FLOATING TOWARDS THE FUTURE

A study on floating structures on the Dutch North Sea.

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Kornelis Kramer
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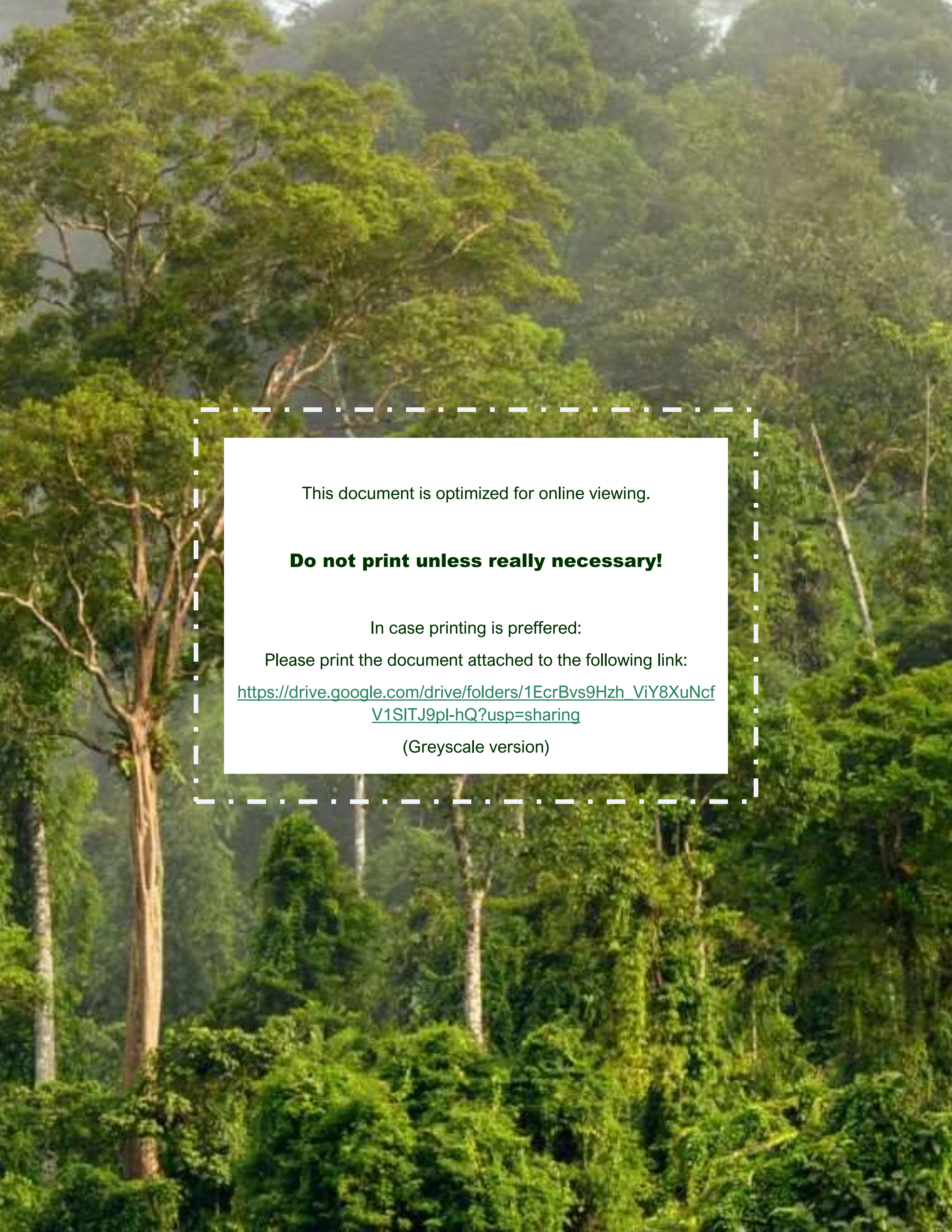

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Acknowledgement

Dear reader,

Throughout my academic career, I have been interested in floating structures. My bachelor thesis investigated the feasibility of the implementation of floating structures made from river retrieved recycled plastic, to increase the livelihood of families in the Mekong Delta, Vietnam. Additionally, essays written for master courses in Oldenburg and Groningen offered a great opportunity for me to explore the many aspects of floating developments including the transition towards floating cities, establishment of floating structures in island nations, floating structures in international maritime law and the role of floating structures in cross border learning. Conclusively this master thesis was written, offering in-depth knowledge on the implementation of floating structures on the Dutch North Sea, my home country.

Additionally, I would like to thank all who have been part of the writing of this thesis. First, thank you, Ferry Van Kann, you have strongly supervised me during the majority of my writing process. During our regular meetings, you provided me with constructive feedback, new inspiration, and a lot of beverages. Additionally, I would like the people interviewed as part of this thesis, specifically Maarten Flikkema, Olaf Waals, Ronald Vuijk, Rutger de Graaf and Karina Czapiewska for sharing their knowledge, I enjoyed speaking to all of you. Furthermore, this acknowledgement is dedicated to my family and friends supporting me during the research and providing distractions.

Kornelis Kramer,

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THANK YOU!

Abstract

Global challenges including climate change, land scarcity, urbanization put pressure on the existing spaces and processes of our society. Simultaneously, offering a window of opportunities for innovations to develop in these challenges. Moreover, become part of solving these complex societal challenges. Floating structures have the potential to offer functionality in the solutions by providing additional functions on water. In this research, the potential of floating structures on the Dutch North Sea was explored. The research question "*What are the opportunities, limitations, and conditions for the development of floating structures on the Dutch North Sea, in the upcoming decennium, using insight obtained from the Diffusion of Innovation Theory and Transition Theory?"* was answered through several subquastions. Out of a database, which was created for this study, 20 functions a floating structure can encompass were identified. Floating structures that have a high potential to diffuse in a social group by making use of insights obtained from the Diffusion of Innovation theory were selected by means of a grading scheme. Resulting in six functions with a high potential in the Dutch North Sea. Subsequently, applying Transition Theory to indicate transitions that would provide a supporting development environment for floating structures were identified and connected to the six high scoring innovations. In other words, the limiting effect the absence of transitions has on the development of floating structures were analysed. Shortcomings in both theories are surmounted by accepting them and countered by the other theory. As a result of this, a total of three functions, food production, energy hub and cyclicity showed to be high scoring innovations that correlate with ongoing transitions. Subsequently, the conditions that are needed for the development of the implementation of floating structures were identified through case studies. The conditions are either innovation specific, or specific to the North Sea. Including, climate characteristics, stability of the platform, prioritization of interest, regulations, and legislation. The conditions are not all factors that can be influenced, it was observed that a key condition is the level of awareness and knowledge on floating innovations. Adding to the prioritization of interest, a SWOT analysis that was drawn up, provides a framework in the decision-making process. Additionally, the research is summarized in a flowchart to support decision-makers in the process of considering a floating spatial intervention like floating structures.

FIGURE 1 PROPOSED FLOATING ISLAND, FRENSH POLYNESIA (DAILY MAIL, 2018)

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Acronyms

DoI – Diffusion of Innovation

PCB - polychlorinated biphenyls

SLR - Sea level rise

RLI - Council for the Environment and Infrastructure

IDI – In-Depth Interview

JIP – Joint Industry Project

1. Introduction

Globally coastal regions are of major importance for cultural lore, ecosystems, social monetary processes and as places for significant settlement of the global population (Lau et al., 2019). At the same time, these areas are high-risk places of human assets, threatened by natural threats (Melet et al., 2020). The natural threats of coastal regions are enforced by the effects of climate change, especially sea-level rise forms a threat to the livelihoods of the coastal communities (Thirumurthy et al., 2020). The IPCC predicts that the sea level will rise to 60 cm around 2100 as a result of climate change caused by greenhouse gas emissions (IPCC, 2021). Already, during the last century, sea levels rose 17 cm which effects can particularly be seen during extreme weather events (Menéndez and Woodworth, 2010). Sea-level rise is relatively strengthened by human activities causing land subsidence (Nicholls and Cazenave, 2010). Land of different human and natural purposes will be lost to the seas, this includes agricultural, terrestrial ecosystems and settlements (Lau et al., 2019).

Halfway into this century, it is expected that 70% of the world population will be living in cities (Barragán and Andrés, 2015). Barragán and Andrés (2015), furthermore state that half of the cities, and most of the megacities, are located within 100 kilometres of the coastline. Expectations are that by 2050 around 50 million people will be leaving atolls, wetlands and other low-lying areas in search of a new place to settle (Ahmed, 2018). Already, land loss due to climate change has caused people to leave their houses, falling victims as climate refugees (Farbotko and Lazrus, 2012; Hauer et al., 2020). Not only the climate refugees will be resettling, but a global migration towards the cities is already observed initiated by different rationales (Hauer et al., 2020).

On top of this, land is globally becoming a scarce resource as land uses compete for suitable space (Lambin and Meyfroidt, 2011). Rapid urbanization as described above is enforcing pressure on the limited space available (Dal Bo Zanon et al., 2017). Land degradation, increasing demands for food production, energy generation and other uses of land add to the already pressured cities (Lambin and Meyfroidt, 2011). To overcome this several suggestions are made including (agricultural) innovation, reformation of land use planning, diet changes and new industrial process (Lambin and Meyfroidt, 2011). However, this research will study floating structures as a means to solve these global challenges.

1.1 Floating solutions

The negative effects of climate change, urbanization, and land scarcity are annually already costing coastal cities billions of dollars (Hallegatte et al., 2013). Whereas it might not even be possible to express the social and ecological losses in monetary value (Adger et al., 2005). Around the world, cities, communities and governments have deployed different strategies to influence the risks to limit the damage (Nicholls and Tol, 2006). Floating development as part of these strategies is thus researched to increase available land, produce resources and boost ecosystems to cope with the presented risks and support the several suggestions to overcome the challenges (de Graaf, 2012). Roeffen et al. (2013) concluded that floating development would offer a potential solution to land scarcity and urbanization. Furthermore, they do not only improve flood safety and offers a solution to land scarcity and improve the living environment (Nakajima and Umeyama, 2015). Additionally, El-Shihy and Ezquiaga (2019) proposed that floating structures would be an applicable solution to deal with the modern risks of climate change.

De Graaf (2017) clearly defined three phases that follow a step-like path of the utilization of floating structures, expanding terrestrial practice towards marine environments (Figure 2). The first phase is to explore inland waters especially in cities and harbour areas for the development of floating housing (de Graaf, 2017). In the Netherlands, there are already some examples of this, one of them can be found in IJburg Amsterdam see Figure 3 (Lupi, 2006). In the second phase, floating development would leave the sheltered waters and move to the territorial water of the seas as an extension of existing cities. The third and final phase is a fully functioning society on the high seas (de Graaf, 2017). Olthuis (2010) describes similar steps in which the urban fabric would expand on the waterfront. The phases either proposal of de Graaf (2017) and Olthuis (2010) aim for floating structures with a collective size of a city, and which could be located and relocated in all coastal regions and the high seas.

FIGURE 2 PHASES AS DESCRIBED BY DE GRAAF (2017).

It is recognized that there is a substantial number of structures that would be characterized as part of the first phase. Recent numbers on inland floating structures stay out but in 2004, around 10.000 houseboats were floating on the Dutch waters (Ploeger, 2004). Even though, recent numbers have not been found, floating buildings claimed some noticeable spots in cityscapes (Rehman, 2020). Examples are the new floating office for the UN Climate Adaptation Centre in Rotterdam, located next to the Floating pavilion and a floating park (Global Center on Adaptation, 2021). Conversely, to the inland developments, implementation of floating structures in the second phase stays out. Even though, the advantages floating structures can offer, implementation is not observed. Departing from this optimistic perspective the reasons for the absence of floating structures are explored. Therefore, will this study focus on the second phase and thus floating development on the seas, especially the Dutch North Sea

FIGURE 3 FLOATING HOUSES IJBURG, AMSTERDAM (THE NEW YORK TIMES, 2015).

Aside from offering possible solutions to societal problems floating development are considered by de Graaf-van Dinther (2021) as an opportunity to provide *"a learning environment for leap-frogging towards Water Sensitive Societies by strengthening transformative capacity*" (p. 203). A water sensitive city incorporated the physical infrastructure with social systems to increase livelihoods (Dolman, 2021). Momentum was observed for the concept as it would secure ecosystem conservation, food supply public health and a sustainable economy (Brown et al., 2009). Through the means of "*the normative values of protecting intergenerational equity with regards to natural resources and ecological integrity, as well as by concern that communities and environments are resilient to climate change*" (Brown et al., 2009, p. 854). Wong et al. (2020), plea for strategic investment for water sensitive cities to overcome current social problems and provide long-term sustainable communities. Furthermore, floating development is researched as an important aspect of the energy transition (de Graaf, 2017). Therefore, floating development is labelled as an important aspect of the different transitions of society. Even though phase two regarding floating development as presented by de Graaf (2017) stays out in the Dutch North Sea, initiatives, and public incentives to develop floating structures are present. Finding an overview of the opportunities, limitation and conditions that can be influenced or managed for the implementation of floating structures on the Dutch North Sea.

1.2 The Netherlands

The geographical context on which this study is investigating is the Dutch North Sea. The Dutch North Sea was chosen as The Netherlands, like many other regions around the world, deals with increasing challenges. Around 59% of the country is flood-prone of which 29% is beneath sea level (Pieterse et al., op. 2009). On top of this, the pressure from land scarcity and urbanization mentioned before also play a role in The Netherlands. The population will grow, especially in the urban areas and the increasing demand for agricultural uses and nature conservation areas continuously try to claim more space (Bouma et al., 2020). In the western part of the country, multiple major cities are located together forming a metropolitan region also known as the Randstad. This polycentric area has no defined borders but consist of major cities, home to around six million people spread out over 4.500 km^2 (Knapp et al., 2005). The metropolitan area is regarded as the powerhouse of the Netherlands and is home to the port of Rotterdam, Schiphol airport and a dense road and rail network (ibid). Floating structures are seen by experts as a way to create additional land surfaces (Flikkema, 2021; Vuijk, 2021; Waals, 2021). On top of this, the Netherlands has a strong maritime sector and experience in dealing with sea-level rise (SLR) (Waals, 2021). While the Dutch North Sea is the adopter context of the floating innovation proposed in this study, examples, plans and proposals from all over the world have been analysed. In order to get an overview of the possibilities, functions and applications floating structures can carry through.

1.3 Knowledge gap

The first phase of floating development, as described by de Graaf (2017), starts in cities and port areas can already be found in the Netherlands. Even though this phase is not fully utilized yet and has the potential to further develop in upcoming years (de Graaf et al., 2019). Implementing the second phase, thus the development of floating structures on the territorial waters, in this study the Netherlands, stays out. One of the reasons for this in the literature is the rough environmental conditions of the North Sea (de Graaf et al., 2019). Contradictory to this is that technical obstacles are often regarded as limited (de Graaf-van Dinther, 2021). On the other hand, governance is observed as the main limitation (van Kessel and Dal Bo Zanon, 2019). Most of the observations derived from the literature focus on knowledge gaps and the aspects of floating development in a more generic setting (de Graaf, 2012) or for a European context (Flikkema et al., 2021). De Graaf et al. (2019) mention the significant importance of floating development on the Dutch North Sea as a solution for The Netherlands. Indicating that the inland waters are not the only area for floating development but there is an interest in moving to the second phase. Despite this, there is limited North Sea specific knowledge for the significant opportunities floating development has to offer.

The Dutch government mentions floating development on the North Sea in several policy agendas, explorative studies and future agendas (Ministerie van Infrastructuur en Milieu and Ministerie van Economische Zaken, 2014; Ministerie van Verkeer en Waterstaat, 2008; Overlegorgaan Fysieke Leefomgeving, 2019). These plans combined with private initiatives and developments of floating structures indicates that there is a societal interest in floating development on the North Sea. The development is expected to lead to many advantages in the transitions wherein floating development was mentioned valuable, as well as additional advantages the development at sea has to offer (Overlegorgaan Fysieke Leefomgeving, 2019). Therefore, this study is aimed towards whoever is included in the wide audience that is potentially interested in floating development. Especially focussing on institutes already studying floating development on the North Sea. On top of that this study is aimed towards the different levels of the Dutch government, as governance and legal frameworks are seen as key in the development of floating structures (van Kessel and Dal Bo Zanon, 2019). Therefore, the Dutch government holds a relevant position in the implementation process.

1.4 The Problem

This research is executed in preparation for the spatial interventions that will occur because of the implementation of floating structures as a reaction to ongoing challenges within society including land scarcity, climate change and urbanization. The potential of floating structures should be analysed to identify a focus for the upcoming years. As a wide variety, a function of floating structures can be observed the most potential function need distinguishment. Whereas the limitation for implementation is clarified to understand the absence of structure in line with the second phase identified by de Graaf (2017). Accordingly, the conditions that would allow for the development of floating structures were distinguished. Through identification of conditions, floating structures can be implemented, supporting the basic elements needed for development. Preparing, decision-makers, politicians, spatial planners, and the private market for the most probably floating innovation in the next decennia.

The aim of this study is thus to identify the innovation likely to be implemented in the Dutch North Sea, supported by a transition that provides a development environment. Plus identifying the conditions that should be present that will allow the innovation to harness the momentum of a transition in the upcoming decennium. The aim of this study lead to the main research question:

What are the opportunities, limitations, and conditions for the development of floating structures on the Dutch North Sea, in the upcoming decennium, using insight obtained from the Diffusion of innovation Theory and Transition Theory?

To answer the main question, supporting secondary questions were answered:

1. What are high potential floating innovations that are probably be adopted by The Netherlands in the next decennium?
2. Can a transition be identified that supports or limits the development of a high potential floating innovation?
3. Which conditions must be present in the Dutch context that would allow for the development of the floating structures?

