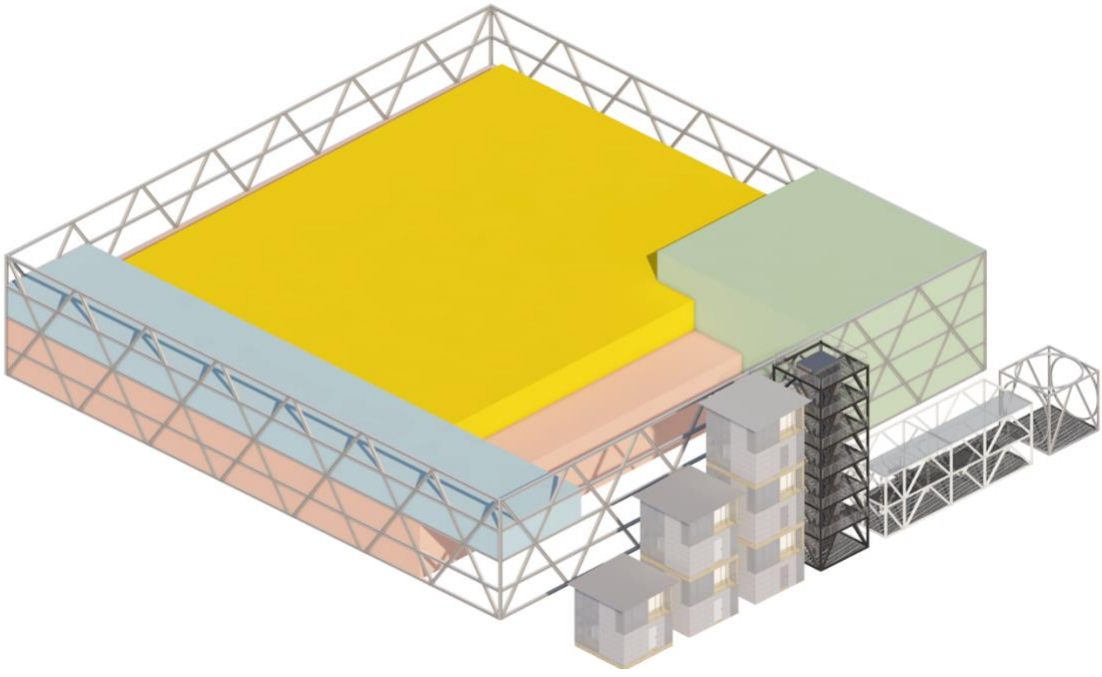
[52] https://www.mosarchitects.com.au/

the more substantial impact of the River Sado hydrodynamics. Energy kits along the network, like solar panels, wind and water turbines, wave energy converters and dynamos, which use the extreme high and low tide variation of the River Sado, as well as the high velocity of the water current (Ribeiro & Neves, 1982), are used to produce enough energy. The key is to use different mediums to catch every renewable energy source. The challenge is to make them all work together, not competing against each other

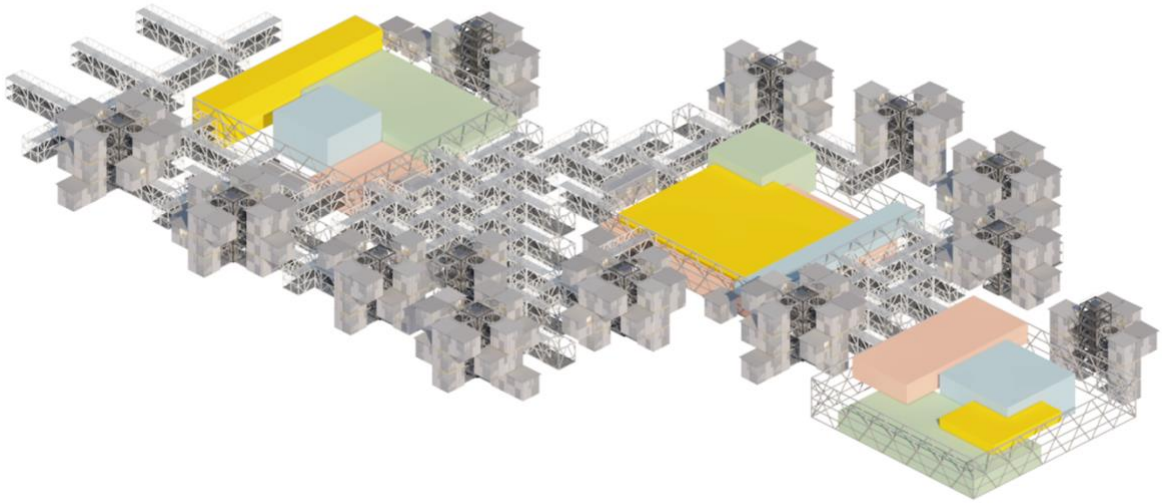
Since the network functions as an intelligent city, data centres must treat all the information from the sensors and other data sources. The data storage will be attached to the cybernetic structure under the water to provide enough cooling for the servers.

construction

The materials and modules are designed to be pre-fabricated in a controlled environment off-site and transported as mentioned off-shore. Since the whole network is constantly moving, conventional harbour cargo cranes, converted into robotic arms, are used to provide self-assembly and automate construction. Control centres coordinate and observe the construction and assembly processes to provide a constantly updated condition of the network, depending on the population and needs of the community.



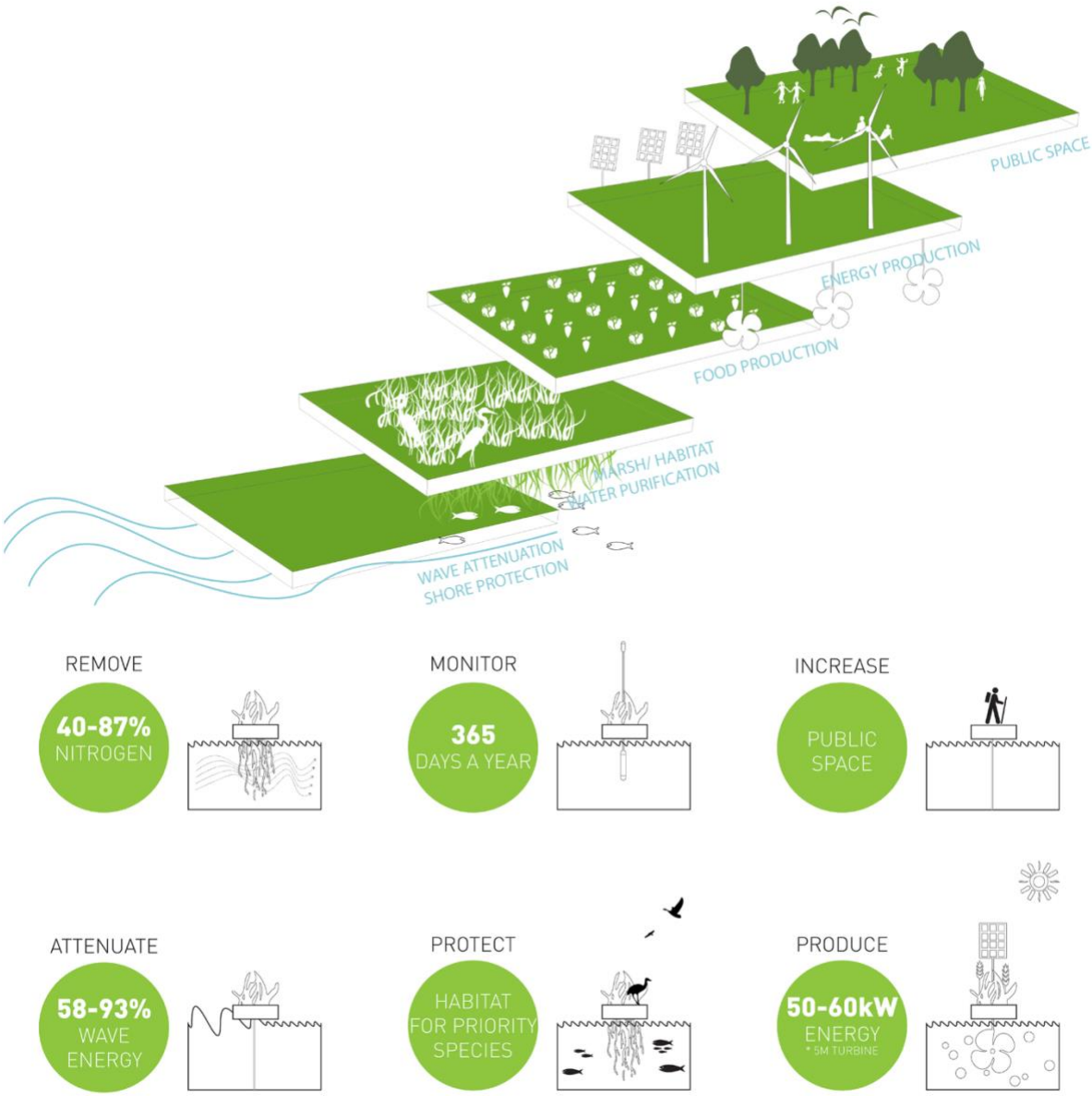
[Figure nº 24, *Axonometric projection of all modules applied within the project ,* Author, 2022.]



