A catalogue of technical requirements and best practices for the design

D7.2

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Executive summary

Living@Sea addresses the conceptualisation of marine floating islands that are intended for human habitation (i.e., living, working, recreation) (Figure 1). These floating islands could be located on the high seas, near economic marine activity, or closer to shore, as an extension of existing cities or port areas. Safety and comfort of such floating islands are of paramount importance and have been the focus of Task 7.3. Available knowledge includes floating offshore accommodation in the offshore and shipping industry, and floating urbanisation on the calm inland and coastal areas; however, offshore and urban environment are completely different worlds and speak different languages. After literature review and interviews, it has been concluded that currently there is no example of large-scale floating development with the purpose of living. Therefore, it was not possible to gather information on the best practices for the design of living at sea. The ones coming closest are from the offshore and shipping industry such as flotels or accommodation units for on offshore platforms; however, rules and regulations with which these structures comply are confined to oil, gas and shipping industries, which are stricter than ones complied in the urban environment. This led to a totally different approach for this task than expected upfront. To find the most optimal solutions, standards from land-based urban planning will have to be integrated with living and building standards from the offshore industry. Preferably this combination should form the basis for new legislation made specifically for floating islands in general and living on these islands.

Figure 1 Living and recreation at sea: design for Space@Sea North Sea conditions (source: Waterstudio.Blue, 2019)

The approach to this study is two-fold. First, attempts to outline the existing technical regulatory frameworks of the offshore-shipping and urban environment have been made. It has been concluded that existing maritime regulatory framework can be extrapolated to fit that of floating islands. In fact, financial incentive has been identified to be the key driver that urges standards to be established, offshore assets to be classed, so as to obtain insurance for the assets. From the urban perspective, building regulations in the Netherlands for instance, have been amended over the years to include more technical details to regulate floating structures. Nonetheless, the most recent supplementary regulation included in the current Building Act is still confined to single floating house unit, rather than a large-scale (community or city) floating island development.

In fact, while the legislation at local scale is work in progress, the legal status of a floating island on the national and international scales has not yet been investigated. The definition and legal framework of a floating island can shed light on not only the rules and civil codes that can be applied from the urban context, the ownership possibilities of the sub-structure and super-structures, but also financial aspects such as insurance and mortgage issues, which are also vital drivers that power the floating islands development for Living@Sea. Thus, it is recommended to follow the trajectory of current law amendments in the Netherlands and talk with relevant stakeholders that are involved for the next phase of this task.

The second part of this study collects the most relevant rules and regulations that need to be considered to guarantee the main desiderata for comfortable and safe living at sea. The assessment of the regulatory issues of safety and comfort will set standard preconditions for the floating island design, construction, installation operation and maintenance. In summary, the following aspects have been considered and relevant regulations collected:

1. Stability and buoyancy (dead load, live load, platform stability);
2. Acceptable motions, accelerations and their duration (comfort requirements);
3. Fire safety protection (additional safety requirements).

Direct regulations for multi-use platforms/islands, such as those being developed within the Space@Sea, do not exist yet. Current regulations for buildings and those applicable in shipping/offshore industry collected in this document are expected to contribute to the design guidelines needed for Task 7.4. The outcomes of this first part of the study include an inventory of rules, regulations and codes of safety and comfort, and a list of international organisations and entities that are responsible in establishing and maintaining these codes and standards. It has been concluded that although floating islands are different from offshore platforms and ships, in order to ensure safety and comfort, several measures still need to be taken to, for example, prevent and detect fire in time. It is also required for inhabitants to keep in mind some safety rules, and for the entity that manages the floating island to establish and implement a Safety Management System.

1. Introduction

The floating island concept is increasingly used in the attempt to find viable and practical solutions for the expansion of urban areas. Because of the growing populations in crowded urban areas, threat of the sea level rise and ecological impacts, these islands become a serious alternative to land reclamation. Floating islands could support human activities at sea in the longer term. The ocean is becoming the new location for the expansion of activities developed on land, such as energy production, aquaculture, logistics and living (Figure 1.1).