1.5 Scientific and societal relevance

Whereas the potential of floating structures is discussed by many (Flikkema et al., 2021; Kizilova, 2019; Mohamad et al., 2012) the implementation stays out. The scientific contribution of this study answers de Graaf (2017), Olthuis (2010) and Dal Bo Zanon et al. (2020) calling for the implementation of floating structures on the North Sea, however they are providing limited applied research on what can be expected in the upcoming years. Breaking away from the optimistic foresight and applying theories to investigate the calling. The theories that provided insight allowed for an analysing function in a selection process and a validation framework for testing the floating structures. Additional insights are provided by combining two theories, accepting their shortcomings, and overcoming those through the characteristics of one and another. The new-fangled duality of theories in this study applies not solely to floating structures but also provides insight into the way innovation can be expected to develop within transitions. Therefore, adding to the theories individually while also providing a fresh perspective on both. At the same time, experts call for planners, decision-makers, and lawmakers to come up with institutional instruments (Flikkema, 2021; Waals, 2021). While understanding and awareness of the development are lacking (ibid.). This study provides a detailed foresight into the innovations that should be considered, and for which should be prepared. As the implementation of floating structures is framed as a spatial intervention, this study supports the thought process of marine spatial planning. Furthermore, for the future implementation of quantitatively greater numbers of floating structures, it is expected that the hard-line dividing terrestrial and marine spatial planning will fade (Vuijk, 2021). Therefore, terrestrial spatial planners obtain a new dimension to their work field in future regional development.

1.6 Research structure

Global challenges feed the need for a turn towards building structures on the North Sea. By taking an optimistic perspective, this empirical research departed from those challenges and looked for potential answers through floating structures. Out of an extensive database the most probably innovation was identified through data mining to be analysed by the Diffusion of Innovation (DoI) theory as described by Rogers (2003). Framing a floating structure as an innovation offered the opportunity to cross-compare them and establish a group of likely implementations. Despite the credibility of the theory, by making use academic literature it is possible to identify shortcomings, on top of the absence of high scoring floating structures. Through the realization of the absence, and by accepting the shortcoming it was possible to enrich the study by adding an additional theory. The second theory, Transition Theory offered a duality in its functioning. On the one hand, providing the identification of transition that provides a development environment for floating innovation. On the other hand, it offered intrinsic characteristics that overcame the shortcoming recognized in the DoI theory. Therefore, both theories function as a selection process to find the most probably innovation to be expected in the upcoming years. Despite a combination of theories, some innovations were found that based on their high scoring and an ongoing transition still didn't show up on the Dutch North Sea. In order to make a prediction of the future, this lacking was analysed through case studies. The case studies provided a more detailed look into the conditions that were missing that would allow for the development of the innovations. With the intention to validate the findings mostly based on secondary data In Depth Interviews (IDI) were conducted. Validation of the findings also lead to enrichment of the findings that were missing in the desk research. In preparation of future implementation, a SWOT was drawn up. Providing a structural overview functional in the decision-making process. The SWOT should according to this study, follow only after elaborate research into the opportunities, and limitations This process is depicted in a flowchart that should be considered as the guide to the implementation process.

1.7 Reading manual

In the first chapter global challenges were introduced as well as floating structures framed as part of the solution to these challenges. Furthermore, the geographical context of this study, the knowledge gap and the research question were identified. On top of that, chapter one provides the relevance of floating structures for the scientific community likewise the society, closing off with the research structure and the reading manual. Chapter 2 defines floating structures and provides insight into the reason why floating structures should be researched. Chapter 3 subsequently gives the theoretical background, constructing an understanding of the theories used, providing the grading characteristics for innovation selection and elements to recognize transitions. Chapter 4 lists the methodological strategy of this study. Providing the motivation and the execution of each method used. Subsequently, chapter 5 present the result of the analyses possible according to the insight derived from both theories. Providing a list resulting from data mining indicating 20 different functions for floating structures. Furthermore, an analysis according to DOI theory, presenting a top six of probable innovations. To eventually be narrowed down to three innovations for which a transition is identified that could provide a developing environment. In chapter 6, the condition for the three innovations is identified making use of case studies. Furthermore, chapter 6 summarizes the findings from the interviews which addressed general conditions or were deemed worthy mentioning separately. Chapter 6 also includes the SWOT analyses and flowchart that summarizes, helps predict implementation and adds to the decision-making process of floating structures. Closing this study off is the conclusion and discussion. Finally, the reference list and the Appendixes are included.

2. Contextual awareness

Chapter 2 distinguishes the contextual awareness allowing for an understanding of the concept of a floating structure. The chapter aims at familiarity with the terminology used in this study when referring to floating structures in an international and Dutch context. First, a definition of floating structures is provided to articulate the technology which is referred to when discussing floating structures. Furthermore, the reasoning for the possible implementation of floating structures will be supported utilizing relative advantages. The relative advantages are in contrast with traditional land reclamation or expansion practices.

2.1 What are floating structures?

First off, a definition of floating structures is constructed. Due to the widespread use of floating structures different types and techniques have been applied to implement floating structures (Kizilova, 2019). Creating floating structures to obtain additional spaces that can be utilized is not a new concept. As Vuijk (2021) stated: "*all around the world there are examples of historic communities that really lived on the water, the idea is not new*"[1]. During the late Aztec period, dating from 1325 – 1521, the Aztecs build a floating island in the marshy area around the city to produce crops (Ebel, 2020). Similar practices can be found around the world including Africa, Asia, South America, and Oceania (ibid.). Much of these practices haven't changed over the past hundreds of years and can still be found (Crossley and Phillip, 2004).

Over the past century, the definition of floating structures has shifted from traditional practices to technological development through the use of new materials and building techniques (Stopp et al., 2016). Mostly starting at the turn of the previous century, army forces invested in offshore floating bases and airstrips (Wang and Tay, 2011). Ko (2015), identifies five additional uses for floating structures, including offshore oil rigs, housing and villages, infrastructure including roads and bridges, breakwaters, and utility structures (Figure 4). Additional uses including, hotels, schools, industrial practices, or greenery can all be found on floating structures (Kizilova, 2019; Riise and Adeyemi, 2015; Wang and Tay, 2011). Watanabe et al. (2004) argue for several events in the previous century that lead to the current uses of floating structures. They mentioned the oil crisis in the seventies, as well as the depleting ozone layer and the negative effects on the environment caused by CO_2 emissions (Watanabe et al., 2004). These events would have resulted in a desire to move toward the more hostile environment as deserts, mountainous areas, the waters and even space (Kieth, 1977). Following this technological optimism, utopian and unprobeable plans were created (Wang, 2019). However, with global challenges and advances in technology, planners are seriously studying the possibilities floating structures provide.

[1] Translated from: "over de hele wereld zijn er voorbeelden van historische gemeenschappen die echt op het water wonen, het idee op zich is niet nieuw"

FIGURE 4 세빛섬 FLOATING ISLAND, SEOUL, SOUTH KOREA (GIJE CHO, N.D.)

As a result of this, differentiating uses and technologies have been observed for floating structures. Different definitions for floating structures arose. Government of Queensland (2006) refers to structures as floating buildings which are *"permanently moored floating building built on a flotation system and not intended for, or useable in, navigation" (Government of Queensland, 2006, p. 3).* Unfortunately, this definition mainly focuses on floating houses. Another term often seen in the literature is floating islands. Described by Flikkema et al. (2021) as an *"artificially built structure, made of steel and/or concrete, on which human activities can take place"* (Flikkema et al., 2021, p. 2). An artificial floating island should not be confused with a natural floating island formed out of built-up plants and potentially soil, as it was used by the Aztec (Mallison et al., 2001). Summarizing several floating projects de Graaf-Van Dinther et al. (2018) define floating structures as *"developments that are based on floating foundations and can adapt to changes in the water level autonomously*" (de Graaf-Van Dinther et al., 2018, p. 1). In the latter part de Graaf-Van Dinther et al. (2018) describe autonomous vertical adaptation, of the ability to float as a reaction to SLR. This study makes use of a combination of these definitions and focuses on artificial structures, stationary located through a mooring system, specifically built to take part in the process of fulfilling human needs. Examples are housing, leisure activities, energy, or food production and industrial or economic practices.

2.2 Why floating structures

Several advantages are linked to floating structures which are lacking in conventional artificial islands or land reclamation projects. These advantages will be outlined in this section. Firstly, traditionally constructing floating structures oppose many threats to marine life. Past research done by Pieters et al. (2001) assessed the possible negative effects of the construction of islands in the North Sea. Groot (1979), stated that "Most of the damage to and disturbance of life in the area where the island will be situated will occur during the building phase." (p. 212). During this process, the stationed organism will be extracted in the process of sand dredging or covered with thick layers of sand to generate artificial land above sea level. On top of that, surrounding areas will see an effect in terms of turbulent waters, changing heavy metal levels and release of trapped pesticides and polychlorinated biphenyls (PCB). The sand replacement in combination with the physical and chemical changes of the water column, in turn, affect flora and fauna, including plankton, bottom flora, and fish. The effects and changes will mainly be witnessed during the construction as it is expected that through succession the ecosystem that was once present will recover itself (Groot, 1979). Nevertheless, the land that will make up the artificial island will be lost for the ecosystem. In contrast to this, floating structures can be constructed in shipping yards and towed into place. Leaving a smaller footprint on the seafloor as it needs solely mooring construction (Flikkema et al., 2021). While at the end of their lifecycle floating structures can be towed to a deconstruction side making room for new structures and reducing deconstruction stress on the surrounding areas. On the other hand, the effects of large-scale floating structures is still being researched. Research shows that the net primary production of the ecosystem decreases as the covered

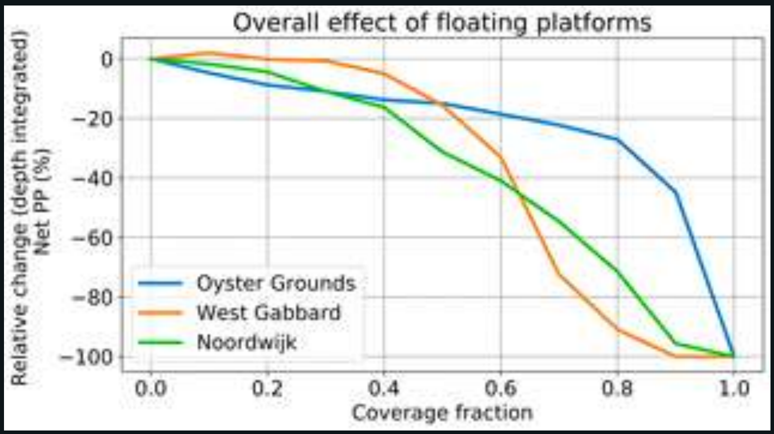

FIGURE 5 DECREASE IN NET PRIMARY PRODUCTION CAUSED BY AN INCREASE OF SURFACE COVERAGE AT THREE DIFFERENT LOCATIONS (KARPOUZOGLOU ET AL., 2020).

water column increases (Karpouzoglou et al., 2020). The effects are influenced by the tidal currents and decreased wave activity. Likewise, Karpouzoglou et al. (2020), expert Vuijk (2021) also warned for the missing knowledge on the effect of implementing large scale floating structures. Floating structures take away the sunlight used by organisms in photosynthesis that supports the ecosystem. Vuijk (2021) states this should be considered when designing and planning large scale floating structures. **B**eseeching that "*parts in the middle should be left open … as through small scale experiment, these issues don't show up.*"[2] *(Vuijk, 2021).*

Additionally, to the effect on the ecosystem in which a floating structure is placed. Floating structures offer advantages in terms of floating. Contrary to land reclamation or some parts of the Netherlands, floating structures are not vulnerable to flooding as they float on top of the water (Wang, 2019). It should be mentioned that a washover of waves can occur when the floating structure is of substantial size (Waals, 2021). However, most structures are not large enough or are built up out of multiple modules allowing for some resonation with the waves. With floating on water, the risk caused by SLR become nihil. Therefore, floating structures are seen as part of creating climate-proof communities (Flikkema, 2021; Waals, 2021). Aside from preventing wave overtopping, a modular design serves an additional advantage. A modular design incorporates flexibility in the function a collective structure offers (Drummen and Olbert, 2021). A function can be removed or added based on the demand for that specific location and be implemented in phases. The flexibility of floating structures comes with the modular design, in terms of moving segments to different places (Waals, 2021). Figure 6 showcases the advantages of both reclaimed land and floating structures. It encompasses advantages stated so far as well as some that will follow in the other chapters.

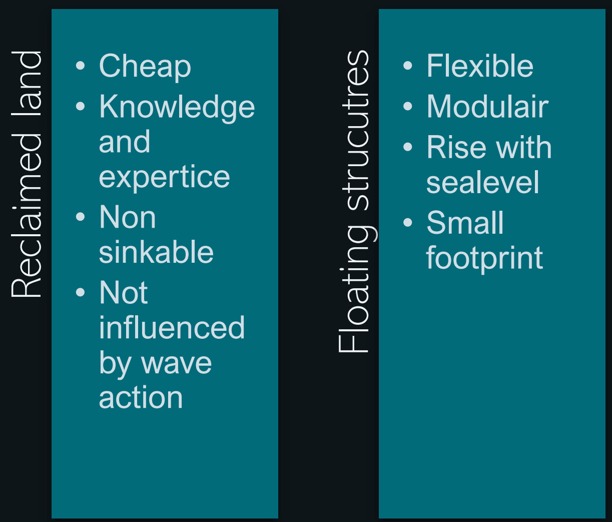

FIGURE 6 ADVANTAGES OF DIFFERENT TECHNIQUES

[2] Translated from: "delen In het midden open laten… je experimenten op kleine schaal doet de kom je zulke vraagstukken niet tegen"

3. Theoretical understanding

After establishing a contextual awareness when referring to floating structures, chapter 3 will familiarize the theoretical framework. Starting with the Diffusion of Innovation theory consecutive the Transition Theory. The diffusion of innovation provides insight that are used to create a framework to identify high potential floating structures. While the Transition Theory lays out the suitable developing environments.

3.1 Diffusion of Innovation

Diffusion of Innovation originates back from the early 20th century when Gabriel Tarde was working on diffusion research (Kinnunen, 1996). Diffusion research focuses on how innovations like new means, advancements or ideas flow through society and become generally accepted (Katz, 1999). However, the process is dynamic and flow through different stages, with each actor that influences the flow of adaptation (Figure 7). Furthermore, the characteristics of the innovations are an influential part of the way they flow through society. The dynamic flow of innovations formed the inspiration to Evertt Rogers and many others to extensively research the phenomenon and create the Diffusion of Innovation theory that will be used in this study (Kaminski, 2011; Meade and Islam, 2006). As for this study, a floating structure will be identified as an innovation.

FIGURE 7 PROSSES OF DIFFUSION. ADOPTED FROM (KAMINSKI, 2011)

The definition of innovation according to Rogers is “an idea, practice, or object that is perceived as new by an individual or other unit of adoption” (Rogers, 2003, p. 11). He adds that it does not matter if the idea is relatively new, given that the innovation is perceived as new. In the first chapter, it was introduced that floating structures have been around for many thousands of years. Despite this, the technique and function of floating structures referred to in this study are new. It can occur that an individual might have known about the innovation but neither accepted it nor rejected it. Therefore, innovation is determined by the perceived newness, knowledge about the innovation and attitude towards the innovation (ibid.) When an innovation is presented to society, it presumably follows a specific path. The trajectory of innovation can be subdivided into four stages like Transition Theory which will be explained in chapter 3.2. Diffusion of innovation however defines the stages based on the actors that influence the shape of the curve at that point.

The first group of actors, the *innovators*, are those who need little effort or time to use innovations (Kaminski, 2011). They are, technology enthusiasts, driven by venturesomeness, they possess the complex understanding of the innovation to accept the higher risk that comes with the innovation (Rogers, 2003). This is also seen regarding floating structures; they adopt floating structures because it is new. The rationale for implementation seems to be absent to the majority of the social group (Kaminski, 2011). An example of this in floating structures is the duo trying to create a seastead in front of the coast of Thailand explained in Box 1.

Consecutively are the *early adopters*, a group of actors with strong opinions, and regarded as role models in society (Rogers, 2003) Early adaptors are not led by monetary means, therefore willing to pay relatively more (Kaminski, 2011). Kaminski (2011) adds to this that this group can be referred to as a tester of innovation. This group can be observed in Rotterdam where the floating pavilion is installed. The project took place in the lowest-lying metropolitan region of the world and was installed to explore possibilities towards floating cities (DeltaSync, 2014). Testing not only the technical aspects but also challenging the jurisdiction and laws applicable to floating structures (Ibid.).

Whereas Figure 8 shows a continuous bell curve, Moore (2002) argues for a cham between each group. Rogers also describes a transferring period between each actor group, however Moore (2002) specifically describes the chasm that follows after the Early adaptors. Moore (2002) based his research on high tech innovation, and pleas for a bigger gap or 'Chams' between the first two adopter groups of early adaptors and the early majority. The chasm is bigger here due to the characterises of the early adaptors. According to Moore (2002), early adaptors are typically wealthy individuals taking looking for business advantages over competitors not adopting innovations (Moore, 2002). On the other side are the early adopters who adopt innovation to increase productivity through evolution rather than revolution (Kaminski, 2011). When an innovation is saturated through the early majority the process continues to the late majority actors.

The late majority are sensitive to pressure and economic necessities (Rogers, 2003). This group is shy regarding new technologies and require bulletproof innovation, however, are also highly influenced by the last group on the curve (Kaminski, 2011). The early and late majority consist of more than 2/3 of the society and therefore together form the biggest group.

The final group are the laggards, characterized by isolation, mistrust, traditionalism (ibid.). Laggards

Box 1: The First Seastead

In 2019 Chad Elwartowski and Nadia Supranee Thepdet installed a floating structure in international water of the coast of Thailand. Claiming it to be the first seastead (Seastead: a complete planned and designed artificial island or structure floating in the world's seas or oceans. Through a collective goal and efforts of individuals a community is created. This is done outside of the power of any government or regulating body (Steinberg et al., 2012)).