[Figure nº 25, *Axonometric projection of a possible quarter within the floating megastructure without the cybernetic floating structure ,* Author, 2022.]

landscape

We are familiar with green roofs or green traffic lanes but rarely informed about floating landscapes. While green roofs function as an interface between landscape and city, floating islands are a model for the interface between water, landscape and urban areas. Floating landscapes, that is, a complementary instance, has many social and ecological advantages and does not only serve as recreational areas (Balmori Associates, 2016). Flexible and mobile, they provide the accommodation of public squares and parks and serve different neighbourhoods. Floating landscapes act as sponges that filter clean water and provide wildlife habitats in the city. Floating islands also adapt to and address rising seas. Floating landscapes can offer a base for an infrastructure to capture the energy of waves, tides and currents. Moreover, they could also grow food and provide a green environment and recreational public spaces to the community.



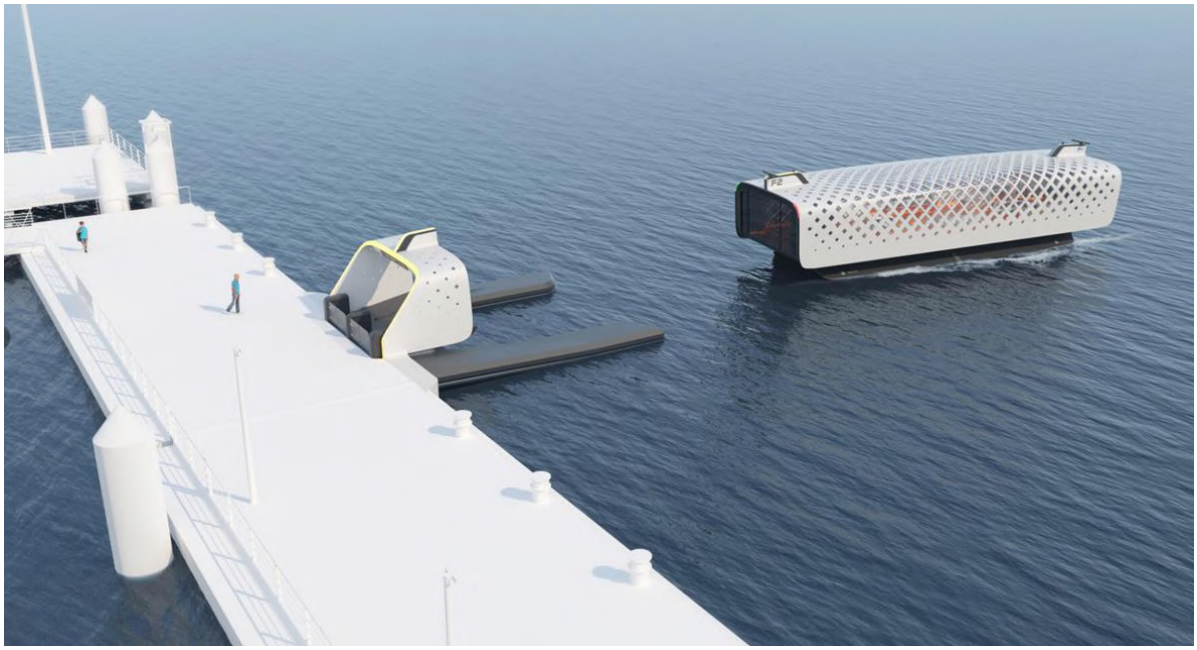
[Figure nº 26, *Graph and representations of advantages of a floating landscape,* Balmori Associates, 2020.]

mobility and transportation

A floating city is still largely dependent on water traffic as this is arguably the most flexible way of travelling from the mainland to the floating city and vice versa. Even within the floating city, it is handy to travel using boats and ferries to reduce the dependency on infrastructure for travelling purposes (Ko, 2015, pp.10). A concept which has been working for several centuries in cities like Venice, Hamburg or Bangkok. When the scale of the floating megastructure reaches a city's scale, the area cannot be crossed by foot or bike alone. That would take too long to reach a destination within

the community. The infrastructure and public transport are a must in the design of a floating city, mixing individual and public transport on water.

Several companies provide innovative public transport systems company provides an integrated network mobility chain of autonomous clean ways of transport on the water with water-land interfaces for local public transport. An example is the company CAPTN[53], which utilises electric propulsion, in order to create nearly noiseless ferries boat, emission-free travel, with electricity from renewable sources. The autonomous operation, in turn, can significantly increase service frequency.



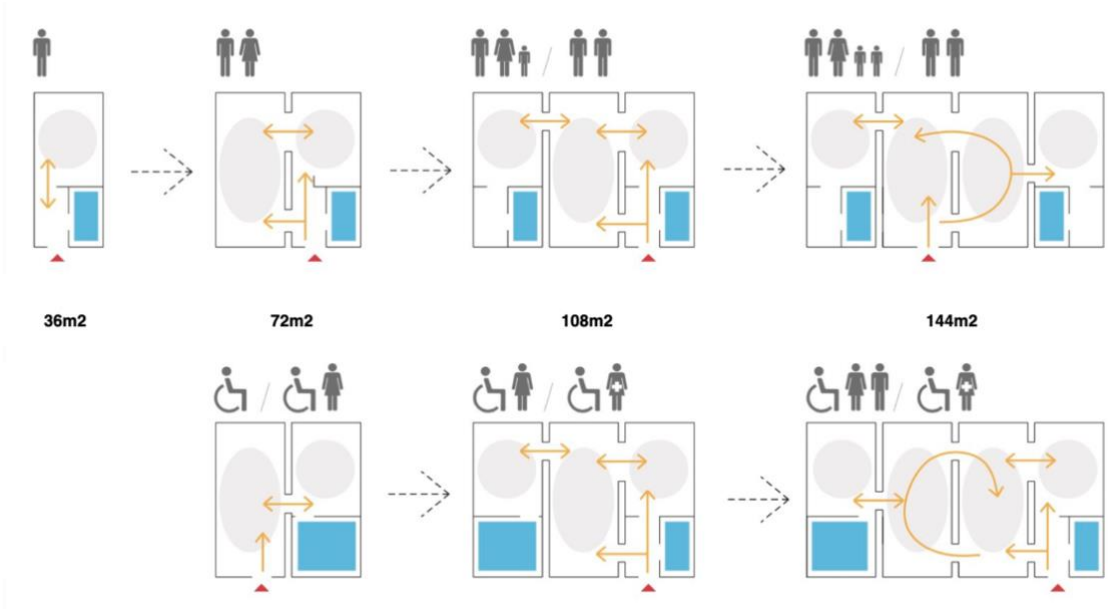
[Figure nº 12, *Simulated Image of the autonomous floating public transportation ,* CAPTN, 2022.]

meta-1.0[54]

The first module consists of a cube module measuring 6x6x6 metres. It works as a living predefined and evolutive domestic module for individual and, later on, collective domestic purposes based on the adopted system of blocks. One module can contain a residential space for 2 people, a bathroom unit, a kitchen unit, and a universal unit for housing or work.

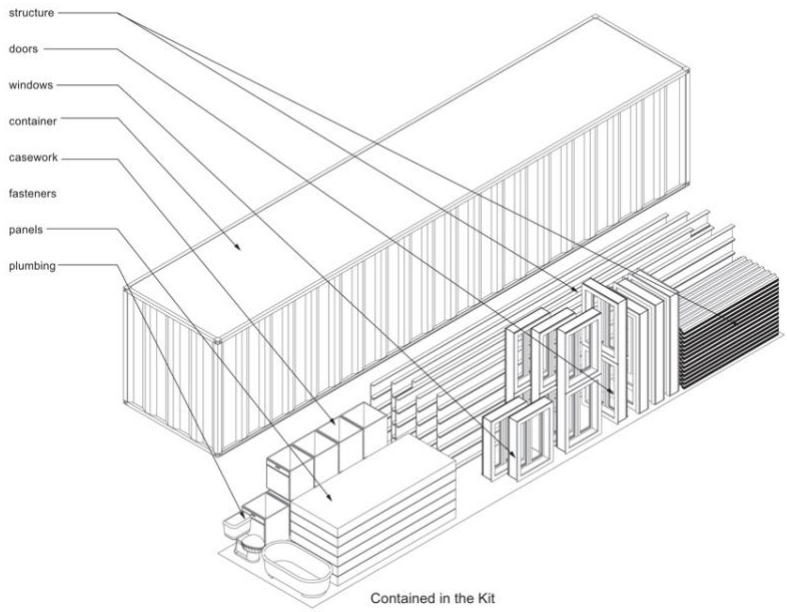
[53] https://captn.sh

[54] From the Greek μετά, meaning "after" or "beyond". In Physic the word meta describes the transcending status of something. (Oxford Dictionary, 2022)



[Figure nº 27, *Graph of possible expandability of the domestic modules ,* Author, 2022.]