The Space@Sea project sets out to provide sustainable and affordable workspace at sea by developing modular floating islands. The project will develop and demonstrate the modular floating islands, corresponding to the considered business cases. Work Package 7, Living@Sea, aims at developing safe, healthy and comfortable living and working space (offices, retails, etc) on floating platforms, that could eventually grow into a floating city. A floating city will consist of multiple buoyant platforms connected to one another on water and moored to the bottom of the sea. The platforms can adapt to changing sea levels and can be towed to other locations for repurposing if needed. There are two scenarios for Living@Sea, the floating city could be either regarded as a stand-alone "city" offshore that improves the living environment of offshore workers, as is also considered in WP 6 for the Operation and Maintenance hub for offshore wind parks. Or it could be considered urban extension of an existing coastal city. However, there are still unanswered questions on for example how much movement should be allowed to ensure comfort and safety in such a city? Who will develop such a city and what are their interests and concerns?

Figure 1.1 Floating city examples: Living@Sea (top) by Waterstudio Blue in 2019, and Floating City (bottom) by Blue21/Deltasync in 2015

1.1 Objective, research questions, approach and outcomes

The objective of Task 7.3-Technical, comfort and safety requirements of Living@Sea is to collect the most relevant requirements for floating islands from both offshore and urban perspectives, ensuring enough safety and comfort for future inhabitants. To find the most optimal solutions, standards from land-based urban planning will have to be integrated with living and building standards from the offshore industry. It is a combination that does not exist yet, and still needs quite some effort particularly from the legal perspective. This research expects to shed light on such a combination. Thus, the main research question that this report aims to answer is:

"What rules and regulations regarding comfort and safety need to be taken into account, from both urban and offshore perspectives, for Living@Sea floating islands development?"

Sub-questions (and responsible parties to answer):

- What do the regulatory framework, the formation and functioning of the offshore industry look like? *(MARIN)*
- How is floating development currently considered within the urban regulatory framework? *(Deltasync/ Blue21)*
- What umbrella legal entities are responsible for setting technical, safety and comfort rules, regulations, standards or codes? *(ICE/MARIN/Deltasync/Blue21)*
- What financial parties in the offshore and urban environment play an important role in powering the development of floating islands? *(Deltasync/Blue21/MARIN/ICE)*
- What rules, regulations and standards from the offshore perspective can be referred to in Living@Sea? *(ICE)*

The approach to answer these questions is divided into two parts, the steps in each part is shown in Figure 1.2. The outcome of PART I is technical regulatory framework of both offshore and urban environment. This gives readers an idea of how offshore structures or urban land and buildings have been developed and the big picture of its current functioning. Whereas, the outcome of PART II is an overview of the current state of the art on rules and regulations. A first attempt has been made in order to form the technical safety guidelines which are vital inputs for the design process in Task 7.4.