The Thai navy however considered this action as a threat to their sovereignty and removed the structure, leaving Elwartowski and Thepdet a fugitive of the Thai state (Jackson, 2019). Right after the inhabitation of the floating structure, a video was made to showcase the life on the seastead and in this video Thepdet states; "We have to count from zero to one to a hundred. You cannot jump from zero to a hundred to be a big seastead." (Jackson, 2019). Herein she directly refers to their seastead as well as the book by Peter Thiel and Blake Masters (2014) called Zero to One: Notes on Startups, or How to Build the Future (Jackson, 2019). As Elwartowski and Thepdet attempt was the 'One' before the hundred.

only adopt if no Suitable alternative is available or might not even adopt an innovation at all (Rogers, 2003).

Aside from the chasm described by Moore (2002), five main features influence the diffusion of an innovation. First, the innovation itself, according to Rogers (2003) contains five characteristics that affect the diffusion. The first characteristic is the *observability* of an innovation, referring to the observability of the result of innovation, as observable advantage stimulate dialogue. Secondly, the *relative advantage* over other or past innovation perceived from the adopters, therefore the advantage of the objective is subservient to perceived advantages. For floating structures, this was shortly discussed in chapter 1 and shown in Figure 6. For floating structures, the relative advantage is compared to land-based practices that do not possess the advantages that come with floating on the water. The third characteristic is the degree to which an innovation is *compatible* with the current society, this includes experience, values and beliefs, and socio-cultural commons. Incompatible innovation often requires a social change in the value system which are lengthy processes. Fourthly is the *trialability* of an innovation that would allow for piloting and testing. Small scale experimentation and upscaling lower investment risks and allow for tailoring. The final characteristic is the *complexity*, of an innovation. Innovations that are straightforward and comprehensible are expected to be faster diffused compared to innovations that require additional education (Rogers, 2003).

Furthermore, influencing adaptation arises after the first implementation of the innovation. Diffusion theory assumed innovations as stagnant and unchanged once implemented. However, innovation changes after adoption through a re-invention process that allows for increased adaptability and integrated saturation in a social system (Box2).

Next is the feature of communication, communication channels are used to transfer knowledge concerning an innovation. Rogers (2003) identified mass media as the most rapid and efficient way of communicating innovation to the greater society. However, he adds that interactor links are highly effective in pursuing individuals to adopt an innovation. Especially if the actors are similar in social status, economic wealth or other characteristics which are perceived as important.

The time feature is subdivided into three parts. The first period is the duration between initial introduction to an innovation and the moment of decision whether to adopt or reject and innovation. secondly the rate of diffusion that refers to the adopter groups early described. Investors have a short time span to adopt an innovation while the late majority will most likely relatively be described as slower adopters. The last time span refers to the time it takes to fully adopt an innovation within an organization for example.

The final feature of a diffusion is the social system the diffusion takes place. There is validity in social group referring to different geographical and demographic scales. A social group consist of organisation, institutions or individuals which share solution seeking for a common problem (Rogers, 2003). Diffusion theory provides a theoretical framework to analyse innovation and the way diffusion occurs within a social group. Allowing lawmakers, innovators, or entrepreneurs to solve common problems and come up with strategies for change (Kaminski, 2011).

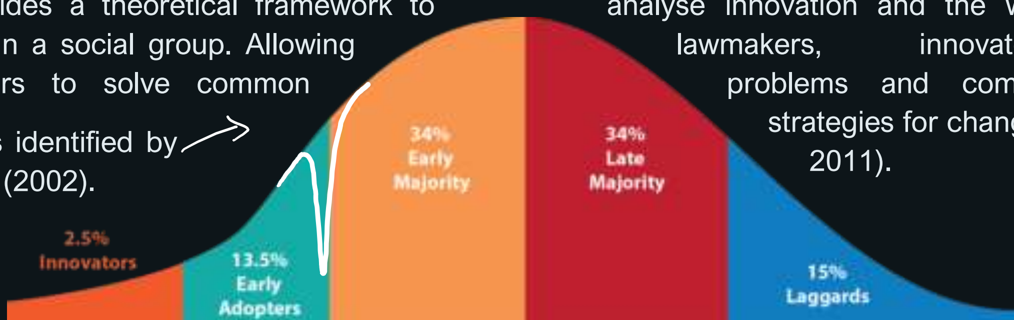

FIGURE 8 BELL CURVE OF ADAPTATION

Shortcomings

The DoI theory provides a framework to assess the ease with which innovations will diffuse within societies. However, some shortcomings in DoI theory are recognized. In the real world, it can be expected that the high scoring innovation should be widely implemented. However, the absence indicates additional factors influencing the implementation process nonetheless the high scoring. When looking for an explanation in the literature some arguments are given. Observing the world as a complex system, DoI tries to rationalize a social process and by doing so it tends to neglect the complexity found in a social group, and consequently form a blind spot (Davis and Simon, 2013). Nicholls et al. (2015) argue that DoI as described by Rogers, make several assumptions or minor changes based on Trade's research that should be understood to recognize the shortcomings of DoI theory. Roger assumed an innovation existed and investigated the way these are accepted by a social group. As a result of this "*Rogers severed the direct connection between invention and innovation – through which an invention becomes an innovation – and reduced the creative process of imitation to its adaptive function*" (Nicholls et al., 2015, p. 40). Hence, a valid argument for the assertion that Rogers investigates the acceptance of an innovation rather than the quality of an innovation. The grading sheet that is created using the insight of DoI, and which will be introduced in chapter 4.2, might not look into the high scoring probable floating innovations but rather to what extent it will be accepted in the context of the North Sea. Nicholls et al. (2015) furthermore add the innovation bias intrinsic to the theory by Rogers. Focusing on convincing the adopter groups of the legitimacy of the innovation rather than assessing the innovation as is. Assuming Rogers rather discusses inventions rather than innovation, it can be expected that Rogers looked into an opening for new social practices. By the creation and development of new social practices, the inventions will be innovations (Nicholls et al., 2015). Recognizing and accepting these shortcomings of a continuous developing theory also allows us to try to overcome these. To overcome these shortcomings, a second theory will be introduced in this study.

Box 2: Different shapes

MARIN, (Maritime Research Institute Netherlands) has been working of floating structures for many years. Looking at social challenges, the research facility feels a strong responsibility in solving these. Land scarcity, population growth and climate changes are motives for investigating floating structures. it became technically very hard to create very large solid structures. Therefore, a modular design was constructed consisting of smaller triangles. Triangles have the lowest amount of axis to turn, and therefore reduces the amount of force.

Even though triangles have a structural preference, the following prototype is made up of squares. Urban planners and developers decided this was preferred over triangles and easier to construct. It was shown that the forces increased.

MARIN current research is looking into a hybrid form of floating structures and traditional land reclamation as a breakwater. Here the construction can be observed to be rectangles. Tests are currently still going on, so the effect and forces on this other shape of floating structures has not be made public as of writing this study (Waals, 2021).

3.2 Transition Theory

The second theory that will be discussed is the Transition Theory, offering insight to select development environment for floating structures and overcome the shortcoming identified in DoI Theory. Transition Theory finds its roots in complexity theory, which in turn comes from the general systems theory (Rotmans and Loorbach, 2009). System theory offers a framework to analyse complex systems made from interrelated parts resulting in a greater outcome than the sum of its parts, examples of these are cities, organisms, societies, or sectors (ibid). Bertalanffy (1973) states that these systems do not just consist of parts that interact but incorporate different types of interaction, describing the interaction as an equation, ranging from rarer to basic and common interaction as well as general or specialized interaction. He adds to this that in these far and wide systems of parts, interaction and equations, cause and effect relations become unclear. Bertalanffy (1973) describes the blurred relationship between cause and effect as the "*blind laws of nature*" (p. 30). These laws bind the measurable parts and interactions studied by natural sciences, to complexity studied by social sciences (ibid.). System theory can therefore be found in many disciplines, for example, computer science, biology, economics, and social studies (Rotmans and Loorbach, 2009). De Roo (2010), links spatial planning and complexity thinking stating that planners should accept time, development and progress into their theoretical scope. With the widespread adaptation of the system, theory come different adaptations to the theory, each still not fully developed (ibid). Rotmans and Loorbach (2009) define multiple adaptations of complex systems theory, however, as for Transition Theory, they focus on the behavioural understandings of a complex system.

A complex system consists of a network of parts and interactions connected through nodes. On top of that, a complex system is an open system that reacts to outside changes and influences (Rotmans and Loorbach, 2009). Another characteristic of a complex system is that interactions and developments occur non-linear, which according to Ladyman et al. (2013) is not mandatory nor sufficient for a complex system. Contrary, Loorbach et al. (2008) states that a transition happens in virtue of non-linearity. Later in this chapter non-linearity will be elaborated on in more detail. Furthermore, a system is believed to contain feedback loops that react to changes in influences adaptations. Feedback loop either suppress changes (negative feedback loop) or boost and accelerate certain changes (positive feedback loops) (Rotmans and Loorbach, 2009). These feedback loops are important as big impacts or pressure can result in small nihil changes because of a negative feedback loop. While at the same time the opposite is true for small changes causing big disturbances due to positive feedback loops.

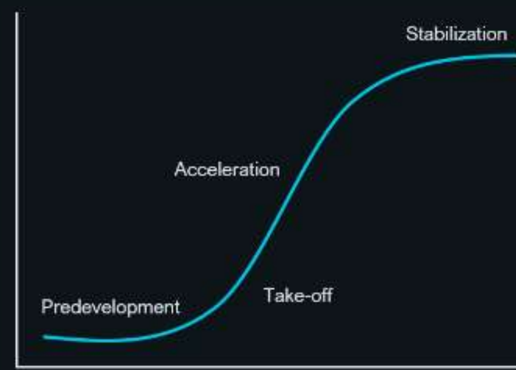

FIGURE 9 STAGES OF A TRANSITION. ADAPTED FROM (LOORBACH ET AL., 2008A).

As part of Transition Theory, it is important to understand that complex systems have previous states. Due to the non-linearity of a complex system, non-chronicle events that happened in other states can affect the course of the future states, creating path dependency (Levin, 1998). Path dependency is a result of previous events that now due to contingent actions produce institutional commons that later influence new events (Djelic and Quack, 2007). Within a complex system, different layers can be recognized, by which higher levels interact with lower levels and the other way around to reach attractors (Rotmans and Loorbach, 2009). Attractors are defined as states which are deemed preferable or aimed for through interactions (ibid.) Thus, complex systems, like our society, are open systems that react to internal and external influences in a non-linear manner, in which different layers interact while aiming for a certain envisioned state.

Transition Theory gives insight into the process a system undergoes when changing from a certain state to a new one. Transitions are large scale changes within a society wherein the structure and composition of the systems are reshaped (Loorbach et al., 2008). Van der Brugge et al. (2005) describe a transition as “a process of the co-evolution of markets, networks, institutions, technologies, policies, individual behaviour and autonomous trends from one relatively Stable system state to another” (p. 166). Each transition goes presumably through a couple of phases and has a list of characteristics that will be discussed in this chapter. Before discussing the different phases, an understanding of the system will be depicted.

A transition starts in an old equilibrium (state), in an equilibrium three layers can be identified, representatively the Macro level, Meso layer and Micro level according to the multi-layer perspective approach within transition theory (van der Brugge, er al. 2005). The macro level, retrieved from the multi-level perspective, or when viewed from the multi-level governance approach it is referred to as the landscape level, represents large scale politics, economics, natural environments, cultural aspect and general world views (ibid.). Loorbach et al. (2008), add to this by referring to the macro level as the layer of “*trends and autonomous developments*” (p. 298). Scaling down a level is the Meso level, consisting of regimes, their main goal is sustaining social life and economic development (van der Brugge et al., 2005). Examples of these are national governments, NGO’s, international organizations, and other institutes supported by a set of norms and agreements (Loorbach et al., 2008). The lowest layer is the niche level, this layer houses for example innovations and entrepreneurship (ibid.). The niche level provides a space to test new forms of governing, newly developed technologies, and a stage for individual actors to spread ideas and believes (van der Brugge et al., 2005).

During a transition, change is likely to occur on all different levels. The stable equilibrium becomes disrupted and transitions through four phases to a new stable equilibrium (Figure 9). The first phase is the pre-development phase, in which the regime level remains rather rigid, whereas some small changes can be observed on the landscape level (Loorbach et al., 2008). On top of that, the niche level pushes the transition forward (ibid.). The process continues for a while and reaches a threshold that changes the progress of the transition. The take-off phase is when regimes are changing and adapt to the changes that mainly occurred on the micro and macro level (van der Brugge et al., 2005). van der Brugge et al. (2005), furthermore adds that the micro and macro level interchangeably influence each other. Whereas Rotmans and Loorbach (2009) mention the importance of the regime level in the second phase to move away from the old stable equilibrium and allow for social change to happen. Leading to the third phase where the structural change in all sectors of society, supported by the institutionalisation of the new development (Rotmans and Loorbach, 2009). Each of the changes is reinforced by another and structural changes are solidified (van der Brugge et al., 2005). The final phase comes at the end of the transition and entails the stabilization of the new equilibrium when development, innovation and adaptation of new norms level off (Rotmans and Loorbach, 2009; van der Brugge et al., 2005). At this point, a new equilibrium came into existence wherein the transition is complete and remains stable until a new transition predevelops.

Shortcomings

However, likewise the developing theory of DoI, for Transition Theory shortcomings were identified. First of all, a fair number of authors criticised Transition Theory, according to them it might not be as spontaneous and unsteerable as presumed by Rotmans and Loorbach (Rotmans et al., 2007). Rotmans et al. (2007), continuous in the self-reflective article with scepticism on the manageability and steering of transitions. As well as arguing for the forerunners of the direction a transition moves to.

The combination of both theories

The combination of both theories would help to overcome the shortcomings to a certain extend. Using Transition Theory allows us to overcome the blind spot for complexity that might occur from the DoI theory (Figure 10). As Transition Theory is retrieved from the complexity theory, it inherently incorporates the complexity of societies and attempts to understand behaviours within complex societies, as it is most likely a missing factor in the DOI theory. The next point of critique is DoI could investigate acceptance rather than the quality of innovation. A complex system contains feedback loops into the process of development (Rotmans and Loorback, 2009). Providing a process that potentially filters out these falsely perceived high scoring innovations. The final point of critique defines innovation and invention. Stating that a change of social practices is needed for an invention to become an innovation. Transition Theory allows us to recognise changes in social practices to a new equilibrium. It is this process of changing societies that would make an invention an innovation and Transition Theory tries rationalizes the social change at hand, allowing for prediction making. Therefore, a transition is needed for the innovation to develop, or in other words, the absence of a transition is a limiting factor for a floating innovation to develop and be implemented.

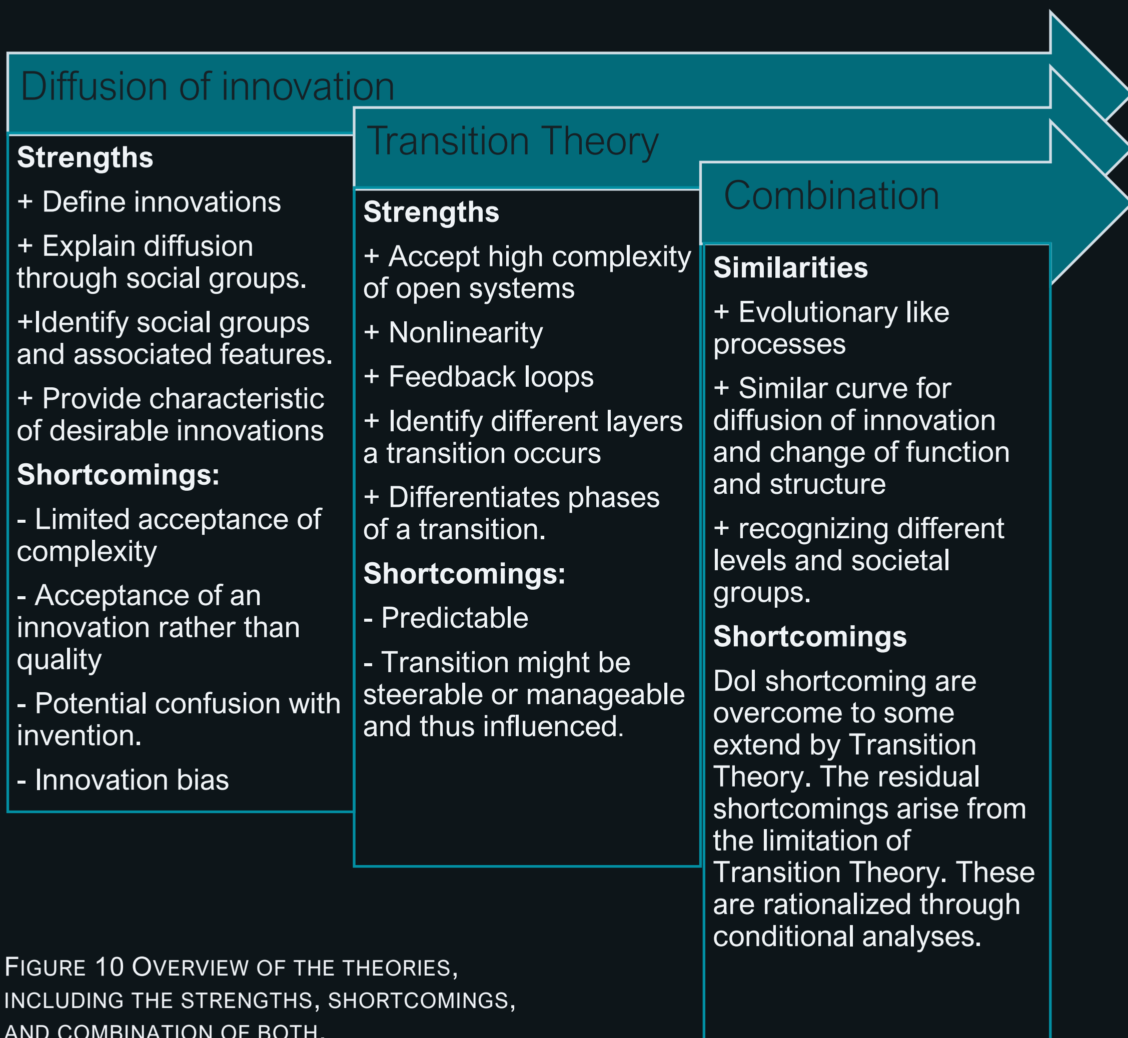

FIGURE 10 OVERVIEW OF THE THEORIES, INCLUDING THE STRENGTHS, SHORTCOMINGS, AND COMBINATION OF BOTH.