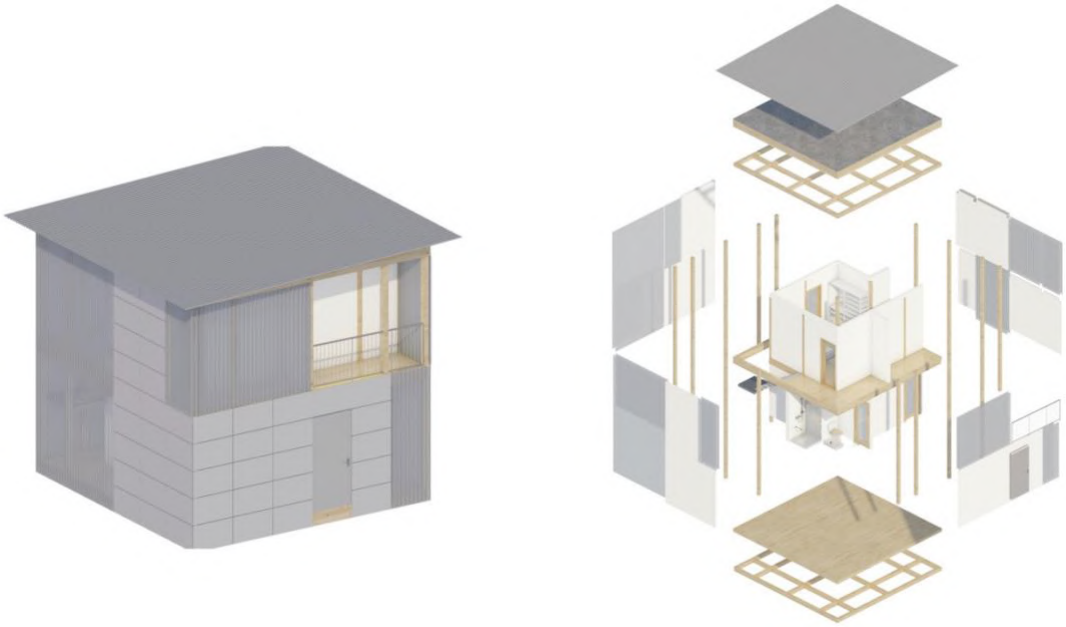
The composed final module concentrates on the circularity aspect. They consist of a timber structure, marine wood flooring, recycled metal, and polyethylene-terephthalate (rPTE) finishes, that can be created in a different location, packaged as a kit-of-parts[55] set and assembled directly on the site.



[55] The Kit-of-Parts[55] is a packaged set of components that results in a cohesive end product, not categorised by materiality; often, the shipping package is used as a portion of the finished product. It can include any number and combination of the fabricated unit, the panel system, or precast components. Coordination of products is done off-site and then delivered. The "Packaged House" is an extraordinary example of a prefabricated modular construction system designed by Konrad Wachsmann and Walter Gropius (Imperiale, 2012)

[Figure nº 28, *Representation of packaged construction of modules,* Technical University of Delft, 2019.]

The spatial organization of the module led to the location of the electric and water infrastructure into the inner core of the structure, in order to free the outer core for circulation and living, which provides a stronger visual connection to the surroundings (community and estuary) and at the same time establishes a standardization in order to 'plug-in' the module to the functioning network.



[Figure nº 29, *Axonometric projection of the domestic module,* Author, 2022.]

meta- 2.2

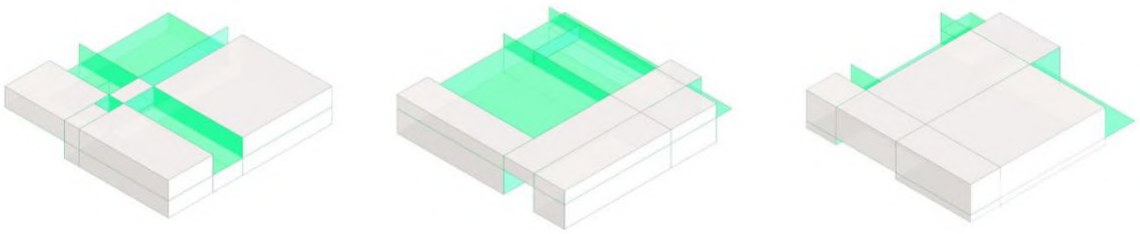
The vertical, horizontal and link hubs, provide the connection between all modules inside the network and facilitate the dynamic circulation, an advantageous labyrinth (Wigley, 1998, pp.165) through a system of stairs, ramps, platforms, and elevators. It acts as an urban layer, serving all other modules, adaptable and conducive, designed to provide transparency, as well as protection.

meta- 2.0

The idea behind having a more extensive module between the domestic units concentrates on social factors to facilitate the orientation of the community inside the network. Moreover, to create a gathering and territorial mark where people can meet, interact and socialise. The public cell modules, corresponding to the classic public space are in contrast to the domestic modules, not evolutive, but adaptable depending on the community needs in a more metamorphic and political but decisive way, with the help of architects and constructors, backed by intelligent(smart) city functions

and self-assembly processes, constantly evaluated and updated. The volumetric size of the cell is based on an average, which emerges from a survey and comparative study of public spaces in Lisbon and Barcelona (Silva, 2012) and measures 50x50x15m.

The cell modules are intended as a multifunctional, more extensive public module, which provides, if needed, several public services, recreating spaces and managing resources.



[Figure nº 30, *Axonometric projection of the variability of the public cell module,* Author, 2022.]

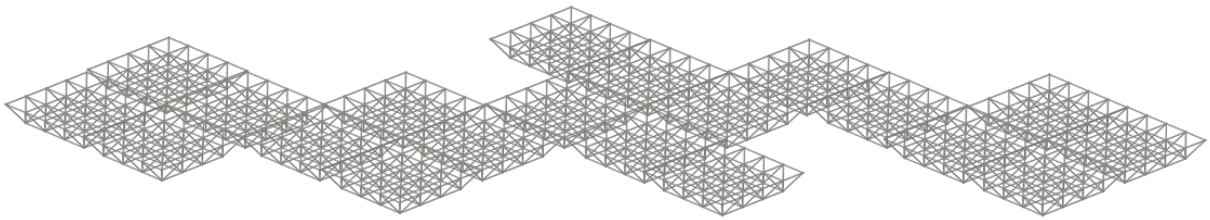
From schools, hospital, governmental facilities but also for industrial and economic purposes. If needed the cell modules also offer the capability to be docked by domestic modules, temporary or definitive.

meta-3.0

The *cybernetic structure*[56] is based on a modular floating structure (MFS).[57] This modular network can be defined as an arrangement of relatively small floating elements. MFS can be designed for different functions and their modular construction allows a dynamic spatial growth or shrinkage compatible with its urban use. The modular design allows for the addition or subtraction of parts of the overall functioning network. This characteristic is also linked to the ability to move a floating community when a particular site is no longer suitable for a variety of reasons. The various possibilities of the flexible floating megastructure are directly linked to the system and to its flexibility.

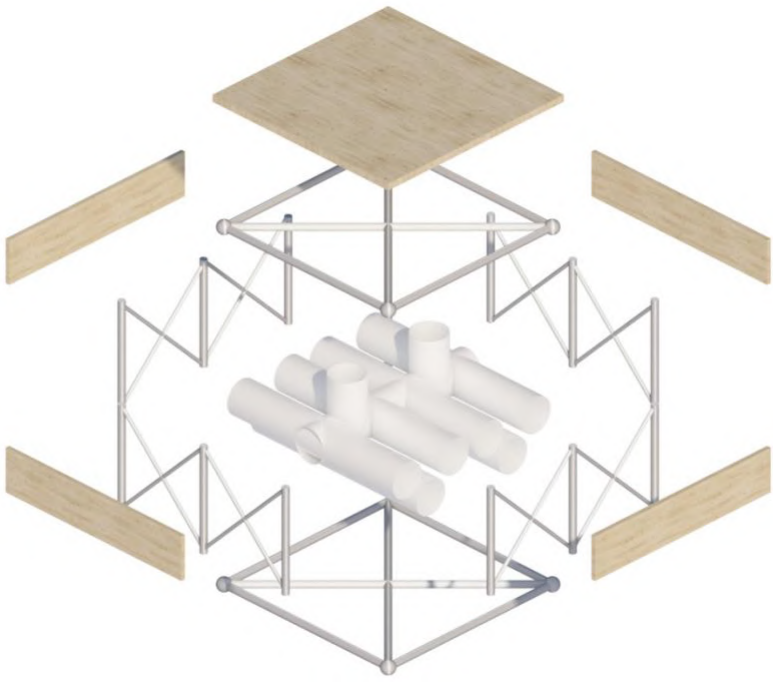
[56] Term given by the author.