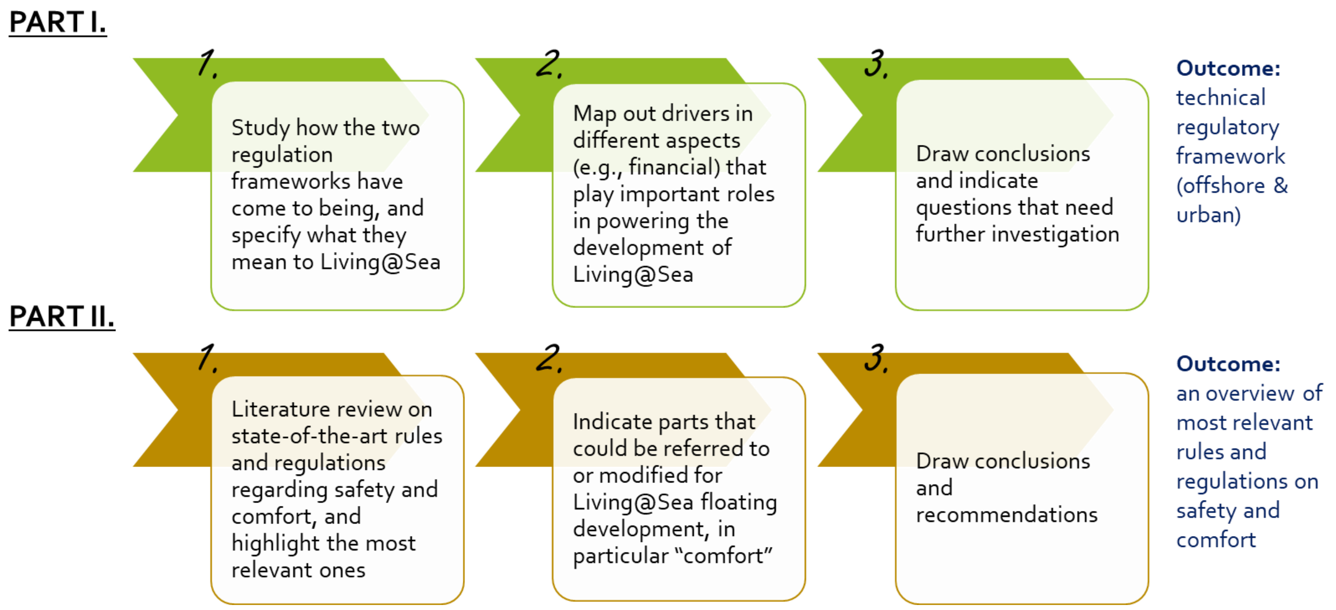

Figure 1.2 Two-folded research approach and their outcomes

1.2 Structure of the report

The report consists of 7 Chapters. Chapter 1 introduces the background and objective of the project, as well as the research question, approach and expected outcomes. A short historical context of living at sea is also included, showing the trends in both offshore and urban developments. Chapter 2 points out the necessity of defining Living@Sea floating island, briefly introduced its importance and how the definition affects different stakeholders. More information about key stakeholders in Work Package 7, and overview of the Work Package have been included in Appendix 1.

As previously mentioned, the research approach is divided into two parts. The outcome of PART I is included in Chapter 3 and 4. The two chapters describe respectively the regulatory frameworks for Living@Sea from both shipping/offshore and urban perspectives. The outcome of PART II is Chapter 5 and 6. Chapter 5 introduces the general safety, giving an overview of the risks and the associated hazards in the offshore/shipping environment. The importance of fire safety, its probability of ignition and various ways to detect fire, heat and smoke are also described here. Chapter 6 elaborates on the human comfort, indicating existing regulations and implications that could be referred to and contributed to other tasks such as design Task 7.4 or demonstrator test of Work Package 10. This chapter is of paramount importance for living at sea. Thus, a plethora of information about buoyancy, stability, accelerations and their indications to urban setting have been collected. Chapter 7 draws conclusions from this study and recommendations for further investigation.

1.3 Historical context and current trends

Living on water is not something new. Historically human has settled at sea or large inland water bodies for different reasons for centuries. For instance, in the China south-eastern Fujian province in Luoyuan Bay, floating villages were created at where peoples “livelihood”, fish farming was. Floating islands in Lake Titicaca in South America were created by UROS, the indigenous people of Peru and Bolivia, in order to escape fierce assaults by the ruling tribes hundreds of years ago (Figure 1.3). While these communities continue to exist, living and working on water for different reasons can be observed all over the world.

Figure 1.3 Floating village in Fujian Province, China (left) and floating islands between Peru and Bolivia (right) (source: Dailymail,and Natgeotraveller, retrieved in May, 2019)

Mankind has ventured the sea and oceans for centuries, either to make a living (work), travel towards a better future, or for leisure. People stay and live on ships and offshore islands for weeks/months in succession, but they are principally there for occupational and not domestic reasons. Offshore personnel have to live on ships or platforms to exploit resource at sea (e.g., oil drilling, fish farming, etc.). This saves the costs of transporting the offshore workers from and to the mainland on a daily basis. These offshore workplaces are usually at a noticeable distance from existing civilisation and families and friends. Moreover, sea conditions can be rather tough and any extra square meter on the floating structure adds extra costs to the offshore projects. The living environment is therefore designed to be very minimalistic (Figure 1.4), which gives it quite some room for improvement.