In summery to the contextual awareness, in combination with the insight retrieved form the theories a conceptual model was created (Figure 11). The conceptual model allows for the identification of the data that should be collected and analysed in the empirical part of this study.

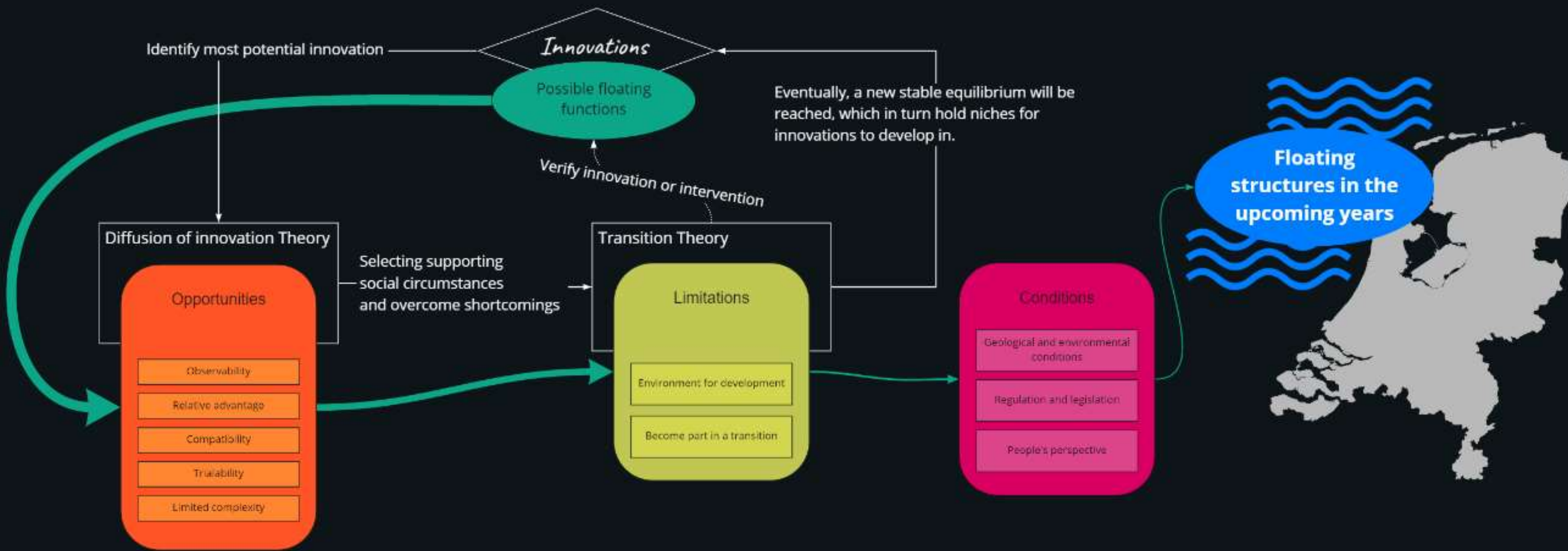

FIGURE 11 CONCEPTUAL MODEL. TO ENLARGE, CTRL+CLICK ON THE CONCEPTUAL MODEL OR FOLLOW THIS LINK.

4. Methodology

This research made use of several forms of data retrieved through separate research methods. Through data mining, desk research and semi-structured interviews the sub questioned were answered. Even though this research is primarily qualitative, quantitative methods are used to identify potential innovations. The theories discussed in the previous parts provide insight to create a framework for data analysis, to identify the opportunities, barriers, and conditions for floating developments. The next subchapters will explain the use of research methods. The primary data adds to the secondary data through new perceptions and verifies or debunk the observed patterns and result. Thus, the methodology of this study composes several techniques and methods to answer the main questions. Each sub-question is answered separately through a combination of different methods. The process of answering each sub-question as well as the correlating research method is shown in Figure 12.

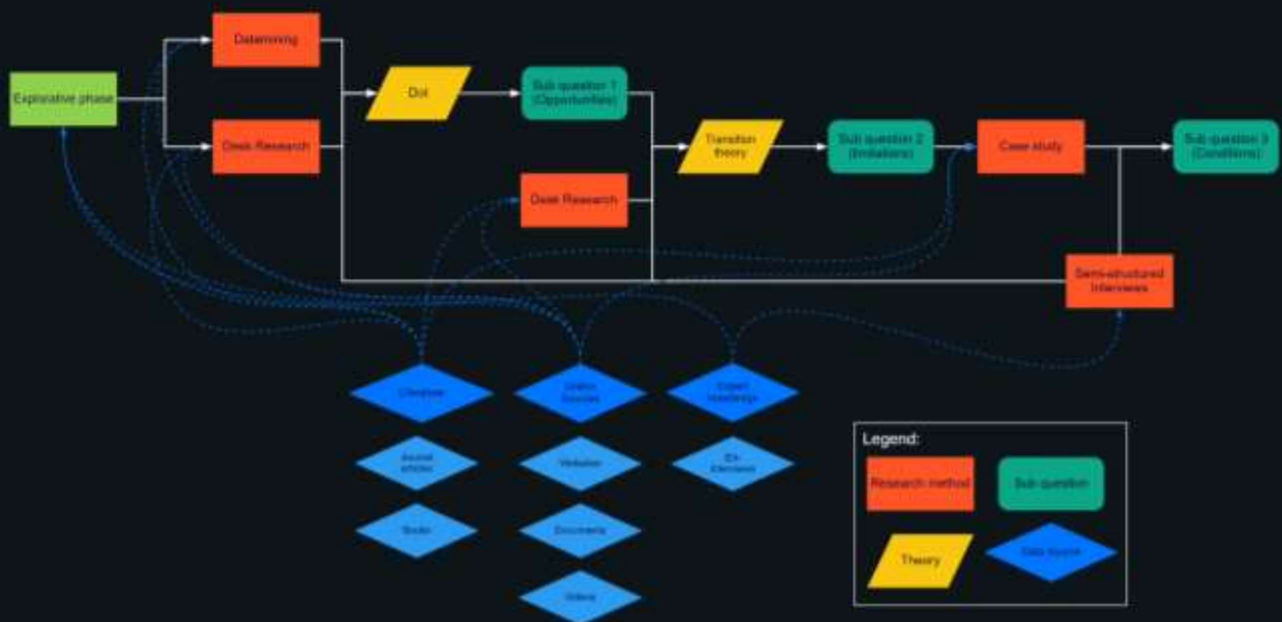

FIGURE 12 RESEARCH STRATEGY TO ENLARGE, CTRL+CLICK ON THE CONCEPTUAL MODEL OR FOLLOW THIS LINK.

Through the combination of several research methods, and multiple data sources, data triangulation was possible. Triangulation, as described by Carter et al. (2014), is a strategy used in qualitative research, to examine the validity of this study. Four types of triangulations are identified: method triangulation, investigator triangulation, theory triangulation, and data source triangulation (ibid.). This study makes use of the latter and to an extend the first. As Carter et al. (2014) describe, method triangularity uses a combination of methods to investigate a certain phenomenon. In this study, multiple methods were used, at different times of the study, and for different purposes. A total of four methods were utilized including, data mining, desk research, case study and interviews. On the contrary, the different methods all served a purpose in retrieving suitable information for that part of the study. The data was retrieved from three different sources, hance data triangulation. For most of the study, interviews were not included in the data collection. The main sources of data up until that point included literature and online sources. Due to a large amount of information available, it offered the right resources that ensures the validity of this study. To further increase the validity of this study an additional source of information was consulted. Carter et al. (2014), refers to in-depth interviews (IDI) interviews as “one of the most powerful tools for gaining an understanding of human beings and exploring topics in-depth” (p. 545). In- Depth Interviews (IDI) provide perspectives and personal experiences on sensitive topics or discussions. To incorporate expert experience into the study, several expert interviews were conducted. The semi-structured interviews held a dual purpose in this study, which will be further elaborated on in the next part of this chapter.

This study started off with an explorative phase on floating structures, what they entail, and the function that can have. Part of this explorative phase are research (pre-)proposal and interviews with expert. More on these interviews is explained in chapter 4.5. The explorative phase allowed for the scope for this study, the theory selection and the empirical data collection.

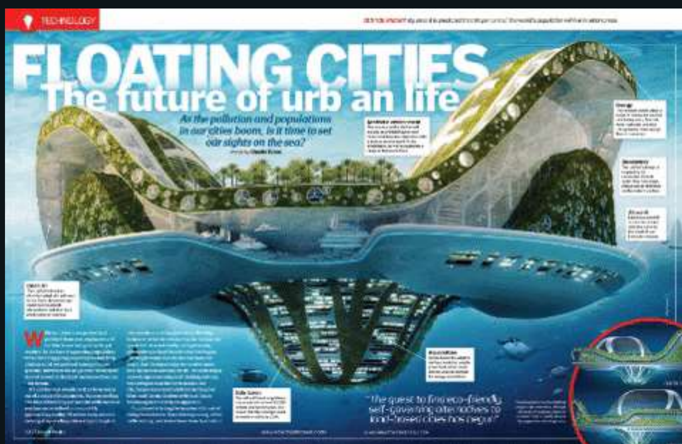

FIGURE 13 EXAMPLES OF ANALYSED FUNCTIONS IN DATA MINING (HOW IT WORKS DAILY, 2018).

4.1 Data mining

The first research method used is data mining. Data mining can be used for several purposes, it can predict, classify, cluster, recognise patterns or outline detection. Through data mining, information can be extracted from large amounts of data based on a theoretical foundation (Pujari, 2001). In recent years, data mining has gained popularity in the field of IT and computer science, nonetheless, data mining has been around for over 30 years, also in the field of social sciences (van Hoesel, 2020). Conversely, van Hoesel (2020), adds that no noticeable results have been shown from these types of data analysis and stresses the importance of a theoretical foundation to support the process. In this study, data mining was chosen to identify innovations in the field of floating structures. In journals, on websites and in books there is a richness of floating initiatives. This is expected according to the DoI theory, in which Roger (2003) identified mass media as the most efficient and rapid way to communicate an innovation to a greater society. To apply the DoI theory to these initiatives, in the way explained in chapter 4.2, the innovations must first be identified. Datamining showed to be a useful technique to select and identify the individual initiatives and categorize them and limit the great number of ideas.

When composing a definition of floating structures, it became clear that there is a vast number of technical differences in the way the floating foundation can be made. Only to recognize that this was merely the number of options available for possible uses of floating structures. To overcome the fastness of the available data, datamining was selected as the method. Thuraisingham (2000), describes the steps of datamining which will be followed in this study. The first step of data mining is to analyse is the data group that will be analysed of such a magnitude data mining should be applied. The second step of data mining is to identify the data to be analysed. The data was collected from online and offline sources, offline sources are primarily books. The online sources come from literature search engines like 'google scholar' and the online environment from the university's library. Furthermore, websites of companies or institutes that are involved with floating construction are explored. Some of these provide vast data based on scientific research, article, papers, and detailed proposals. Examples of these are the website of Blue 21 and The Seasteading Institute. The third step is the creation of a data warehouse, for this research an online database was created to collect documents, articles, books, videos, and other

materials. In total 72 individual data units were collected, and 15 links were saved. An individual unit could either include a single proposed use for a floating structure, for example, project plan for floating houses, or a feasibility study for floating cities. Additionally, a data unit can also be composed of multiple ideas for floating structures, examples are collected works, conference proceedings or online copies of books regarding the subject. Meaning that the total of 87 units does not mean 87 data points. A datapoint would be mentioning a single use of a floating structure, and thus the total amount of analysed data points is greater than 87. To clarify, the data mining was used to identify possible functions of floating structures and it was therefore not of interest to track the number of data points as these statistics is not the purpose of the method. On the other hand, the third step of data mining is to identify the desired outcome. As already stated, the outcome should be the different functions a floating structure could have, should be categorized.

The fourth step describes two separate methods for analysing the data once the outcome is established. For this step, a top-down approach or a bottom-up approach can be used. In a top-down approach, a hypothesis is the starting point and through data mining, the set hypothesis is tested. In contrast to the bottom-up approach, the data is analysed to construct a hypothesis. Thuraisingham (2000), adds that a bottom-up approach is suitable if the outcome is clear. In this study, the outcome is clear (categorizing function) and therefore the bottom-up approach was used. The bottom-up approach was executed by analysing each data unit and recording each function. The functions were logged in a spread sheet. The final step is to examine and prune the found data. Some functions could be merged into one category as they fulfil similar or the same function. An example of this is energy production and handling methods, this turned into one category after merging floating wind turbine, tidal energy, wave energy, energy hubs, production of hydrogen and the storage of energy as hydrogen or fossil fuels. Subsequently to examining and pruning the data the result was posted and that lead to a list of 20 functions. A combination of individual functions or merged functions see Table 1.

TABLE 1 LIST OF THE FUNCTION OF FLOATING STRUCTURES

Pavilion
Airport
(Mega) City
Information/event centre
Hotel
Cemetery
Pool
Stadium
Mosque
Districts
Food production (plant-based)
Food production (animal protein)
Coral reef (nature conservation)
Lab/ research centre
Energy hub/ production
Nuclear reactor
Port/cruise terminal
Desalination plant
Cyclicity
Breakwater

4.2 DoI scoring

Now that a manageable list of functions was established, the DoI could be applied. In this study, a function of a floating structures is the innovation, as it in new in contrast to similar land-based function as described in the DoI theory. A function in itself is not an innovation, but since this research looks into floating structures most of these functions have not or been only rarely implemented. Floating functions can be perceived as new, according to Rogers (2003) perceiving an idea as new it becomes an innovation. On the other hand, it was also found that this is rather an invention rather than an innovation as described in the shortcoming part of chapter 3.1. To overcome this shortcoming, social changes must be present. Identifying social changes will be explained in chapter 4.3.

The DoI theory describes how innovation flow through our society and to what extent it will be accepted. To get an indication of the extend an innovation is expected to diffuse within a society the characteristics of the innovation can be assessed. The characteristics are *Observability, Relative advantage, Compatibility, Trialability and, Complexity*. An innovation that is expected to be generally accepted within a society contains the five main characteristics. For each characteristic, a short description was added

	Observability	Relative advantage	Compatibility	Trialability	Limited complexity
Airport	4	3	4	4	2
Breakwater	1	2	1	1	4
etc.					

TABLE 2 EXAMPLE OF THE GRADING SHEET USED TO ANALYSE THE CHARACTERISTICS OF EACH INNOVATION.

based on Rogers (2003) and as previously stated in chapter 3.1. Taking the result from the data mining shown in Table 1, the floating innovation were screened based on the presence of the characteristics.

For each innovation screening, desk research was executed to get a grasp of the characteristics of the innovation. The innovation was placed in a spreadsheet as shown in Table 2. Table 2 is just a snapshot of the total table wherein all 20 functions have been adopted. Each category was either assigned a 0 if not present or one if this characteristic could be observed based on desk research. It should be mentioned here that for complexity that indicated a lower level of complexity was used for assessment reasons. It was thus decided to use the term limited complexity indicating the absence of complexity as this is a characteristic of high potential innovation.

The result of this analysis can be found in Appendix 1. Despite this, limited variation occurred in the highest-scoring potential innovation. Considering the grading process is based on limited desk research and perception of the observer an innovation could falsely be eliminated. To limit the effect of this, it was decided to grade the categories on a gradient scale ranging from zero to five. Allowing for a more gradient scaling system as well differentiating between the innovations. It, therefore, becomes possible to grade the innovation relative to each other. This led to a different ranking as shown in Appendix 2, it was decided that the most promising innovation should at least score 15 points in total. For an innovation to score 15 points an average of three or higher per category is sufficient. The result is a comprehensive list of floating innovations that are expected to be adopted into our society. Based on experience and perspective it might occur that the grading sheet is utilized differently and would lead to some differentiation results. Generally, the outcome gives a good indication of the most probable floating innovations.

4.3 Recognizing transitions

In the previous part, the most probable floating innovations were identified (Table 3). Nonetheless, the probable innovations are not implemented in the North Sea. To identify a transition for each high-ranking floating innovation, desk research was done. A transition happens on three different levels of society, the landscape level, the regime level and the niche level. By making use of articles, proceedings, books, and online sources possible indicators of transition were identified. The used sources were collected by making use of online sources retrieved from websites providing literature and plans on floating structures supported by academic sources retrieved from search engines including but not limited to Google Scholar, University library online environment, and journal website as well as offline sources like books. For each floating structure possible factors on the different levels were investigated. Allowing for filtering out high scoring innovations that are possible false identified as a result of the critique identified of the DoI Theory.

Despite the legitimacy of the critique stated in the self-reflection and by other authors, the absence of floating structures in the North Sea was still not elucidated. Therefore, it could be assumed that conditions are influencing the implementation of floating structures. As of that point in the study, the most probable innovation was identified as well as linking them to transition that would provide a comfortable development environment. It was therefore decided to investigate these scenarios and look for conditions that would allow for the development of floating structures.

4.4 The conditions

In continuation with the previous part, it became clear other factors play a significant role in the process of floating structure development. From the six probable innovations, three were in line with an observable transition. To get a better understanding of the condition, case studies were executed. The three different innovations formed the unit of analyses for the case studies. By analysing the units, a case study provides a contextual understanding of what was planned and what occurred in the real world and its complexity (Noor, 2008). The case studies were executed using additional information about the specific plans especially in relation to the geographical context of this study. By making use of additional resources including websites, project plans, and proposals in-depth knowledge on the determining conditions was collected. These new inputs could then be used for a descriptive case study, observing conditions, and evaluating them.