[57] A modular floating structure is a system of multiple floating structures (MFS) that are assembled to form a large, connected group (Wang, Goldfeld & Drimer, 2018).



[Figure nº 31, *Axonometric projection of supporting elements of the cybernetic structure,* Author, 2022.]

The structure in form of a floating space-frame aims to be a light structure in terms of weight, still offering stability to serve as a support base and to create enough space to clip different infrastructures, which provide several resources to the community and work as a docking platform. Deconstructable, the assemblage of cells is made of four equilateral triangles, adaptable and standardised, creating space or/and structure at the same time.[58]



[Figure nº 32, *Axonometric projection of supporting elements and mechanical infrastructure of the cybernetic structure,* Author, 2022.]

[58] Dominique Rouillard wrote: "something gifted by the engineer to the architect, whose mission would consist in doing something with it, in translating it from engineering to architecture." (Rouillard, 2018)

[Figure nº 33, *Axonometric rendered projection of a cybernetic structure module ,* Author, 2022.]

[CHAPTER VIII]

NON-LINEAR PLAUSIBLE REALITY

The last and following chapter aims to provide a critical evaluation of the proposal by creating in this thesis a form of experimental laboratory. Comparing, analysing and concluding different factors to past, present and future methods and models helps us to understand and learn from the proposed response.

automation

Industrialisation, standardisation, and autonomous robotic assembly processes have been chosen in this thesis as efficient ways for adaptation and flexibility. It is possible to automate the entire process, speeding up the construction time, debugging errors and achieve more flexibility. It will constantly update the system by inserting algorithms and sensors, constantly evaluating and analysing the community's needs. Research by Gramazio Kohler from the ETH Zurich investigates robotically fabricated building processes and the reversibility and scalability of such systems and proof its benefits in term of time, costs and efficiency. Additionally, research at MIT (Tibbits, 2011, pp. 48–51) has tested self-assembly processes that can be programmed to assemble by pre-designing showing its advantages.

The building industry can adopt the existing large-scale shipping crane technologies in waterfront cities as automated and robotic assembly systems for urban-scale interventions in city port areas being converted from industrial zones to new urban areas. The automated crane systems can be upgraded with other multi or single-task robots to provide a self-assembly construction system. Operable simultaneously from different locations, programmed and digital interfaces, the user can control and change the scenario construction environment according to the information provided (Nolte & Witt, 2014, pp. 82–89). Like this, the city network reacts according to the community's demands. Indeed, it requires multidisciplinary cooperation considering all technical aspects and logistics and should be tested at scale in existing port areas.[59] An advantageous construction technique, already existing systems are placed on-site that can also be compared with other traditional strategies.

technical viability

Many floating projects that have been realised demonstrate that it is technically possible to build on the water. Offshore projects such as oil platforms and large cruise ships have such a scale that they can almost be considered floating cities. Other elements such as floating infrastructures, airports, shallow water and deep-water mooring systems, artificial reefs, and floating wetlands are already available on the market. This is also the case for decentralised production technologies of drinking water, energy and other utilities (de Graaf, 2012, pp. 15). The significant technical knowledge gap for the development of floating cities is not the development of new technologies but the integration of a considerable amount of different existing technologies and the upscaling and improvement of these technologies.

materials

The main object when considering the materials' weight, strength and aesthetic choices were to consider their materials generally fulfil the disassembly, reusable and recyclable requirements. It is possible to find already several building standards related to stability and float -ability and resistance against the influence of water (Queensland Floating Building Standards, 2006).

ETFE Cushion offers glass-like characteristics, with better insulation values, is cheaper and is made of PTFE which is nearly 100% recyclable;

[59] ''(…)automation, collective ownership and disappearance of productive work will generate a different social model.'' (Wigley, 1998, pp.160)

Wood sandwich walls and partially supporting structure elements offer durable and naturally resistant material suitable for marine applications for centuries;[60]

Steel structural elements can be the primary load-bearing material in the superstructure. Equipped with marine-resistant coating and structurally calculated, it has been used in oil rigs for decades and can be assembled and dissembled without attrition (Lima, 2014, pp.19).

When considering the weight and strength of the materials, the decision was to use more robust and more strength-demanding, more durable materials in the lower parts of the cybernetic floating structure and have lighter and more flexible material towards the upper parts, which are the modules.

(alternative) energy production

In order to create a self-sustaining community on the water, the floating megastructure will acquire a sustainable energy supply through wind, water, and sun which are highly features in the context of the City of Setubal and its Sado estuary. For communities on water, hydroelectric and solar power could be the most efficient option for energy production. The climatic conditions of estuary provide an average of 12 hours of sun light in which every domestic module (6x6x6meteres) could generate up to 14 kWh per day.

Tidal power turns also to be a strong energy producer since the estuary present a tidal average of 3,4 metres. Tidal fluctuations, which can be converted into tidal energy, are one of the most underrated forms of generating electricity that converts the energy of tides into a valuable form of power and is already in practice for centuries (Environmental Engineering Network, 2010).

Another way of generating energy is using the temperature change between deeper seawater and warmer surface seawater that runs a power cycle and produces electricity with the help of the so-called Ocean Thermal Energy Conversion or OTEC (Makai Ocean Engineering, 2020). A clean energy source, environmentally sustainable, and capable of providing massive energy levels 24 hours and 365 days a year. OTEC produces no greenhouse gases and requires minimal maintenance. Since four-fifths of all solar energy that reaches the earth is stored thermally in the oceans, it can provide an unlimited energy source (Friedman, 2017, pp. 146-148).

This, combined with the already conventional solar and hydro energy strategies, will generates sufficient energy to provide a self-sufficient environment.

[60] Dutch Building Standards (Bartels & Vedder, 2011)

produce resources

Floating cities can play a crucial role in increasing global food supply and energy production by productively using their own waste products and even the land-based city's waste.[61] The floating megastructure could use these waste products to produce nutrients and biofuels. These outcomes can feed floating algae and seaweed farms. The process results in the absorption of CO2 and nutrient waste of the Sado estuary and, at the same time, produce biofuels and food resources for the floating community and land-based city of Setubal.

Food production, in particular aquaculture, can be realised in floating cities and promote the already existing fishing industry of the Sado estuary. There are multiple concepts and technologies available for water-based food production. The schematic of aquaponics, a combination of hydroponics and aquaculture, consists of a method to grow plants in a liquid solution. Aquaponics combines plant growing with fish farming in a self-contained ecosystem. Plants and bacteria use the excrements that fish create and purify the water. Both freshwater fish and marine fish can be produced in floating tanks or directly attached tanks inside the estuary.

A freshwater generator is an essential type of machinery onboard every bigger ship and is part of every self-sustainable floating community. Freshwater produced from the generator is used for drinking, cooking, washing, and even running other necessary machinery which uses freshwater as a cooling medium. Freshwater is generally produced onboard using the evaporation method, with the help of seawater and heat. The temperature of the seawater then cools the evaporated seawater, and even this process generates energy to reduce the resources in this cycle.[62] This technique can even provide fresh and filtered water to immediate surrounding urban areas in times of water shortage.

grey water filtration methods

Subsequently, the 'grey' water (sinks, showers, etc.) would be disinfected and reused for appropriate purposes such as irrigation within its loop. 'Grey' water (from toilets) would be cleansed in greenhouse machines. Microbial cells in these machines would harvest naturally occurring energy, produced by bacteria during the cleaning process. Once the process has concluded, the water would be returned to the original water source through an artificial wetland filtration process located within the respective aquaculture vicinity.