Figure 1.4 Exterior (left) and interior (right) of the offshore accommodation facility (source:Wikimedia and Jamestwonmetal, retrieved in May, 2019)

In the urban environment, living in a floating building has gradually gained ground as an innovative climate-adaptive solution in times of increasing floods or rising sea level. Floating development has been viewed as a way to deal with land scarcity in coastal cities. Due to the fast-growing population, urbanisation and ever-increasing demand of resources and housing, more space is required and floating could help by creating “new land”. In IJburg, Amsterdam, the Netherlands, a floating community consists of 75 floating houses has been created since 2009. In recent years, more and more large-scale floating structures for living purpose have also been built. One of the most famous ones is the world’s largest floating villa made by ADMARES in 2017 (Figure 1.5).

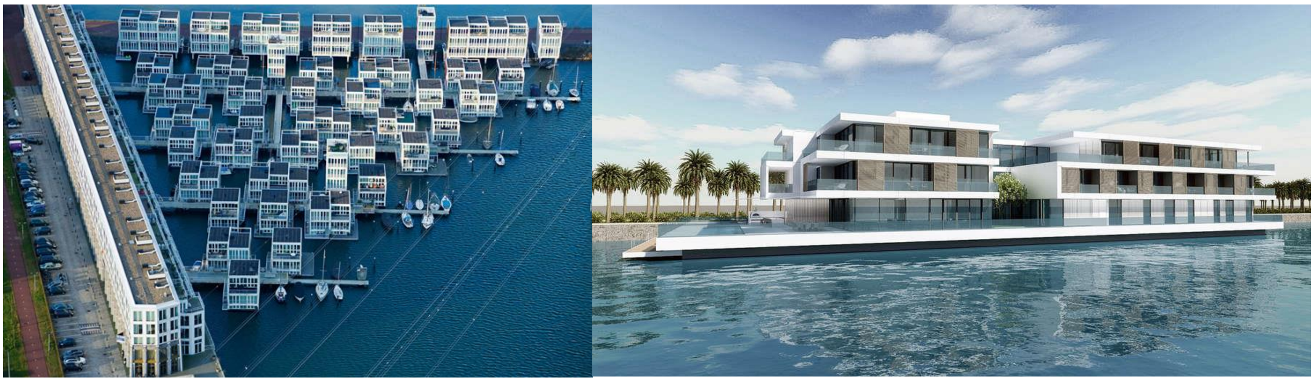

Figure 1.5 IJburg floating houses in Amsterdam, the Netherlands (left) and world's largest floating villa made by ADMARES, Finland (right) (source: JLG real estate and ADMARES, retrieved in May, 2019)

Recently the topic of large-scale floating development has also received international attention. In April 2019, UN-Habitat convened a roundtable discussion of architects, designers, academics and entrepreneurs at UN Headquarters on how floating cities could be a viable solution to urban challenges such as climate change and lack of affordable housing.

Figure 1.6 Floating city roundtable discussion in April, 2019 (source: [Smart Water Magazine](), retrieved in May, 2019)

2. Definition of Living@Sea structure

Floating city is a structure consisting out of a superstructure and a substructure. Before investigating technical, safety and comfort requirements for floating city development, one of the most fundamental questions that needs being answered is the definition of the floating structure that a city sits on (Figure 2.1). While the superstructure of a floating city can resemble buildings on land, it remains ambiguous what the substructure is and how to define it. Can a floating platform be defined as land, an artificial island, an installation or something else? Should a floating platform be treated as an offshore platform or as ship or vessel? These are important questions that need being answered as the definition would determine the kinds of rules, regulations and standards that the floating islands would need to comply with. In this chapter, activities offshore have been described, followed by the possibilities of treating floating islands as artificial islands or flotels.