The first step for a case study is describing the formulation of the theory. In this study this was done in chapter 3, describing the DoI theory and the Transition Theory. The next step would be the identification of the cases. The cases rather than being selected, are the result of previous analyses and according to the formulated theories. Resulting from six probably innovations, to three innovations in line with a transition. The third step is to analyse these three innovations. Data analyses from the previously stated sources in combination with knowledge retrieved from additional sources, allowed us to observe the main conditions. The next step is to compare the condition identified and draw a conclusion from those. Whether they applied to all found conditions or that there are innovation specific conditions. Thus, the case study allowed us to investigate floating constructions with greater depth, to indicate the contextual real-world conditions which were not observed because of the theoretical analyses. Leading to some conditions that are specific to the North Sea, floating structures, or a combination of both.

4.5 Expert interviews

To further develop this study, and increase its validity, an additional source of data was consulted. Multiple semi-structured interviews were held with experts in the field of floating structures. the interviews served a duality in their functioning. Some interviews served an explorative function, done in the early stages of this study. The semi-structured interview held at that point offered the opportunity to better get a grasp of the innovations and the field of floating structures. The interview was a result of email communication starting in October 2020 with R. de Graaf and K. Czapiewska, both co-founders of Blue21. Blue21 is a world-leading company in researching, designing, and realizing floating structures (Blue21, 2019). De Graaf published or contributed over 40 articles on urban water, resilience, adaptive urban development, innovative monitoring of climate adaptation measures and water quality. Moreover, Czapiewska contributed to several articles on the potential, effectiveness, and opportunities of floating structures. Both were consulted as part of the explorative phase of this study. Email contact and document exchange including feedback were made around these explorative interactions. Unfortunately, neither de Graaf nor Czapiewska was available for further interviews in the latter part of this study.

An additional purpose of the interviews was served in a later stage of the study. In the end phase, IDI were held in a semi-structured manner. Through these interviews, the findings of this study were validated, and additional knowledge was retrieved. The interviews were done with three experts with experience in the field of floating structures. In chronicle order of interviews held, the first interviewee was M. Flikkema on November 29th, 2021, at 15:00 and will be cited as (Flikkema, 2021) or Flikkema, (2021). Flikkema has experience at MARIN and was contacted as he is stated as the project coordinator for the SPACE@SEA project. A project funded by the Horizon2020 Programme of the EU looking into possibilities for floating functions on the seas of Europe. The second interview was held with O. Waals on December 2nd, 2021, at 14:00, Waals is an Offshore manager at MARIN but initially surfaced in the study as part of the Stichting Blue Revolution Foundation. Since last summer Waals is the chairman of the think tank, Stichting Blue Revolution Foundation, which focuses on the realisation process and governance of floating structures. In text citation is (Waals, 2021) or Waals (2021) Waals was the successor of R. Vuijk, who was the chairman up until last summer as well as co-founder of the foundation. Vuijk was interviewed on December 3rd, at 9:00 in the morning. Back in 2017 he founded the foundation together with de Graaf and has since been part of the think tank. Vuijk was introduced into floating structures when he was an alderman in Delft. Both Waals and Vuijk have been involved in the research programme the Floating Future, looking into interdisciplinary knowledge on the implementation of floating structures. The research is part of a network of the Dutch top sector Maritime and water facilitated by the NWO-NIOZ Royal Netherlands Institute for Sea Research (NOIZ, 2021). Vuijk will be referred to as (Vuijk, 2021) or Vuijk (2021). The interview with Waals provided new insights on a condition for floating structures. Flikkema was contacted over email to evaluate this finding, further explanation on the conditions is explained in chapter 6.2.

Each of the experts on floating structures was interviewed according to questions that can be found in Appendix 3. The proposed timespan of the interviews was approximately one hour, and this was toughly followed, most went over an hour but no longer than an hour and a half. The interview was subdivided into three parts. The first part asked for their perspective on floating structures and what can be expected when implementing floating structures. For this part, the interviewees were not introduced to the findings of this research to eliminate bias or be influenced by the findings of his study. The second part of the interview followed a summary of the findings off this study. The highest-ranking innovation was presented as well as the corresponding transition. On top of that, the main conditions for floating structures of the North Sea were presented. It was then possible to ask the experts opinion on the result found. It must be mentioned that part two was skipped when interviewing Vuijk due to time limits. However, some data could be retrieved for this part based on the answer on the other parts. The third and final part of the interview referred to planning, the role of spatial planners and the relation between floating structures and the field of social sciences, specifically spatial planning. Which contrasts with the most, rather technical, and natural science-oriented data out there.

Referring to the missed opportunity to interview Vuijk in part two of the interview. The IDI were semi-structured. Therefore, the intention of the interviews was not to strictly follow the question presented. Rather have a discussion on floating structures and through this discussion, it would be possible to find the data intended to find using this method. It allowed for a more open discussion in which unasked significant data could be brought up. In the progression of the loose structure of the interviews, they were held in Dutch as this was the native language of all participants. The interviews were transcribed and analysed by relating transcribed answers to the correlation questions. Due to the loose nature of interviewing some question had been answered in a different part. Therefore, some questions were skipped as answer were already provided. The analyses process re connected the answers with the question. On top of this, quotes that would possibly provide insights to the study were selected. When the quotes are applied into the study, they were translated by the author. Before the interview started the interviewee were asked for permission of recording the interview for processing purposes. The transcribed interviews can be obtained from the author upon request. On top of that, the interviewees were made aware of their right to cancel the interview at withdraw from the interview at any given time. As well as the opportunity to adjust their answer or remove statements made, this could be during the interview up until the point of submission of this thesis.

As discussed, the transcribed interviews were analysed in a spreadsheet. Creating an overview of answers to each question. Additionally, it made a cross-examination of the answer comprehensible. The spreadsheet was furthermore used to provide an overview of quotes referring to statements made in this study (Appendix 4). As for the three interviews, they will be referred to or when quoted. The validating data was added to the corresponding chapters. New insights are summarised in chapter 6.4 providing an additional understanding of floating structures on the North Sea.

5 Selection process

Chapter 5 present the result of this study. Following the research strategy, the found functions are analysed. Starting with the opportunities floating structures offer and the possible innovation for the North Sea. Subsequently, during the interview limiting factors of transition were identified and will be discussed.

5.1 Opportunities

To indicate innovation that could be implemented in the North Sea, several sources have been researched generating a list of possible floating structures. By making use of data mining, a list of floating structures is created (Table 1). This selection was used to identify floating structures suiable for the North Sea. To do so the diffusion of innovation theory was used by structuring the theory in a grading scheme (Table 2) Based on the theory's five characteristics of innovation (*observability*, *relative advantage, compatibility, trialability* and *complexity)* each structure was rated. The initial scheme was limited to present (1) or absent (0). However, this led to limited variation in the outcome to identify the more likely innovation. Therefore, the grading options were extended to cover a wider scale ranging from zero to five (Appendix 2).

Using a gradient scale, more variation in the scores were made possible. As a result of this increased variation in grading, it was possible to select the most suiTable innovation. As said before the scores will change amidst graders, as well as the current knowledge available. On top of that, some additional explanation on the grading process. Observability was graded looking from the perspective of the Randstad and the effects that will be experienced on the mainland as an effect of the implemented structure. Zero regarding no effect or change and five means major changes in the daily life and functioning of the Randstad. Relative advantage relates to the advantage a floating structure would experience over its terrestrial counterpart. Here a zero would mean no advantage over a land-based alternative whereas a five would mean and tremendous increase in socio-economic profits. No innovation obtained a zero in the category due to the increasing land scarcity in the Randstad, therefore floating could already be beneficial to all functions (Borra and Urhahn, 2020). Compatibility focuses on the socio-cultural values of Randstad reflected by the need for innovation and trends. A zero is awarded when there is no need for the structure, or it does not fit the socio-cultural landscape. A high score (5) is awarded to structures in line with the trends and needs. Trialability contains a lot of high scores of five, this is because some of these innovations have already been implemented somewhere else and therefore tried before and are scalable. Finally, the complexity, or for the sake of the grading limited complexity. High scores are awarded to those innovations the are simple to understand with limited complexity. A low score means that the innovation is highly complex.

TABLE 3 TOP 6 HIGHEST SCORING FLOATING INNOVATIONS

Rank	Points	Innovation	
1	20	Food production	
2	18	Stadium	
3 + 4	17	Energy Hub	Airport
5 + 6	16	Cyclicity	port/cruise terminal

The grading of the innovation lead to a top six of structures that scored 15 points or more. The highest scoring innovations are the production food (20 points). The Netherlands is already familiar with floating food production in terms of mussel farming and a floating dairy farm located in Rotterdam (www.floatingfarm.nl). Plant-based food production in the Netherlands remains out or on very limited scales, algae production is mainly terrestrial, and floating agriculture stays out. In the interview with Waals (2021) and Vuijk (2021) floating food production was mentioned in an explanatory manner or possible opportunity. Neither of them indicated any short-term potential in the system. The second-highest scoring innovation is a floating stadium. Currently, plans are being developed for a new football stadium for the city of Rotterdam (www.nieuwstadion.feyenoord-city.nl). The plans are not based on a floating structure, however, there has been a semi-floating stadium in other parts of the world, like the floating field in Singapore (Figure 14). However, the idea discussed in this study involves a full stadium that could be towed around following major sports events like football cups or the Olympics (Wang and Tay, 2011).

Ranking below the stadium is the airport and the energy hub/ production site. A floating airport has been an ongoing discourse in the Netherlands for decades starting in the 1990s. In 2019 it was debated by the House of Representatives and in 2020 the plan regarding national air traffic for the Netherlands was presented stating that expansion towards the North Sea would not be needed until at least 2050 (Ministerie van Infrastructuur en Waterstaat, 2020). Identical grading was awarded to an energy hub/ production site. Denmark decided to create an artificial island in the North Sea to redistribute and produce energy from wind farms and local energy production (Ministry of Climate, Energy and Utilities, 2021). Whereas this plan is not floating, similar ideas for floating energy production have been discussed including floating windfarms, tidal energy, or other forms of green energy (Piątek et al., 2020). The last two structures which are potentially interesting for the Randstad is a floating cruise terminal/ port terminal and the cyclicity concept. The latter is a concept described by de Graaf (2012, p. 43) as "*a floating city based on cyclic resource flows*" recycling and reusing lost or waste nutrients from terrestrial cities. Lastly a floating port, maybe the most known example of this originates from the second world war. To facilitate the battles of Normandy with goods, the allies implemented large floating ports to quickly facility the troops while at the same time automatically adjusting to the large tidal differences in the water level (Liberation Route Europe, n.d.). Currently, the Maritime Research Institute Netherlands has built a scale model of a floating port terminal (Drummen and Olbert, 2021). Such a port area would act as an outpost of the terrestrial port where containers can be offloaded and then be transported on smaller ships to the mainland.

FIGURE 14 SINGAPORE FLOATING STADIUM (YUAN, N.D.)

5.2 Limitations

5.2.1 Food production

A study conducted by the Council for the Environment and Infrastructure (Rli) investigates transition regarding sustainable development. The Rli independently conducts studies to advise the Dutch government on long-term matters and developments. Through these studies, Rli hopes to widen and deepen the dialogue on sociological and political themes including economy, sustainability, energy, and food production. For a study into the interfaces between several transitions, the Rli also looked at the food transition in the Netherlands. Council for the Environment and Infrastructure (Raad voor de leefomgeving en infrastructuur, 2019), discussed a transition in which animal products will make up a smaller part of our diet, and the effect on the environment and biodiversity are considered. The Rli recognizes similar phases in the transition process, however, an additional phase is added referring to institutional integration after the acceleration phase. Simultaneously to the transition, Rli refers to a degrading process of the status quo. According to (Raad voor de leefomgeving en infrastructuur, 2019), the food system shows traits of destabilisation due to growing concerns regarding bio-industry, pesticides and soil management (landscape level). At the same time, they also recognize some experimentation whereas the acceleration stays out. Large scale production for national and international trade seems to be the main driver of the current practices. Similarly, Tziva et al. (2020) observe increasing pressure on the landscape level concerning health risks linked to the high yield bio industry. Furthermore, they recognize niche development in meat substitutes and a change to environmental sound alternatives. Both these transitions focus on sustainable development within the food systems, especially the increased plant-based diets.

Floating food production on the North Sea knows different potential applications. The first application would build on the expansion of the current floating mussel and oyster growing sector (Figure 15). The expansion of this market is often discussed in combination with other uses (van den Burg et al., 2017). Existing structures like wind farms could provide an anchoring point for the floating mussel farms. Fish can also be farmed in floating farms. These are the open basin of nets that contain the fish (Piątek et al., 2020). Allowing for easy harvesting and controlled feeding schemes. Furthermore, crop production on floating structures in greenhouses can be found in the literature, however, this design is mainly for inland water bodies and is not discussed for the marine environment (Bakker et al., 2004). During the IDI, Waals (2021) and Vuijk (2021), floating agriculture was referred to as an extension of the current land-based practices in the Netherland. Thus, creating plots of land that could be used for crop production rather than an innovation following a food transition. Neither of them saw short term potential in this form of food production. Nor did any of the experts recognize any other form of food production of the North Sea also not the final proposed form of food production. The final proposed use of a floating food production system

FIGURE 15 HANGING FLOATING MUSSELS (ERKEND STREEK PRODUCT, N.D.).

incorporates algae farming. Algae can be used as a source of nutrients or protein, for human consumption but also animal feed like fish or pets (Dal Bo Zanon et al., 2017). Aside from food production, the algae can be used to produce biofuels, nonetheless, this application was not considered when analysing the innovation due to the focus on food production. Moreover, a combination of different food production techniques can be used. An example of this is aquaponics, a closed nutrient system wherein fish and plants form a closed cycle and continuously recycle 'waste' nutrients (Pantanella et al., 2010).

5.2.2 Stadium

The floating stadium concept discussed in this study arises from a German architect who designed a football stadium for the FIFA World Cup 2022 (Figure 16). The floating offshore stadium would be able to relocate between cities to serve as a venue for a wide variety of sports events like the World Cup or the Olympics (Moon, 2013). The architects state that in contrast to terrestrial stadiums, the floating stadium would have a long-term utilization and usage efficiency due to its global mobility (Jordana, 2011). Whereas stadiums specifically built for big sports events often cope with neglect and low utility once the events are over (Moon, 2013). Before the construction of mega-event stadiums like the Olympics, negative social impacts are observed in hosts cities around the world (Lenskyj, 2020).

Negative impacts include relocation of millions of people, highest numbers coming from Seoul and Beijing, representative relocating 720,000 people and 1.25 million people (Centre on Housing Rights and Evictions, 2006). Lenskyj (2020) furthermore adds the violation of an indigenous right in Sydney and the major social effect of slump tourism in Rio. Moreover, criticising the Tokyo 2020 Olympics for its poor labour laws especially for immigrant workers. Pattisson and McIntyre (2021) report over 6,500 passed away in Qatar, during construction work on the infrastructure and seven stadiums in preparation for the 2022 World Cup. Critique on Mega-sports events can be observed more frequently, and it, therefore, can be discussed how mega-sports events can be organized in the future in social and environmentally friendly ways. In this study, this is an indication of increasing pressure on the landscape level, especially from a global perspective. On the niche level we also observe changes, Bale (1993) critiques stadiums for being dead zones in cities when not in use, disconnected from the surrounding neighbourhoods and with relatively low revenue compared to housing or shopping. In contrast to this is the development in the Randstad, especially Rotterdam, where plans for a new football station are made. The new football stadium is planned to be a sports park, recreational area, integrated with apartments and a new nature area with tidal influences (Nieuw Stadion, 2021). Thus, for a stadium, the pressure might be observed on the landscape level towards the socio-environmental use of a large stadium. As well as niche developments regarding the use and services stadium provide. However, a clear transition in mega sports events was not found in this study. However, Flikkema (2021) and Waals (2021) both referred to the innovation differently. Flikkema (2021) perceived this function as "*new but interesting*". Waals (2021), already mentioned the innovation before the results were presented. He became aware of it through a Dutch tv show and found it to be a "*funny application*". Nevertheless, a Floating Stadium could not only serve the Randstad but should be seen in an international context to achieve long-term utilization and increase efficiency.