[61] Food and Agricultural Organisation of The United Nations, 2014
[62] *Ibidem*

positive impact on ecosystems

By extracting nutrients and CO2 from the surroundings, the floating megastructure already positively impact the ecosystems in estuary areas. Extracting CO2 will also be a measure against the increasing acidity of seawater, which is a significant threat to coral reefs worldwide (van Dinther, 2018) and will create artificial coral reefs attached to the cybernetic structure (meta-3.0) in order to promote the aquatic ecosystem.

transportation services: alternative mobility

Because of flexibility reasons the megastructure will maintain its independence from the land by implementing alternative mobility (Tassinari et al., 2010, pp.33). The connection to land will allow a constant access in form of pedestrian and micro-mobility ways. Aquatic mobility will be the primary means of transport, public or private, within the community. Taking advantage of the certified and tested collaboration with the company mentioned before will help to ensure an automated and efficient way of mobility, docking in different docks along the system and land. In addition to the small unit docks for private use, there will be a larger area within the floating megastructure to accommodate cargo boats.

flux/circulation

The floating megastructure presents itself a dynamic 'mat-building' circulation system which can organise and manage a complex flow, movement and exchange systems.[63] "Mat-building can epitomise the anonymous collectives; (…) based on interconnection, close-knit patterns of association, and possibility for growth, diminution, and change." (Smithson, 1974). The changes of scale and association tend to produce the field condition of infrastructure in response to incremental adjustments and changing environmental conditions. Applying the 'mat characteristics' also offers a flexible framework for relating to a site through an uninterrupted continuation of the existing urban condition into its spatial network. The network of pathways, courtyards and platforms can establish a system of relationships, present and potential between the built and the natural. The spaces of transition and connection offer a dynamic of movement and connectivity (Fores, 2006, pp.79).

parking facility

The surface of the floating megastructure is limited and mainly intended for buildings, infrastructure, adapted to the floating mobility and their users. When the development is still on a small scale, and the area is in a walkable dimension, parking can be provided on the mainland, where

[63] The Architectural Review. Calabuig, Gomez & Ramos, 2013

the link between land and water happens. It is more efficient to gather all the cars in a parking building. Parking buildings on the mainland can be partly/entirely above or below ground level (Ko, 2015, pp.10). The main goal is to reduce the use of cars and convert them into public transport.

governance

How could a floating city be governed? We can observe a shift from top-down hierarchical steering (government) towards more network-driven decentralised forms of policy-making with multiple actors (governance). Floating cities offer an opportunity to take this development further by using the opportunities that decentralised technologies offer. In the floating city, decentralised concepts for water supply, energy production and other utilities are applied. Citizens have the opportunity and choice, to manage their utilities and produce electricity and water instead of only being passive consumers. The help of user-friendly methods and technical interfaces can increase the notion of an ethical community and strengthen their independence (de Graaf, 2012, pp.48).

image

The reason to communicate a particular fusion between a traditional and a neo-industrial marine image arises from the decision to obtain a soft transition present along the waterfront areas of the City of Setubal and the importance of an industrial heritage[64]. It transmits the same values as archaeological, architectural or urban heritage and identity.[65] In Portugal, industrial heritage began to be studied, safeguarded and disseminated in a more scientific and systematic way, based on a theoretical and/or conceptual body, essentially from the 1980s onwards *(Direcção-Geral do Património Cultural*, 2010). Industrial heritage reflects values of memory, antiquity, originality, rarity, uniqueness or exemplarity. The industrial heritage includes technological, scientific, social, economic, and aesthetic values (Paiva, 2010, pp.10). The industrial heritage includes all the goods resulting from a productive activity carried out over generations, creating its own identify. It is also understood as the material and immaterial legacy produced by the different social and economic agents that perpetuate collective memory. These, combined with the simplification and beneficial aspect of

[64] In 1920, the architect Le Corbusier in turn illustrated one of his articles with photographs of silos, some of which were borrowed from Walter Gropius's text. Le Corbusier concludes his article thus: "Not pursuing an architectural idea, but simply guided by the effects of calculation (derived from the principles that govern our universe) and the design of a viable organ, today's engineers make use of the primary elements and, coordinating them following the rules, provoking in us architectural emotions, thus making the human work resonate with the universal order. Here are the American silos and factories, magnificent beginnings of the new era. American engineers crush agonizing architecture with their calculations." (Le Corbusier, 1923. in Collyer et al., 2003)

[65] Eduardo Souto de Moura already used with the project of the Auditório A & Centro Cultural de Viana do Castelo different industrial symbology aspect in order to create identity (Diniz & Nunes, 2016).

industrial construction material (disassembly, reusable and recyclable), create certain brutalist transparency and lightness to the construction (Jesberg, 1989, p.76-79).

city as a living organism

The human metabolism hosts vast numbers of ~~these~~ chemical reactions every second (Galle, 2019). This process is similar to what happens in cities. In an urban metabolism, networks of things (goods, capital, information, people, etc.) go in and out. Through time, architects and planners have often refer to the city ~~to be~~ as a living body, the same as a living organism and as a whole ~~as a~~ natural ecosystem. This idea can be traced through the notions of Jane Jacobs or the Metabolist architects (Wong, pp.3, 2020). In a city you can identify chemical reactions that take place in a living body. How urban cells adapt and move to sustain life it is a process that is similar to the biology of living organisms.

To propose a floating megastructure which complements to its community, and processes a constant cycle of changes, growth and decrease, renewal and destruction of its 'organic' tissue, defines flexibility and nature itself (Pernice, pp.3, 2022).

synergic organised complex system

Biological systems show us, that a slight change in one variable can significantly impact the system when we have a substantial level of interrelated and complicated variables. This phenomenon refers to the synergy in science.[66] (Corning, pp. 89-121, 1995) Cities are also under the effect of risks and stresses, and as urban areas and the urban population continue to grow or decrease, the scale and impact of shocks will stress them. The same can be said for positive inputs, even when small-scale. The definitions, rules, constraints of the proposed floating megastructure are aiming to cope with different changes but still providing a constant intact infrastructure and community.

flexibility

The consequences of the global sea level rise will generate the necessity on the land, to migrate or total reconstruct waterfront-based habitats. Unlike a development on land the development on the water brings the advantageous ability to simply move. In order to be flexible, floating structures can easily be moved across the neighbourhoods and, in an extreme case, even across the oceans like off-shore platform are doing it since decades.

[66] According to Cambridge dictionary it means the combined power of a group of things when they are working together that is greater than the total power achieved by each working separately.

In the contemporary world where everything seems to change quickly, we are nowadays able to track the change with information and data. The constant monitoring of the current conditions of the cities, provide planners and decision-makers the sufficient data to react to the required changes with the minimum alteration cost and energy in short time intervals. This is how resilience can be achieved, mainly because the whole system is constantly adapting to the current condition.

Another contribution to flexibility is the capability of reversibility. Which is defined as the process of transforming buildings or dismantling their systems, products and materials without causing damage or remaining. Technically and spatially, reversible building design can support such processes and be seen as a key accelerant of circular economy in construction (Durmisevic, 2018, pp.3).

linear form

The form of a linear organisation is characterised by flexibility, as it can easily respond to to varying terrain conditions. A possible aspect of this linear strategy is the composition of different forms in the same context and organising them along their length.

A clustered organisation, offering physical proximity between its spaces and environment.[67] The linear form consists of cellular, repetitive spaces with similar functions and a common visual feature such as functions and a common visual characteristic, such as shape or orientation. Often times these spaces present themselves different in size, shape and function.

This type of composition does not depend on a rigid geometric concept, i.e., in contrast to what happens in an organisation that is which is centralised and governed by compactness and geometric regularity. By opposition, flexible systems ~~as it~~ can easily accommodate growth and change without affecting its fundamental character.

scale & human relation

The changes in scale, from large-scale high-density structure, through the scale of the neighbourhood to the small-scale unit, produce a "fragment of a city" (Rouillard, 2018, pp.48) within the megastructural network still functioning like a whole urban and comprehensive system. Correspondingly, large-scale or small-scale networks connect to the networks within and between. Communicating, connecting and merging could be seen as the process of a structured and intelligent network (Zhu, 2009, pp.892).

[67] ''Linear structures allow a few meters to the next undeveloped space.'' (Wigley, 1998, pp.134).

The new floating urbanity presents a horizontal shape, spreading in a lengthy morphology opposed to a vertical development. The horizontal emphasis and the circulation characteristics of the 'mat-building' (Smithson, 1974) encourage the change of scales to be consciously unregistered by its users, which means that the experienced human scale is based on visual relations and constant changing spacial experiences (van der Ley & Richter, 2008). The user is aware of the large scale but only consciously aware of the scale *in momentum* and at the same time the 'life on water' creates a different layer to it.

The social and collective practices can be evaluated on an architectural scale and an urban scale (Jin, 2020, pp.7). The architectural scale reflects attributes like circulation, mobility, and flexible and changing spaces, creating more vital social interaction and communication.

Since all functions are concentrated within the network, from the typical public functions to new equipment, related to the investigation and research of water, food and resources production within the element of water, a re-form of the lifestyle can be achieved, which seems to be already imminent but failed in the City of Setubal. New and existing economies, like fishing, logistics and/or tourism, can work parallel, take advantage of the new structure and act as the proposed complement system. Thus, the community of the floating megastructure can consciously live out all the conditions of 'life on water'.

Therefore, the urban scale presents a strong interdependency with the existing urban system, which helps to eliminate flaws or compensate within both systems (existing and complementary) (Fernández-Serrano, 2013, pp.28-37). The existing mobility on water expands with the complement system throughout the estuary and adjacent and surrounding urban and rural areas to create a strong relationship with each other and act as a whole. Implementing this strategy over the urban infrastructure could begin the development of many aspects, encompassing the whole architecture scope, the industry, the service sector and the economy. In any other case the complementation of the urban tissue would impact the social scope since it would provide a new paradigm where the inhabitants could establish new social interactions.

conclusion

The proposed floating community has the potential to respond to global problems, such as the consequences of rising sea levels that the city of Setubal and its estuary will inevitably face. The presented architectural idea reveals that the response should not be evaluated exclusively within a terrestrial mindset. The shift of a architectural paradigm, comparing with emerging technological

methods, it will provide a wide range of possibilities for designing the future and help to respond to complex problems.

Defining the parameters of the systemic network, and evaluating it constantly through intelligent processes, will facilitate and speed up the design process of a constantly updated community. Their habitat is, after all, complex systems, and the human complement system shows a variety of possible constellations and scales generated by a complex response (Dunn & Blaney, 2021, pp.50) .

The proposed model can serve as an architectural and urban response, which presents flexibility, obtains circularity-efficient features and reacts to the predicted or unpredictable changes of its context or society. Indeed, the speculative exploration of the design necessarily raises questions that provide ways for further research. Additionally, this can lead to research related to non-linear associations, which are created within a complex system and their interrelationships, to respond to various social, global, and technological challenges of urban life.

In this research by design investigation a certain degree of utopia was voluntarily admitted, with strict attention being paid to keeping it within the realm of plausibility. This situation results directly from reading Karl Mannheim, among others, and from the resulting conviction that it is difficult to imagine the new. Carrying it out will then be a "simple" matter of time and work.

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APPENDIX

APPENDIX

PROTOTYPE

Figures

Territory before

PROTOTYPE

Figures

Territory after

PROTOTYPE

Figures

Constellation

PROTOTYPE

Figures

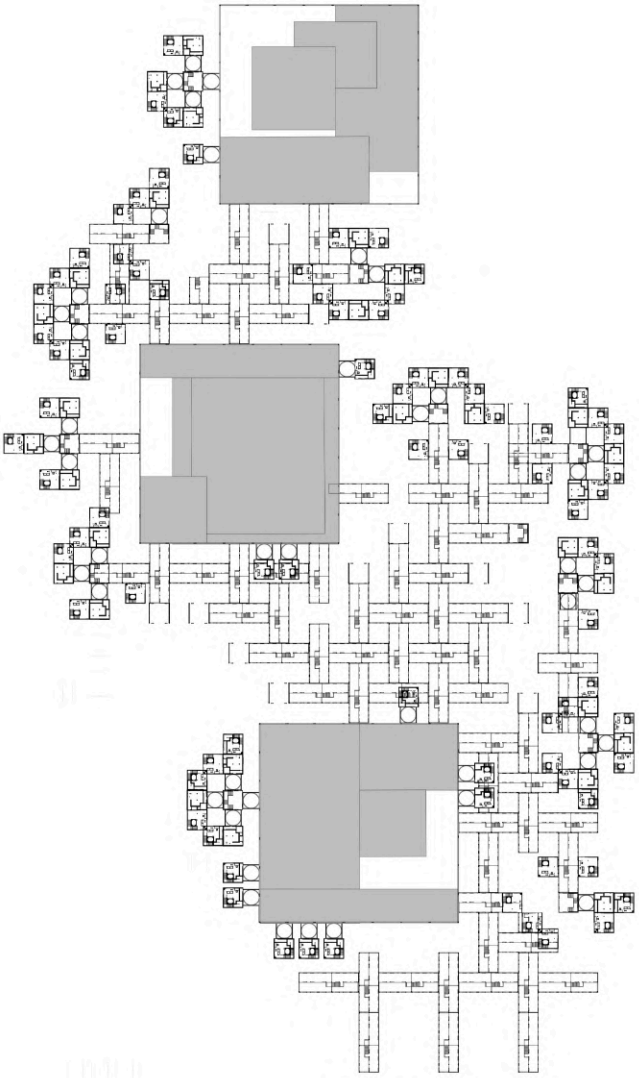
Implementation

0 125 250 500 1000

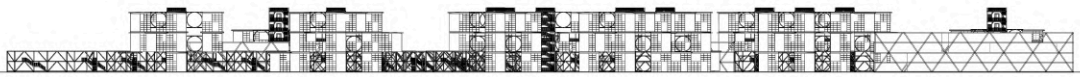
PROTOTYPE

Figures

General Plan



Elevation West



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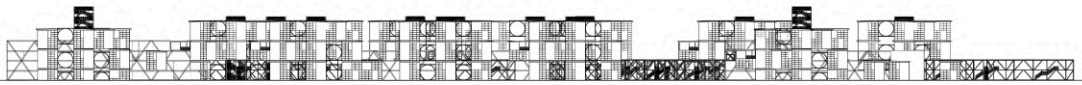
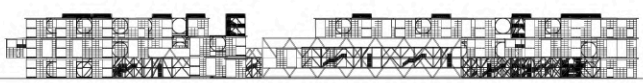