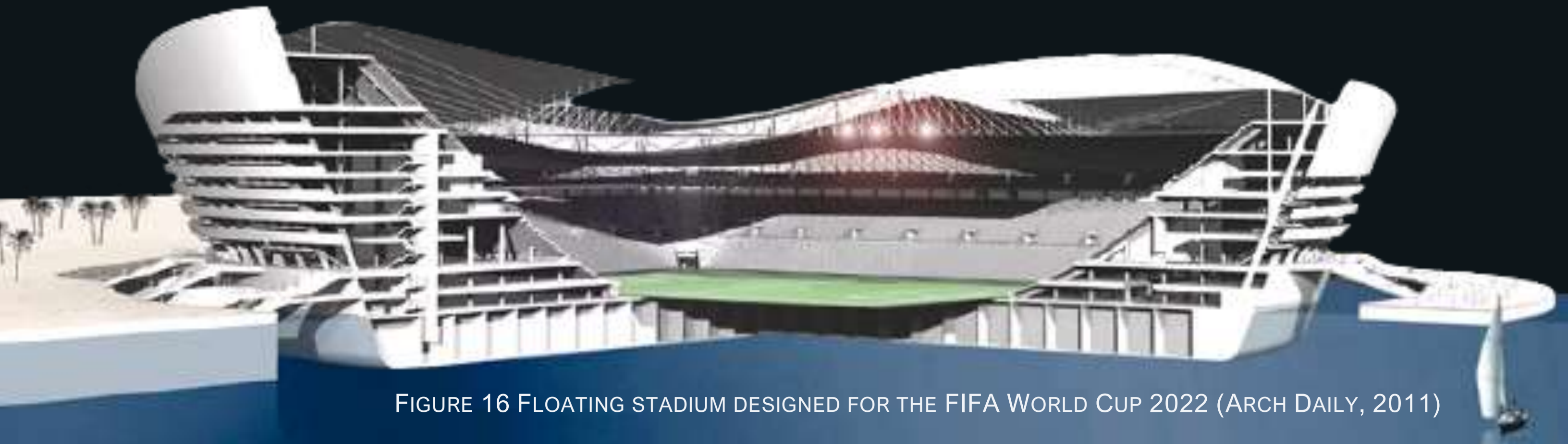

FIGURE 16 FLOATING STADIUM DESIGNED FOR THE FIFA WORLD CUP 2022 (ARCH DAILY, 2011)

5.2.3 Energy

Floating energy production or an energy hub can come in different forms. Sustainable energy production seems to be an important aspect in floating structures regardless of the use or function of the structure. Renewable energy sources are a reoccurring subject in the articles reviewed for the DOI analysis. Different types of energy production have been discussed in the literature. First of all, offshore floating wind turbines, which is particularly focussing on locations that are due to current technological and legislative shortcomings not utilized in offshore renewal energy production (Bento and Fontes, 2019). An example of these locations are parts deeper than 50 meters as shown in making up about 80% of the European seas (Figure 18) (Leimeister et al., 2018). Deepwater floating windmill parks are already realized in countries like Norway, France, Scotland, and Denmark (Bento and Fontes, 2019). The project in

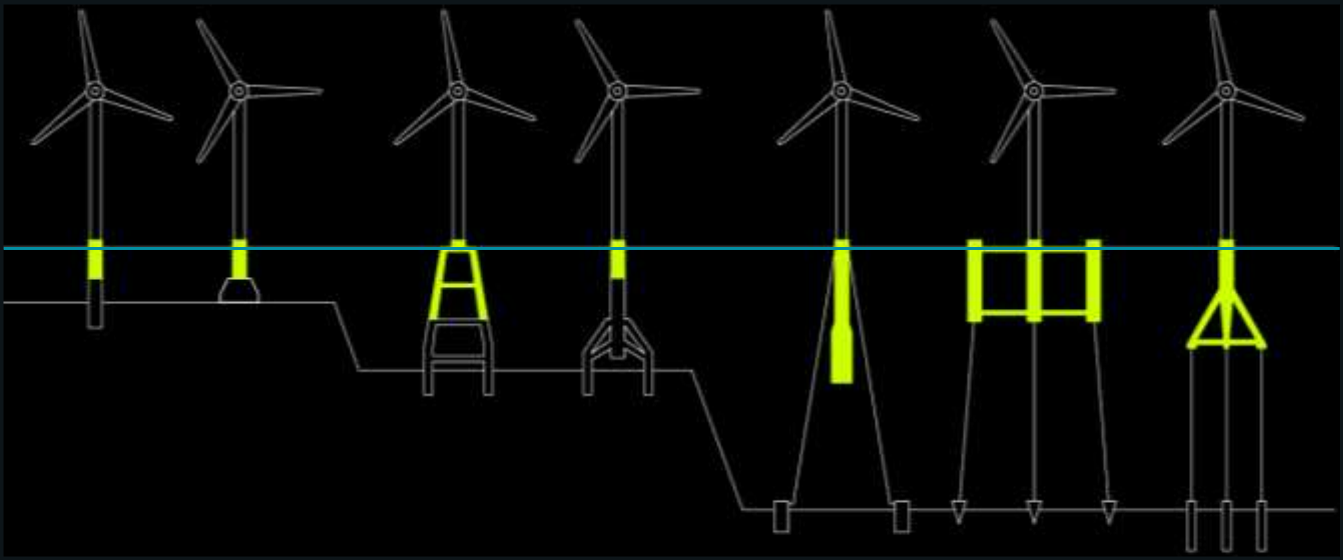

FIGURE 18 TYPES OF WIND TURBINES AND THE LOCATION BASED ON WATER DEPTH (INFLUX, N.D.).

Demark uses a hybrid combination of a floating structure producing wave energy as well as supporting three wind turbines (Yde et al., 2015). Likewise, floating photovoltaic system (solar panels) can be found on different scales, especially quiet inland waters or reservoirs seems to be a suiTable place for floating PV systems (Figure 17). As of 2019, the first offshore floating PV system can be found, the Oceans of Energy project located in the Dutch North Sea (Oceans of Energy, 2019). Additionally, energy can be harvested by making use of the tides. When the tide rises and drops it creates currents that can be used to power underwater turbines to produce energy (Turnock, SR et al., 2007). Aside from the single production of hybrid forms of energy production, plans are proposed to produce hydrogen on offshore floating structures. The French are planning on opening their first floating hydrogen production plant by 2022 (Buljan, 2021), while during the COP26 a hydrogen plant was announced in front of the Scottish coast (Buljan, 2021). The Scottish wind-to-hydrogen project is a

FIGURE 17 FLOATING SOLAR FARM SINGAPORE (TAN, 2021).

reaction to the government's plans for exporting hydrogen and targets to produce 5GW of hydrogen by 2030 (ibid.). The Space@sea consortium took a different approach to the use of floating structures and energy. They developed plans for an offshore floating energy hub that includes *"offshore wind services, accommodation facilities for industrial personnel and renewable energy extractions and housing of spare parts."* (Adam et al., 2021, p. 584). Similarly, Denmark is constructing two energy hubs to collect and distribute offshore wind energy. The energy hubs are not floating, one of them is constructed on an existing island while the other located in the North Sea, will be on an artificial island (Danish Energy Agency, n.d.). A similar structure was designed by Adam et al. (2020), proposing a floating structure that would incorporate several functions. The Energyhub@Sea as the concept is called would house renewable energy production systems, operation and maintenance functions for offshore wind parks, housing for staff and engineers and spare parts for wind turbines. By relocating these functions to an offshore location reaction time during casualties can drastically be reduced and work conditions improved (Adam et al., 2020). Identifying this form of application for a floating structure when asked to identify the most potential innovation to be implemented in the next decennium. He furthermore confirms that this is the most prospective application in the Space@Sea project. Furthermore, Waals (2021) also indicated a floating energy hub to be most likely to be implemented in the next decennia.

To reach the goals set during the 2015 Paris Agreements the Dutch government is actively steering away from the use of fossil fuels. Many countries including the Netherlands agreed on an emission-free energy system by 2050 (Notenboom and Ybema, 2015). By transferring from fossil fuel-based energy sources to renewable sources of energy a transition can be observed according to Uyterlinde et al. (2017). However, back in 2001 the Dutch government already describes an energy transition with additional means and measures to accelerate the transition (VROM, 2001). One of the measures implemented by the Dutch government was to accelerate the transition through the construction of wind turbines further in the North Sea (Jongbloed et al., 2020). In their maritime plan, the Dutch government assigned areas of the North Sea where wind turbines may be constructed that can be seen in Figure 19 (Vrees, 2021). In these areas, the seabed is within the range of contemporary construction of non-floating wind turbines (Rijksoverheid, n.d.). The assigned areas will most likely be sufficient until 2030. Nonetheless, after this point, there might be limited space left for further development of wind parks. Bento and Fontes (2019), states the importance floating wind turbines can have in the energy transition to utilize areas of the North Sea too deep for conventional construction methods. Bento and Fontes (2019) continue by adding the environmental benefits floating wind turbines have over nearshore and shallow water wind turbines.

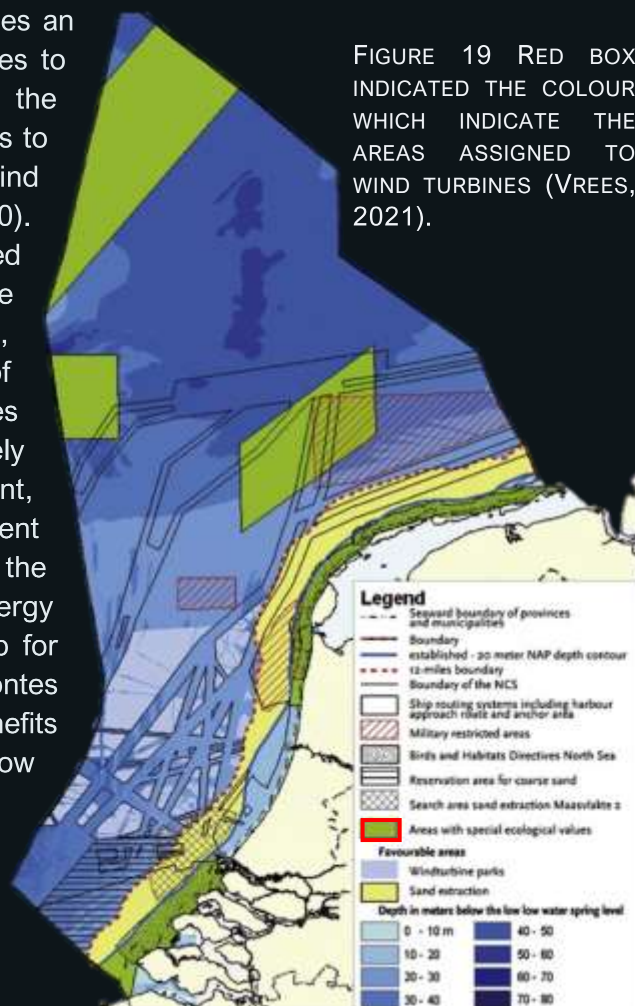

FIGURE 19 RED BOX INDICATED THE COLOUR WHICH INDICATE THE AREAS ASSIGNED TO WIND TURBINES (VREES, 2021).

5.2.4 Airport

Back in the 1990s, Japan has been investigating VLFS to support floating airports and concluded with high feasibility of diffusion (Figure 20) (Wang and Tay, 2011). In that same period, Japan had built the first floating airport the topic of floating airports was discussed in the Netherlands. As a result of the rapid growth of Schiphol airport, policymakers started to investigate possible expansion options. One of these was the seawards expansion of Schiphol on a floating island. Since then, it has been a topic on the agendas of ruling governments. Nevertheless, in 2020, it was argued in a plan regarding the future development of the Dutch air traffic sector, that seawards expansion of Schiphol would not be needed until 2050 (Ministerie van Infrastructuur en Waterstaat, 2020). The verdict by the Dutch ministry is the reason floating airports will not further be investigated. On the contrary, a new discussion on the future of Schiphol arose in the finalizing stages of this study, potentially offering an opportunity for floating development.

FIGURE 20 PROTOTYPE FLOATING AIRPORT TOKYO BAY, JAPAN (ANDRIANOV, 2005).

5.2.5 Cyclicity

In 2012, a Dutch company first introduce the cyclicity concept (DeltaSync, 2012). DeltaSync (2012), sees traditional cities as parasitic systems consuming nutrients from their surrounding areas and ejecting waste products in their environment. The Cyclicity concept is built on a circular metabolism in which nutrients are being recycled, and the city itself becomes a producing system. By taking up waste nutrients and CO_2 the floating structure will energy and food. Rather than a single focus on intake and output, the Cyclicity is a combination of previously discussed concepts and functions a floating structure could possess. It would be a seawards extension of coastal cities supporting housing, food production, renewable energy, algae production, and recreational spaces. DeltaSync (2012) calls for a system innovation for Cyclicity to be implemented, stating that a "*fundamental new way of working is needed that will be anchored in the mainstream practice of professionals and citizens*" (p. 19). Therefore, it could be argued that the implementation of cyclicity is a transition in itself as it calls for changes in the commercial market, development niche innovation and emplacement of new institutional mechanisms (DeltaSync, 2012).

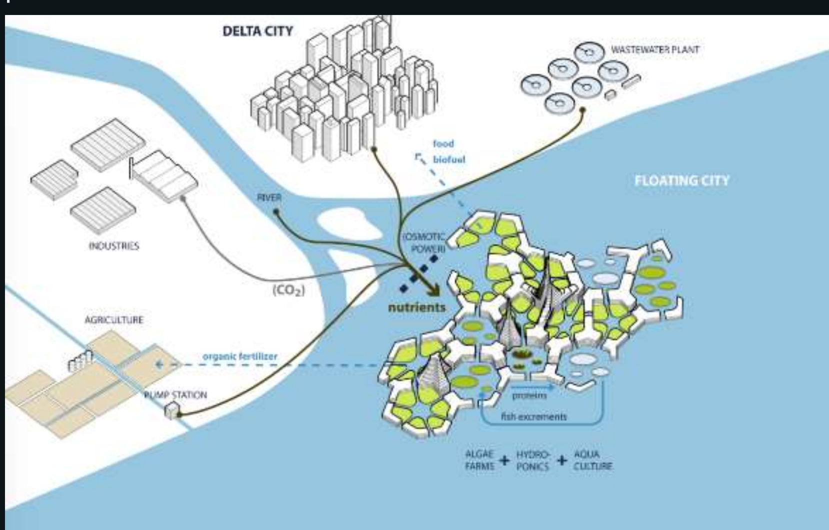

FIGURE 21 CYCLICITY CONCEPT BY DELTASYNC (2012).

5.2.6 Floating terminal

A floating terminal is an extension of land-based ports and takes over certain activities that nowadays happen on the land. By taking over these activities the pressure on the port is reduced which in turn would increase the productivity of the greater port area (Ali, 2005). In this study, a separate terminal function will be discussed. First, floating cruise terminals, floating structures where cruise ships can dock in places that previously were un-accessible for these types of vessels. An example of this is the proposed design by Samsung Heavy Industries for the city of Seoul (Wang and Tay, 2011). The floating terminal would provide a docking station for cruise ships within the city of Seoul and would be directly connected to the shore. Waterstudio NL (2014) designed a floating cruise terminal that would sit on the open sea. Spacious enough for three of the world's largest cruise ships to dock, protected harbour for water taxis and small vessels, and indoor spaces consisting of retail, restaurants, and conference rooms. The design also incorporates and hotel for those wanting to stay longer or wait for their connecting cruise.

Another application of a floating terminal would be for industrial applications like container shipping or fossil fuel storage. The function of floating storage is already practised; however, they take place on ships rather than destined platforms (Baird and Rother, 2013). These reconfigured ships are usually moored in place and are mainly used for the temporary storage of gases or oils. In Japan, however, floating oil storage was already constructed in the past. Floating oil storage make available large quantities of oil to be stored outside of urban areas where spatial limitations take away the possibility to store such quantities. Floating structures might also be used for container shipping, as Baird and Rother (2013) refer to as Floating Container Storage & Transhipment Terminal (FCSTT). Floating structures would form the base of transhipment terminals, meaning ships would dock alongside the structure, the containers would be unloaded and temporarily stored on the structure until smaller vessels take them to shore or they are loaded on a different ship heading towards their destination (Baird and Rother, 2013). Baird and Rother (2013) also found that FCSTT would lower operational costs and increase capital compared to terrestrial port expansion projects if the land must be artificially created. The Maritime Research Institute Netherlands (MARIN) investigated large scale floating ports. In an indoor water basin, they created a scale model of an FCSTT including vessels, breakwaters, housing for staff and recreational areas. The scale model was tested on structural stability and the effects of wind, currents, and waves (Versleijnen, 2017).

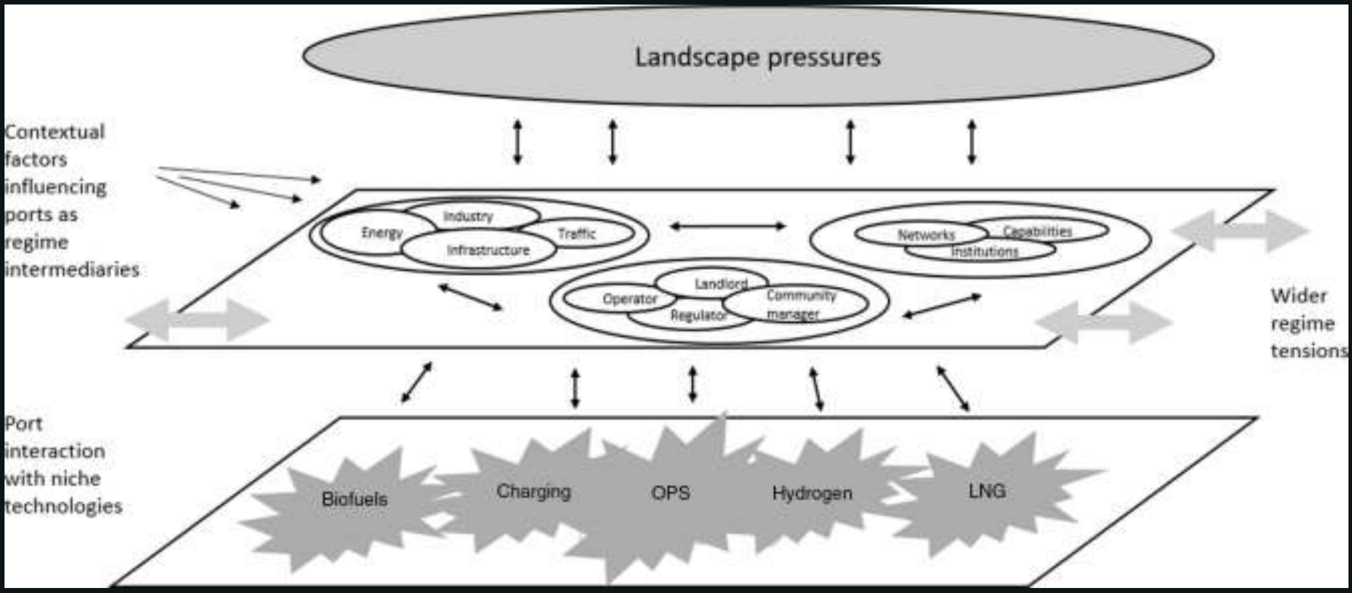

FIGURE 22 SCHEMATIC ILLUSTRATION OF PORTS ON THE REGIME LEVEL (DAMMAN AND STEEN, 2021)

When looking into transitions that have been observed in port areas. Firstly, the transition from a one-way economy to a circular economy will change the way port's function. Not only will the internal function of port areas change, but ports are also becoming more interwoven into urban symbiosis (Haezendonck and van den Berghe, 2020). Haezendonck and van den Berghe (2020), furthermore, found that ports are increasingly being involved in recycling and reusing of waste of leftover materials, especially those in metropolitan areas. The circular transition is missing a link to floating structures. However, energy use and renewable are part of a circular economy but also from the ongoing energy transition discussed before. Hentschel et al. (2018), studied the port of Rotterdam and its transition towards renewable energy sources. The port of Rotterdam was chosen due to the reason that it supports many industries and developments demanding immense amounts of energy, 10-20% of the Dutch energy consumption. On top of that, half of the total throughput of the port is related to fossil fuels, supplying about 50% of Nort-western Europe with fossil fuels (Bosman et al., 2018). Hentschel et al. (2018) add the importance of institutions and key stakeholders in reducing the use of fossil-based industries. Damman and Steen (2021), found the greater significance of ports in the energy transition as well as the transition of ports themselves (Figure 22). This is in line with transition theory in the way pressure from the landscape level can be observed, for example climate awareness and influence climate deals, and comparison to other ports. Leading to changes on the regime level which have become willing to change the status quo. Wherein port areas, many institutions from different governmental levels as well as private sectors come together and go into dialogue on the topic. Niches occur in ports in terms of technological innovation associated with the energy transition like batteries and hydrogen. Finally, Damman and Steen (2021), add that port harbours have a high potential to become an important node within the new energy network. Stating that ports will most likely become energy hubs to collect, store, redistribute and produce renewable energy.