Elevation South

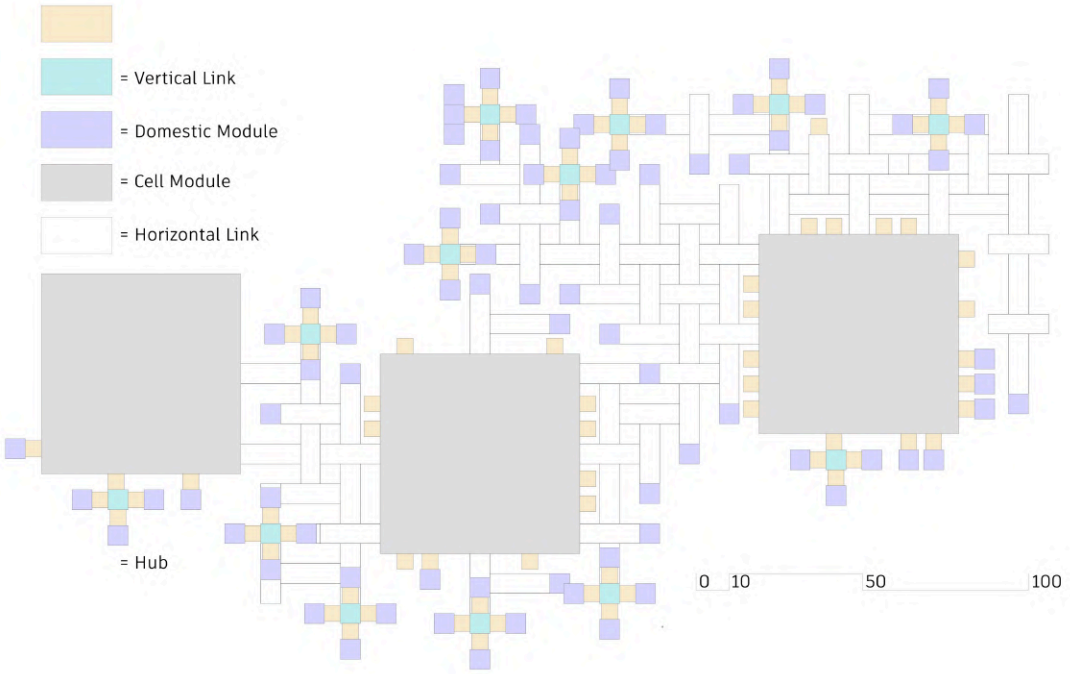


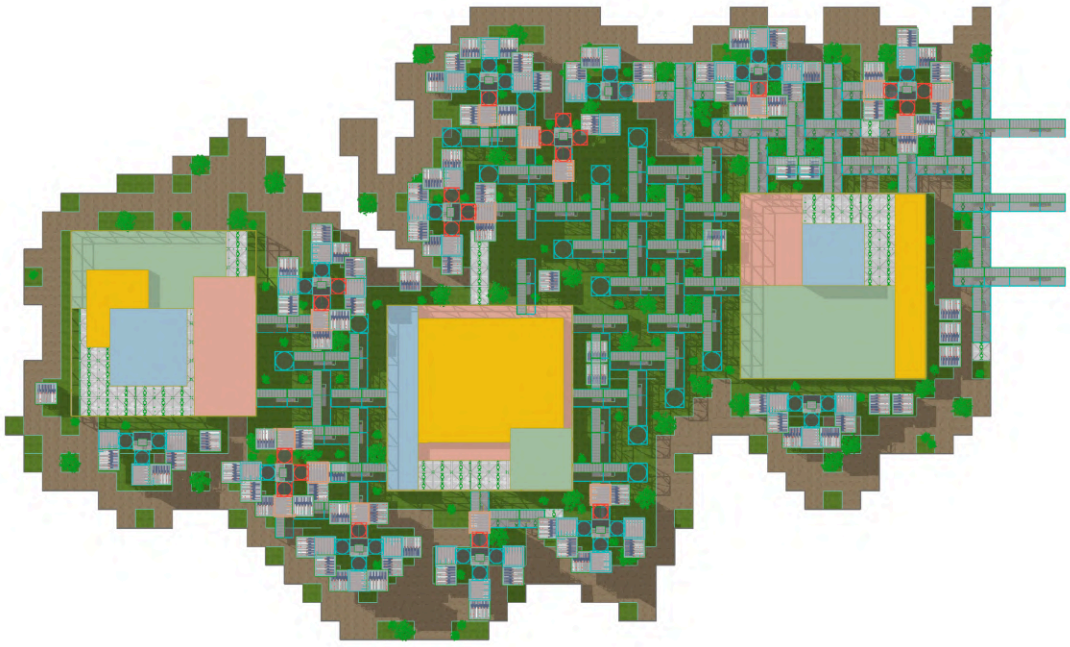
Plan & Elevation
Megastructure

0 10 50 100 200

PROTOTYPE

Figures





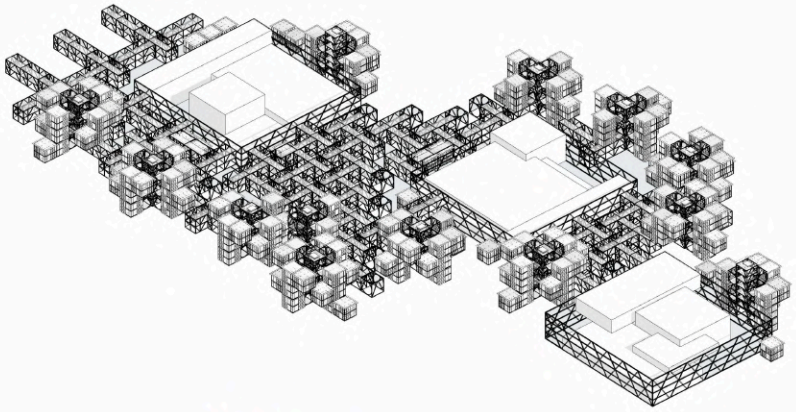
Possible
Distribution Plan

PROTOTYPE

Figures

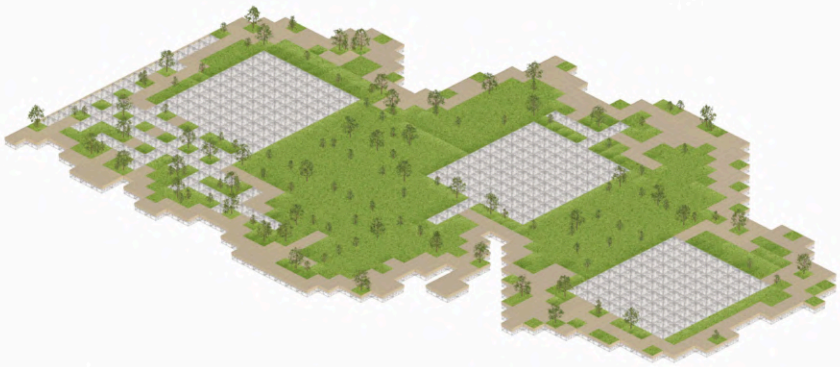
Megastructure 1.0 & 2.0

Isolated



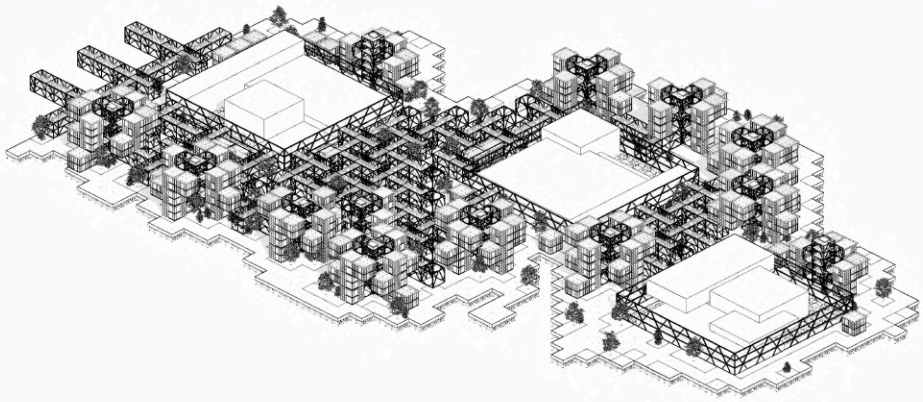
Megastructure 3.0

Isolated



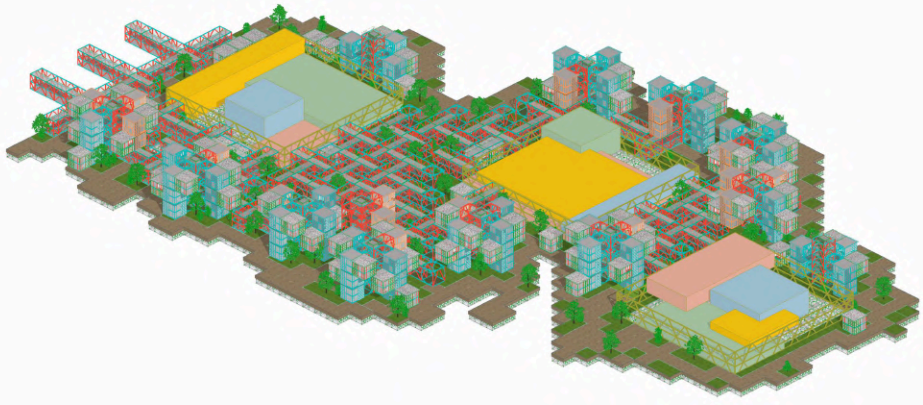
Megastructure

Megamorfose



Megastructure

Megamorfose



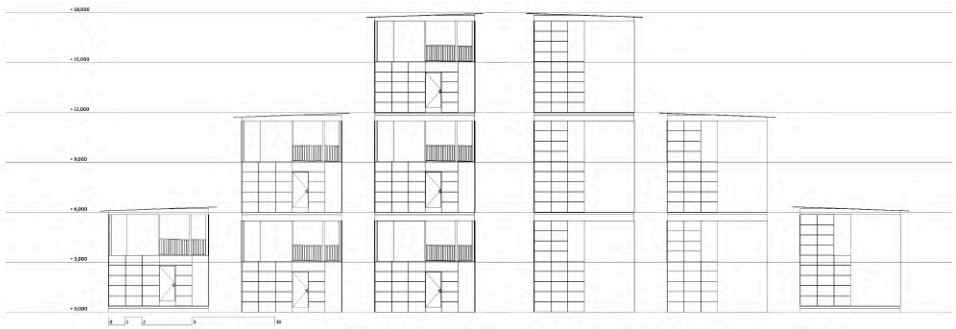
Axonometric