6 Conditions and implementation

Chapter 6 incorporates the case studies executed to identify the conditions needed for the implementation of floating structures on the North Sea. Furthermore, it summarizes the noticeable IDI result. Additionally, a SWOT and the flowchart are provided.

6.1 Food production

There are many ways food can be cultivated by making use of floating structures. Several species including fish, algae, seaweed, and mussels can be cultivated on floating structures. Possible application of floating food production is studied by the Farming@Sea project. Farming @Sea is part of the Space@Sea program, an ongoing EU funded program studying "sustainable and affordable workspace at sea by developing a standardized and cost-efficient modular island with low ecological impact" (Adam, 2020, p. 2). Focussing on several different sectors several projects are in development including Living@Sea, EnergyHub@Sea, Transport&LogisticSpace@Sea, and Farming@Sea. For the North Sea specifically, the Farming@Sea project explored the expansion of mussel farming towards the open waters of the North Sea. As current cultivating practices are limited to inland water bodies. The expansion would focus on the production of mussel seed for the inland farms and the production of mature mussels. The main bottleneck identified by Farming@Sea is the need for seaworthy equipment including ships en technology (Jak et al., 2017). The project aims at eliminating these high investment costs through the creation of the right environment on floating structures developed for the Space@Sea programme. The success of this project is highly dependent on the offset of the mussel production which is rather vulnerable to natural risk. Diseases, predators, or toxins could lead to high mortality rates, depleting profits. The graph in Figure 22 showcases the initial investment costs and the net present value from the start until 25 years after. A multi-modular project is proposed housing many different sectors and uses as covered in the Space@Sea project.

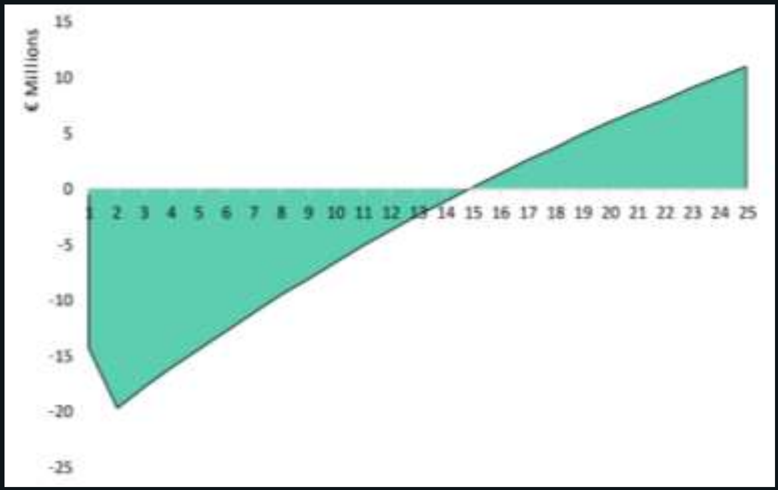

FIGURE 23 CUMULATIVE NET PRESENT VALUE MUSSELS FARMING FARMING@SEA (JAK ET AL., 2017)

Another use for floating structures is the production of algae and micro-algae. By making use of large floating tubes or enclosures, algae are cultivated. The Algea produced can be used in food supplement for humans and animals or be converted to an energy source (Dal Bo Zanon et al., 2017). However, in past studies, the climate in the Netherlands is criticized for algae growth as the winters can be dark and cold, unpreferred variables for large scale algae production (Effting and Wijffels, 2013). Based on this, algae production for food will not be further debated.

6.2 Energy production

Resulting from analysis using insight obtained from Transition Theory it was concluded that an energy source could have the potential to be adopted in the context of the North Sea. This conclusion is based on the innovation and the ongoing energy transition as explained in this part. When looking into energy in the North Sea, a common trend is observed in the use of floating structured specifically for energy hubs. An example of such a hub is the following, disclaiming that these plans presented by The North Sea Wind Power Hub (2021) do not include any use of a floating structure according to the information found. However, the concept whether floating or land-based is that these hubs would connect wind turbine fields far from the coast with other hubs or to the mainland. This concept is referred to as the hub and spoke concept (Figure 26). Whereby, in contrast to a traditional connection between wind farms and shore, as well as international connection or combined in a hybrid station. By combining the two functions The North Sea Wind Power Hub (2021), pleas that electricity could be distributed efficiently bypassing losses due to the fast distances that have to be crossed. The efficiency discussed is based on several forms of hubs (Figure 25). On-site the energy produced could be collectively sent to the shore through cables. Another option is to use the produced energy to desalinize the saltwater and produce hydrogen at the hub and be either shipped or pumped to shore. A third alternative is a hybrid form using both previous alternatives. (The North Sea Wind Power Hub, 2021; Waals, 2021). On February 4, 2021, the Danish government agreed upon the construction of a spoke and hub in the North Sea (Danish Energy Agency, 2021). As was the case for the concept of The North Sea Wind Power Hub, likewise the Danish energy hub will be constructed on a dammed island.

This is contrasting with the result found in chapters 5.1 and 5.2 stating the high score of the innovation as well as the ongoing transition. Therefore, there should be additional conditions that influence the decision-making process of energy hub construction. By looking into comparative studies of fixed and floating structures, a contrasting result was found. A business case study into the Energyhub@Sea project, part of the Space@Sea project found the following. Through

Figure 26. The Hub and spoke concept (The North Sea Wind Power Hub, 2021)

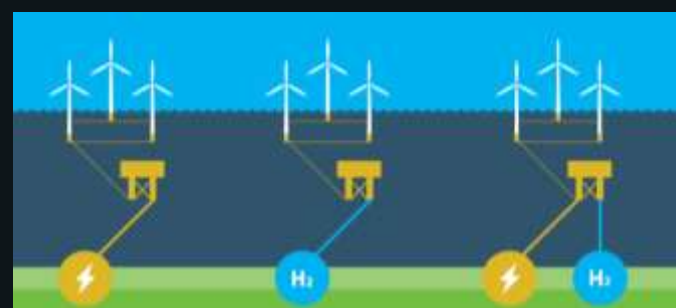

Figure 25 Different functions an energy hub can have in combination with hydrogen production (The North Sea Wind Power Hub, 2021)

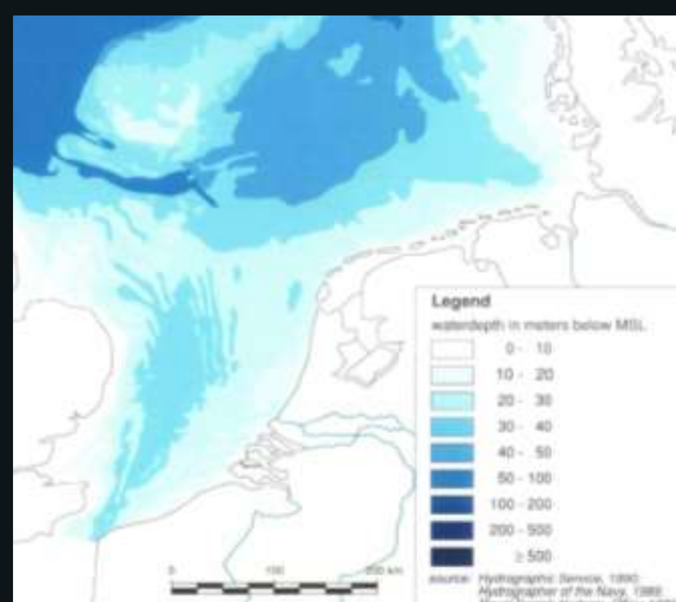

Figure 24 Depth of the North Sea below mean sea level (North Sea atlas for Netherlands policy and management, 1992)

comparison based on a fictional windfarm, the floating energy hub was financially most attractive compared to a fixed platform or a mothership concept (Adam, 2020). It must be mentioned that the water depth at the fictional location was set at 100 meters and floating structures become feasible at a break-even depth of 47.97meters (Figure 24). Whereas these depths are not found in the southern part of the North Sea. For the Dutch part of the North Sea, the deepest point can be found between the Dutch and English coast, where the seafloor can be up to 40 meters below sea level (Noordzeeloket, n.d.). Another study done by the Space@Sea project found similar results for a possible multi-use floating structure that would include an energy hub at a location with a water depth of 25 meters. Likewise, here it was concluded that contemporary land reclamation would be a cheaper option than constructing a floating structure (Flikkema et al., 2021). Back in 2017, a similar result was found in a master thesis supported by the construction and engineering company Witteveen+Bos (Gerrits, 2017). Aside from the research of Flikkema, this was also made clear during the interview by himself. The sand nourishment costs are lower for all parts of the Dutch North Sea. He additionally added that the North Sea is a rough sea to construct in. Due to the shallowness, the waves observed on the North Sea are short and steep. Putting collectively large numbers of force on large floating structures, challenges the mooring of the structure, resulting in the swinging of the structure, which in turn could cause nausea (Flikkema, 2021).

However, this limitation was not found in any of the reviewed documentation of Energy@Sea or Space@Sea. When asked about this Flikkema (2021) replied: *"in Space@Sea we had all sort of application in which this was a criterium therefore, we didn't mention it specifically"*[3] Adding that large scale floating structures are possible for working conditions but when combined with other conditions like living this becomes a significant limitation. Since longer exposure to the swing does not provide a pleasant work and living environment.

Based on this, the implementation of an energy hub is based on the estimated costs of construction as the decisive factor. However, it could be argued that other factors could play an influential role in the decision-making process. Adam (2020) defends a floating energy hub located at a depth shallower than the 47.97 meters by highlighting the non-financial benefits. These benefits are linked to the flexibility that comes with a floating structure and its ability to relocate to different areas as well as the ability to add or distraction functions as part of the modular design (Adam, 2020). Soloot and Beyrami (2021), recommend a floating energy hub by prioritizing land usage footprint and biodiversity. As it was already explained in chapter 2.2 that through traditional land reclamation projects seabed ecosystems are destroyed but also show relatively quick recovery periods. Additionally, SLR is a limited discussed factor in the reviewed document. Gerrits (2017), discusses the effects of SLR, which could be criticized as data from 2002 is used. Floating structures are not influenced by a rising sea level as they automatically rise with the water. Whether this applies to the relatively shallow Dutch North Sea concerning the traditional costs of building an artificial island needs to be validated.

FNPV(K) in dependence of water depth		
water depth [m]	Energyhub @Sea [€]	fixed platform [€]
10	-128,403,512	-116,190,449
20	-128,444,712	-119,458,621
30	-128,485,912	-122,717,583
40	-128,527,112	-125,970,665
50	-128,568,312	-129,219,425
60	-128,609,511	-132,464,769
70	-128,650,711	-135,707,294
80	-128,691,910	-138,947,419
90	-128,733,110	-142,185,457
100	-128,774,309	-145,421,648

Figure 27 Costs of land reclamation and floating structures. Showcasing the break-even depth between 40 and 50 meter. After 50 meters the cost of a fixed platform surpass the Energyhub@Sea's costs (Jak et al., 2017)

[3] Translated from: "binnen Space@Sea hebben wij allemaal applicaties gehad waarin dat een criterium was dus, dat heben we niet meer zo specifiek benoemt"

However, Waals (2021) present a new form of energy island that was not found in literature so far and offers an opportunity for innovation. During the interview a new project was introduced, the HybridEnerSeaHub, a Joint Industry Project (JIP) that combines traditional land reclamation with floating structures (NOIZ, 2021). Creating offshore energy islands protected by a breakwater, and partly with traditional land reclamation and partly providing room for floating structures. Overcoming the steep waves and rough characteristics of the North Sea that would cause swinging of the platform. On top of that, the project focuses on the flexibility and modularity that floating structures provide. It makes it possible to switch out floating modules over time-based according to the needs of the sector. Therefore, trying to overcome the additional costs of floating structures by offering flexibility and modularity. While at the same time involving the traditional techniques of land reclamation. With this, multiple Dutch sectors are enforcing each other. The land reclamation is utilized for the protection of waves and current while the floating part provides flexibility. On top of this, the combination will prevent conflicting interests in land reclamation and the creation of floating structures (Waals, 2021). The research project started in 2019 and will last two and a half years. Findings are published only to JIP members. Waals (2021), introduced the hybrid form in the IDI, overcoming the limitation stated by Flikkema. Therefore, an email was sent to obtain Flikkema's perspective on this. Flikkema agreed that this would overcome the limitation. He furthermore adds that the breakwaters themselves could be constructed as floating structures. As separate structures, they could have an increased swinging on the waves as no activities will take place here. Contrary, he adds that the total cost of all of this would increase.

The hybrid form presented in HybridEnerSeaHub overcomes some of the limiting factors found in the desk research. On top of that, all the three IDI indicated the energy transition as a transition with a high potential for floating structures. Floating structures could provide a workspace for operation and maintenance practices for far offshore energy production systems (Flikkema, 2021; Waals, 2021). Flikkema (2021), also referred to the port areas and their role in the energy transition. Port areas are of major importance for handling all sorts of energy including fossil-based and renewable electricity and probably it the future hydrogen. As part of the energy, transition ports are expected to have a duality in their handling. Providing fossil fuels as well as renewable sources of energy. This requires space and this is an opportunity for floating structures according to Waals (2021).

Concludingly, many different floating structures with several functions are already installed in other places or are technically possible. A transition is observed within the energy sector and experts see the potential for a function for floating structures within this transition. While at the same time also expecting floating energy hubs to be installed in the upcoming decennia. Overcoming the limiting system dynamics, f.e. steep waves, by placing a hybrid form of floating breakwater offers a new window of opportunity.

6.3 Cyclicity

The cyclicity is based on functions earlier discussed in this study like the production of food, algae, and energy as well as living and transportation. As it has been concluded that some of these innovations are not identified as strong innovation, do not seem to align with a transition, or have the correct conditions. The cyclicity concept seems hard to be implemented. As concluded for algae production f.e. it is the non-sufficient environmental circumstances of the Dutch North Sea. Furthermore, DeltaSync (2012) discussed aquaponics, a closed system of producing food and fish through the recycling of nutrients, they proposed Tilapia as a fish to farm. However, they also add that this fish prefers water of a temperature between 26 to 30 degrees Celsius. Such temperatures are warmer than the annual Dutch North Sea, and therefore the Cyclicity plan would need customisation to the specifics of the Dutch context. As the implementation of Cyclicities is a transition of delta cities it might be interesting to further investigate in the research. As Waals (2021), referred to this innovation when showed during the interview. The innovation was discussed after a warning for the negative sides of floating structures. As it might occur that through implementing floating structures, instead of solving a problem, the problem is relocated, referring to the nitrogen crisis in The Netherlands. The Cyclicity incorporates a circular economy as the basis of its functioning and therefore would be a good example of the future floating city. Which were ambitiously referred to when asked about the long-term potential of floating structures (Flikkema, 2021; Vuijk, 2021; Waals, 2021). However, due to the result found earlier based on the individual parts the concept relies on it might not be Suitable for the Dutch context yet.

FIGURE 28 CYCLICITY CONCEPT, ARTIST IMPRESSION (DELTASYNC, 2012)

6.4 Additional result

Additionally, to the results found in relation to the executed research so far. The IDI provided data that does not specifically fit in one of the case studies or was substantially mentioned during the IDI. In this part, these will be further elaborated on. Starting with the environmental loads a floating structure is exposed to. The North Sea is shallow, especially the Dutch part. These geological characteristics result in short steep waves causing larger impact as similar wave conditions (Flikkema, 2021). Making it technically impossible to moor the floating platform in such a way it is Suitable for long term stays or residential purposes. The current mooring system does not provide the stability for this, as a certain depth is required for Stable mooring. Flikkema (2021), added that it is possible to place floating structures on the North Sea depending on the swinging that is accepted. Current techniques allow not for a Suitable living environment on the Dutch North Sea, other functions that do not require a Stable platform like PV systems are therefore possible. Upon further investigation, Waals (2021) confirmed these findings, while at the same time offering a solution to this. By utilizing land reclamation using sand nourishment, to create a protected basin in which wave impact is reduced. Allowing for Stable structures, protected by sand nourishment or even floating breakwaters. Offering a window of opportunity for large floating structures on the North Sea for long term stays or residential purposes.