Projection

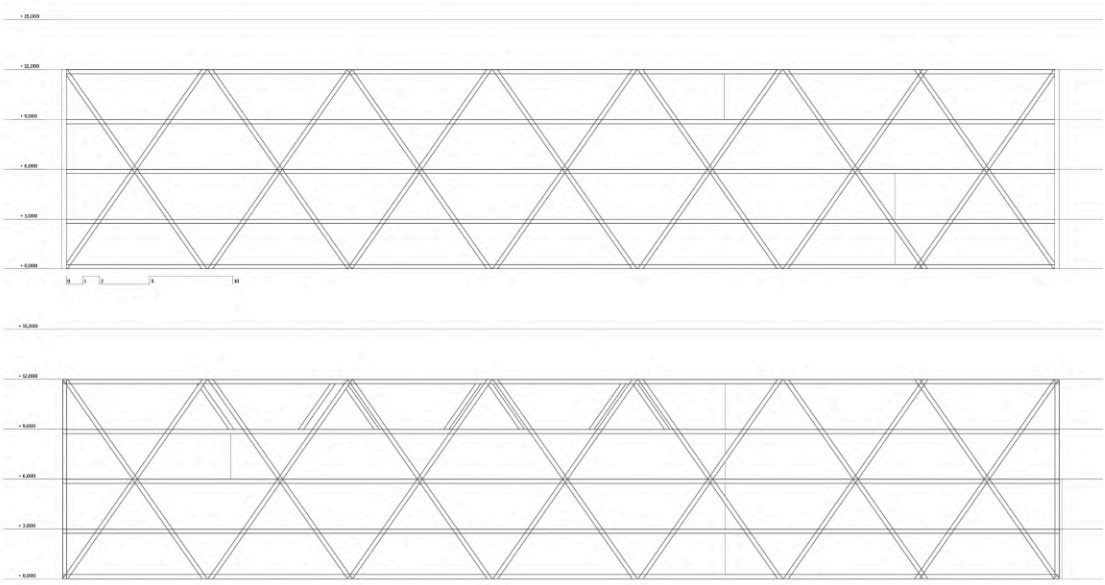
PROTOTYPE

Figures

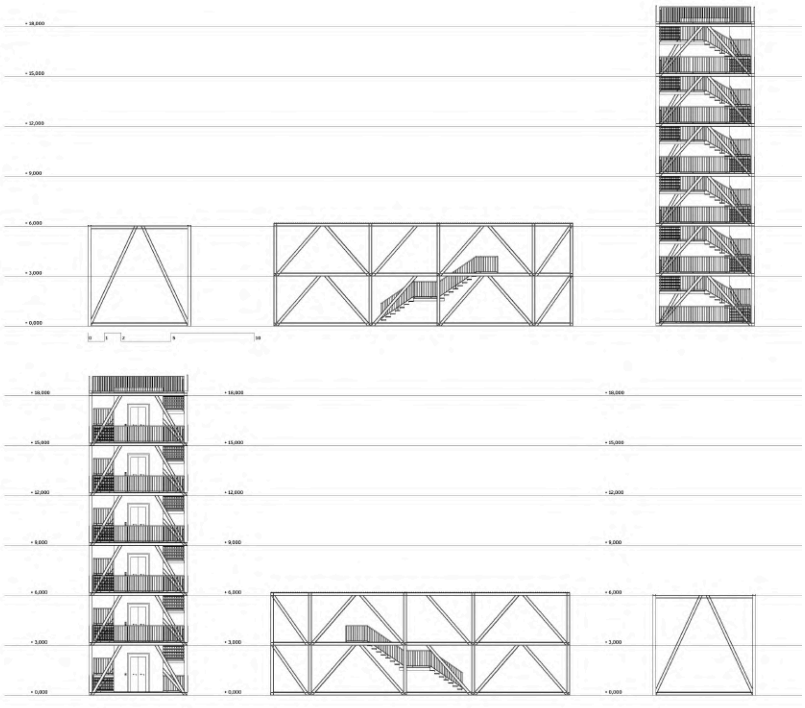
Domestic
Module



Public
Cell



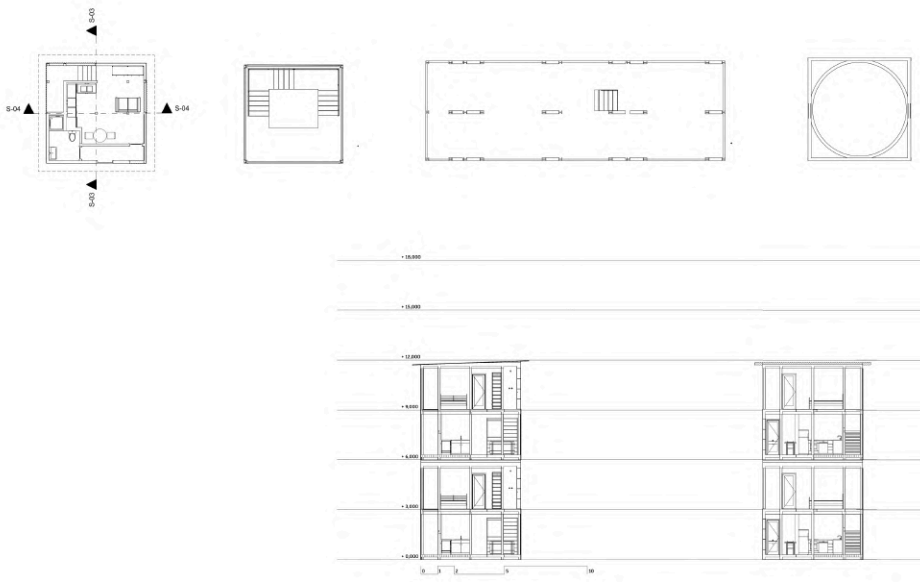
Vertical Link
Horizontal Link
Hub



Elevation
Modules

PROTOTYPE

Figures



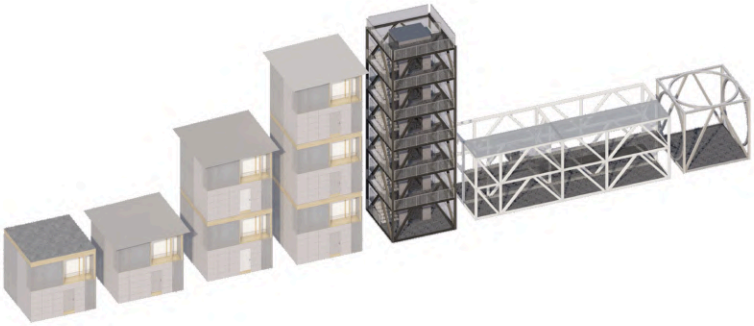
Elevation

Modules

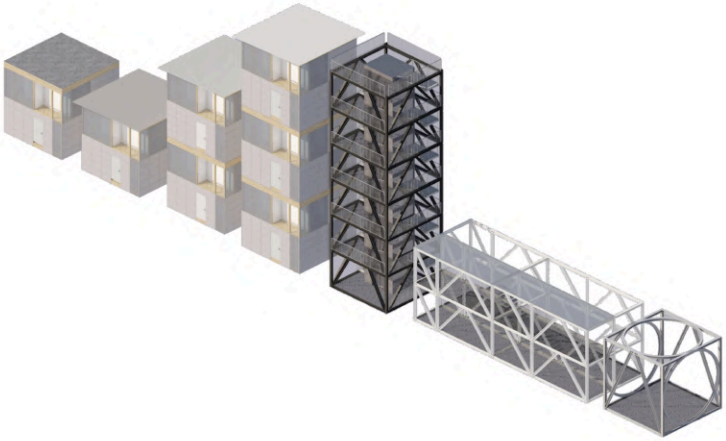
PROTOTYPE

Figures

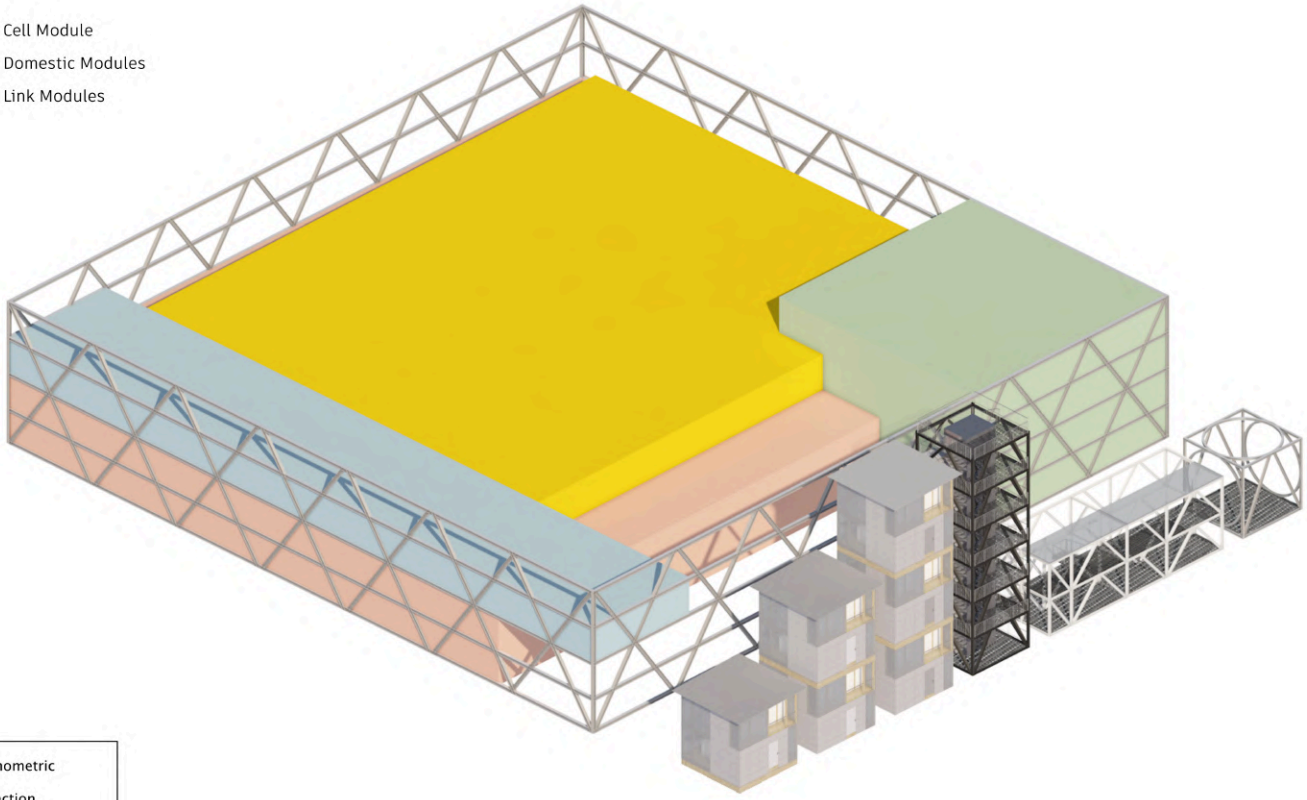
Domestic Modules
Link Modules



Domestic Modules
Link Modules



Cell Module
Domestic Modules
Link Modules



Axonometric
Projection