Furthermore, a reoccurring limitation stressed by the experts was the vacuum of regulation, legislation, and institutional guidance on the concept (Box 3). Whereas governmental instruments could negatively or positively affect the development and diffusion of innovation (Firth and Mellor, 1999). For floating structures, there are barely any instruments in place. The vacuum was already observed when the floating pavilion was installed in Rotterdam, for this zoning plans had to be adjusted in an uncommon manner (DeltaSync, 2014). For the North Sea, this is even vaguer as national as well as international legislation apply, merely any discussing floating structures (Flikkema, 2021). As a result of the many applications floating structures can fulfil and the future ambitions it holds, it is of importance an inclusive, comprehensive and detailed set of institutional instruments is drawn up (Vuijk, 2021). Vuijk (2021) added that legislation and regulation will follow naturally when the social perspectives towards floating structures have changed. Linking the lack of governance regarding floating instruments is deemed as a direct effect of the lack of awareness of the concept. On all levels of society and in all sectors a lack of awareness of floating structures was observed. According to Vuijk (2021), it is the biggest limitation stopping the wide-scale implementation of floating structures. Social acceptance towards floating structures has to change, which in turn will lead to investment, research and an increase in knowledge (Vuijk, 2021; Waals, 2021). Relating to shortcoming of DoI theory which stated that DoI theory investigated the acceptance rather than the quality of an innovation. Through the observation made by the expert, this shortcoming could be given weight.

6.5 Implementation of floating structures

Based on the desk research, case studies and the IDI a SWOT analysis is provided. A SWOT (Strength, Weakness, Opportunities and Threats) analysis is a decision-making tool that can be used by an organisation. It analyses the internal (Strengths & Weaknesses) and external factors (Opportunities & Weakness) of a concept, idea, or innovation (Mohamad et al., 2012). The SWOT depictured in Figure 29 showcases the properties of floating structures that could influence the decision-making process for the implementation of floating structures on the North Sea. In this study, the SWOT analyses follow many innovations that have been analysed and tested through data selection techniques based on two theories as well as the North Sea specific conditions.

BOX 3: L'incredibile storia dell'Isola delle Rose

As part of this study media analyses was executed. Media analyses is content analysing method used to identify how an idea, concept or brand is perceived by the media (Macnamara, 2005). For this study a Netflix movie was analysed proving an understanding of how the implementation is a vague process. In 2020 streaming Netflix released the movie Rose Island, the original title is L'incredibile storia dell'Isola delle Rose. Based on a true story the movie depicts engineer Giorgio Rosa who had the bright idea of founding his own nation off the coast of Rimini, Italy. Fed up with the bureaucracy and regulations of his native Italy, he built an island on steel piles, so not floating. The so-called 'Rose Island' became a place of pilgrimage for headstrong pleasure seekers, where people partied all the time. Until the Italian government got fed up with the utopian structure - which was outside Italian territorial waters - and put an end to Rosa's headstrong project. Whereupon Rosa complained to the European Union in Strasbourg, without success.

The movie showcases the lack of knowledge when individuals or companies will place a structure outside of the territorial waters. Since the movie some changes have been made in international law that make repetition harder however there are still places in the world where this would theoretically still be possible (Vuijk, 2021). But even within the territorial waters or Exclusive economic zones knowledge on the legal status is missing (Flikkema, 2021).

Strength	Opportunity
- Automatically adjust to SLR - Movable/ Relocatable - Small footprint on seabed - Offsite construction and deconstruction - Modular design - Flexibility in location and over time.	- Provide flexibility to the energy transition. - Create an offshore housing facility. - Maintenance and operational functions. - Extend usable surface area. - Provide in the housing crisis
Weakness	**Threats**
- Relatively new and undeveloped innovation - High development costs - Expensive if depth < ~ 50 meters (Dutch North Sea) - Floating structures can sink	- No Legal framework for floating structures - Missing knowledge and experience for construction and maintenance. - Differing interest with other users of the North Sea. - Uncertainty on effects of large-scale implementation on the ecosystem, specifically net-primary production.

FIGURE 29 SWOT FLOATING STRUCTURES

Both the theoretical and empirical parts of this study fed into a synthesis. The synthesis as a flowchart adds to this study by providing a structured overview rationalizing the implementation of floating structures. At the same time, it sketches an overview of the primary steps executed in this study. Furthermore, policymakers, decision-makers and planners can use it as a tool to analyse whether a floating structure could be Suitable to their specific context. Some of the components are North Sea specific. Moreover, the innovations and transitions identified can be observed differently based on the context as well as the observer. Therefore, the analyses should be redone by the adopter of the floating structures. On top of providing an overview of this study and serving as a tool for potential adopters (Figure 30). Upon further analyses of the flowchart, a generalized pattern on the implementation of innovations can be witnessed. According, to a non-Relatable example this will be illustrated.

Electrical vehicles are like floating structures, not a new phenomenon. They have been around since the late 1800's however, wide-scale implementation stayed out (Burton, 2013). In that period, it was an invention rather than an innovation since there was no social environment in transition that would support the development of this type of propulsion. On the other hand, in the early 20th century, fossil fuel cars took over due to the global transition towards the use of fossil fuels and later accelerated by the second world war (Thoms and Holden, 2016). In recent years the energy transition took off, providing the right environment for electric cars to be implemented. The strength of an electric car (low carbon emission) in a social environment (climate crisis) provided the combination to allow for wide-scale implementation. Conditions for implementation were established through for example charging station, governmental support, and public opinion. The combination of these two theories thus provides a generalized framework to make predictions on innovations. Both theories have strong components, as well as shortcomings, these shortcomings are overcome in the collaboration between the theories. With additional adjustment to the conditions, it can be expected an innovation will spread through society harnessing the momentum of social transition.

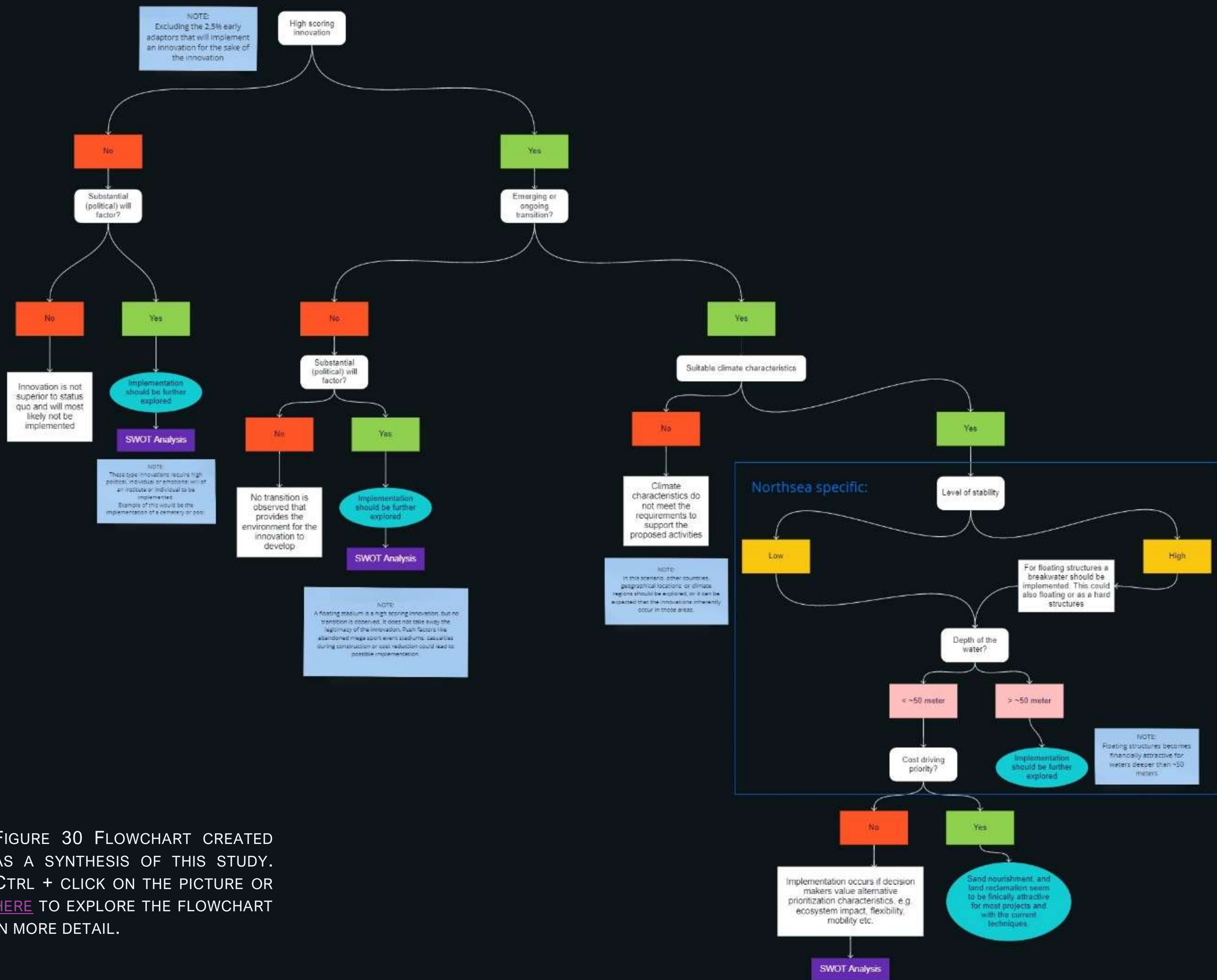

FIGURE 30 FLOWCHART CREATED AS A SYNTHESIS OF THIS STUDY. CTRL + CLICK ON THE PICTURE OR HERE TO EXPLORE THE FLOWCHART IN MORE DETAIL.

Conclusion

Departing from an optimistic perspective on floating structures and recognizing the potential they have, this study aimed at rationalizing the absence of floating structures on the Dutch North Sea. By recognizing the potential, they carry in being part of solutions for global challenges like climate change, urbanization, and land scarcity this study helps to prepare for what may very well be, the most likely floating structure on the Dutch North Sea in the upcoming years. In preparation for implementation this study answered the research question: What are the opportunities, limitations, and conditions for the development of floating structures on the Dutch North Sea, in the upcoming decennium, using insight obtained from the Diffusion of innovation Theory and Transition Theory?

This was done by datamining, desk research, case studies and IDI were executed retrieving information from multiple sources. A combination of theories was used that allowed for analyses of floating structures. The first theory, the DOI theory, provided factors that allowed to identify innovation that will most likely diffuse in a social group. To identify the innovation a vast database was set up with floating structures currently floating somewhere in the world, proposed for future implementation, or existed in the past. From the innovation identified a small selection scored highest for their potential on diffusion including food production, stadium, energy Hub, airport, cyclicity and port/cruise terminal. However, shortcomings in the DOI theory were recognised, in innovation bias, acceptance of innovation rather than the quality, reflectance of the complexity of social groups and systems and being restricted in the ability to identify between an innovation or an invention. Therefore, an additional theory was added to this study to overcome the shortcomings of the DoI theory. Additionally, indicating a transition that could transmit the development of a floating structure. At the same time, shortcomings in Transition Theory were recognized.

In conclusion, 20 functions for floating structures were found through data mining. Out of these 20, six opportunities were analysed according to factors obtained from DoI theory. The six opportunities were showcased in Table 3, and included Food production, Stadium, Energy hub, Airport, Cyclicity, Port/Cruise terminal. For these six opportunities limitation have been identified though identifying and analysis the presence of transition. As the absence of a transition would not offer the suitable developing environment for a floating structure to be implemented in or the social change which validates a floating structure as an innovation rather than an invention. Three innovations were in correlation with an ongoing transition including, Food production, Energy hub, and Cyclicity. Out of these three, the Energy hub was indicated as the presumed innovation that will most likely be implemented in the upcoming decade. Most foremost conditions for the implementation are suitable environmental condition, a relatively quiet sea, of willingness for implementation of the society and regulatory and legislative frameworks.

It must be mentioned that the implementation of a floating Energy hub will likely be in combination with a structure that protects it from the forces, caused by waves and currents. Otherwise, the structure will not be stable on the waves to support long term activities like living. The additional two innovations for which a suitable transition was identified, seem to be lacking uninfluential conditions, including climate conditions for the system proposed in this study. A North Sea specific condition was the climate characteristic that limited the implementation of algae or some fish species that the floating structures based their functioning on. No solution surfaced for this condition to be fulfilled. On the other hand, other climate regions would provide these conditions and their implementation in those regions should be researched. Furthermore, research showed that floating structures become economically attractive at a water depth of about 50 meters. While the Dutch part of the North Sea does not reach such depth. Despite this implementation of floating structures should be considered when characteristics of floating structures are valued more than the economic advantage of the structure. Modularity, being able to shift the composition of the structures, and flexibility, capability to relocate a floating structure, are characteristics that could be substantially valued. Additionally, floating structures do not require huge relocations of soil or building material to be able to create a surface above the water level. Therefore, not disturbing the ecosystem on its footprint and the material source locations. On the contrary, the environmental effect of floating structures is mostly unknown and could even show a reduction in the Net primary production.

Governmental instruments, regulations and legislations on floating structures are widely missing. Resulting in a vacuum of knowledge and know how's on the implementation and legal status of floating structures. Some expect that this will change when awareness and perspective on floating structures will develop. Awareness in perceiving floating structures as a potential opportunity for spatial problems seems to be missing by decision-makers. DoI theory taught us that being unaware of floating structures does not influence the legitimacy of its quality nor its ability to be able to diffuse in an innovation. In addition to that transition learned the through niches separate from the regime floating structures can be tested and improved. It can thus be concluded that the optimistic perspective from which this research took off can be held in continuum towards the implementation of floating structures.

The implementation of floating structures is a spatial intervention. Even though, implementation will most likely occur far form land, in the middle of the Dutch North Sea, they should not be seen as independent units. Floating structures are part of a web of nodes which can only function through connections with terrestrial counter parts. In the future, experts expect the hard-line dividing land and sea planning, will fade. To what extend this will manifest can only be experienced by time. On this journey it should be recognised that floating structures will be implemented in open system in which they will influence and will be influenced by their surroundings, and other nodes in their web. By recognizing this aspect of time and complexity this study answers to the call of de Roo to incorporate this aspect into the theoretical scope of planning. In this research this was done through factors obtained from DoI theory and analysing transition according to transition theory.

Furthermore, this study adds to the practical aspect of spatial planning by offering planners a perspective towards the future on the possibilities at hand. As well as indicating the most probably function for which should be prepared. Simultaneously, this study is a call to decision and law makers to start looking into a legislative and regulatory frameworks and instruments that allow for implementation in the near future and beyond that. Space is limited, and therefore the planning of these spaces is crucial. When done correctly, floating structures can offer a significant role in social transition and simultaneously reinforce existing sectors.

Discussion

Moreover, it could be argued an intrinsic bias towards floating structures leads towards a slant research strategy. On the other hand, it did allow to investigate the North Sea as an open field of possibilities for floating structures, exploring the wide variety of opportunities. The system's characteristics were not neglected, and the system was throughout perceived as open. However, the research strategy consciousness turned away from factors that otherwise halter the explorative attribute of this study, for example the missing legal framework, as also discussed during the IDI. This could forestall further research into the opportunities the structures possible offer, limiting the push on the regime level deriving from the niche level. Any which way, more research on the legal framework is needed that explores the vacuum present in the regulatory and legal field.

The duality in theories used for this research provided knowledge on the development of floating structures within society. However, it has been considered for the incorporation of an additional third theory. The theory of Social Innovations, viewing innovations as those who “are both social in their ends and their means. Social Innovations are new ideas (products, services and models) that simultaneously meet social needs (more effectively than alternatives) and create new social relationships or collaborations” (Osburg, 2013, p. 17). Through the use of this theory, the implementation could be further explored socially. It was decided that this would be outside the scope of this research as it looks into the socially responsible implementation of the innovation. Nevertheless, the theory could provide insight in implementing floating structures on the North Sea and therefore would be advice for subsequent research.

Furthermore, the data used to identify the functions was a snapshot of the data available at this time. During the collection of data to generate the database it was decided to end the search for innovation based on markers including the date, function or in line with the definition of floating structures used in this study. Repetition of functions occurred more frequently as the list was created. Therefore, the possibility innovations have been missed is existing. By incorporating surveys with experts this could be prevented but based on the vastness of the database this research was confidently executed.

Additionally, as already explained in chapter 4.2, the grading of the innovation could provide different results based on the observer. In case of reputation of this study, or adoption of the flowchart by decisionmakers, it would be advised to gather a group of experts and collective grade the innovation. contextual factors, observer perspectives and experience can influence the grading to a certain extend the ranking might change. Moreover, additional functions should be added ones recognized or observed.

In continuum of this research, and as part of the development of floating structures additional research on the functions, technical stability, transitions, and legal framework possible will add valuable knowledge. Increasing the understanding of the innovation, likewise the conditions needed for development.

In recurrence of this research, the explorative phase should be handled differently. Even though it still provided insight in floating structures, it was not the most efficient and fruitful part of this study. Due to the extended possibilities of floating structures, and the limited relation between floating structures and spatial planning the possible research topics became humongous. Significance energy was put into dead ends which could have been prevented. What was key in the shift form the low productive phase of the study was change of supervisor. Early recognition of this limiting factor would have been preferred. On top of that, writing a thesis during a global pandemic is not preferred. It was hard to share thoughts and ideas with classmates, which resulted misleading thought on the progress and productivity. Aside from regular meetings with my supervisor, regular meetings with colleague students should be seriously considered.

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Appendixes

The references of this research are collected online.

Through the following link they can be accessed:

https://drive.google.com/drive/folders/1DF49PKZHX4Ic000Kqs0F5MB7kh75Bn-5?usp=sharing

De Google drive consist of the following Appendixes:

Appendix 1: DoI analysis 0-1

https://drive.google.com/drive/folders/1_4dvIxmCiXrJWgx8wWZIXpYPJ8AX169f?usp=sharing

Appendix 2: DoI analysis 0-5

https://drive.google.com/drive/folders/1HfbQ0boaJDBcKAJjqvTiupKbOFTfpXKk?usp=sharing

Appendix 3: Interview questions

https://drive.google.com/drive/folders/1b1EhmdzmZiLwFpzfeFitmaQS-wwyHV3U?usp=sharing

Appendix 4: Analysis interviews

https://drive.google.com/drive/folders/1JUOvt9xA4-mguS3PjrHGhcJpQN1NF38I?usp=sharing

Appendix 5: Database

https://drive.google.com/drive/folders/1_8MPdvh3qsHdNIPeXrmet4BQ6NTITEvG?usp=sharing