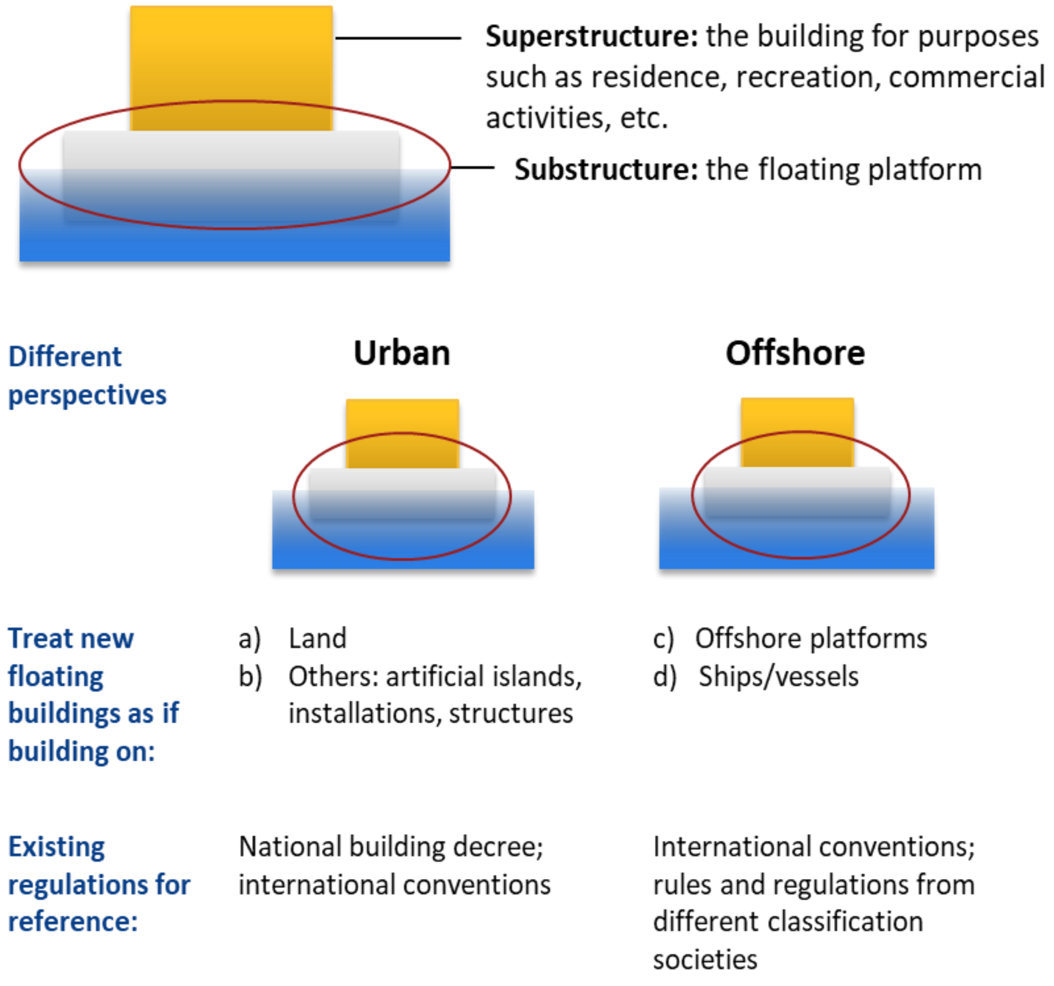

Figure 2.1 Possibilities to define the substructure of a floating city unit

2.1 Floating island as an artificial island

As the floating island will have a quite similar purpose as current artificial islands, usually constructed by land reclamation, dredging or poldering, it could be a useful comparison for defining the legal status as an artificial island. An artificial island is an island that has been created by people instead of nature. The source for this investigation has been the United Nations Convention on the Law of the Sea. The LOSC (The United Nations Convention on the Law of the Sea) is an international agreement which defines the rights and responsibilities of nations with respect to their use of the world's oceans, establishing guidelines for businesses, the environment, and the management of marine natural resources. It also defines the different man-made objects that are present in the seas.

However, an artificial island does not really have any clear status at all. Regarding the legal regime of the artificial islands, based on the LOSC stipulations, an artificial island is neither a natural island nor a ship. The legal status of the island remains ambiguous. Although a distinction is made between artificial islands and ships, there is no clear distinction in the use of terminology of 'artificial islands', installations, structures and devices.[1]

Moreover, after an interview investigation at the Netherlands Institute for the Law of the Sea (NILOS), the researchers working on this topic stated that floating city or floating islands cannot be regarded as an artificial island due to its buoyant characteristics. To be able to define the legal status of these floating islands for living purposes, an investigation into various international conventions to gain more insights is requested[2].

2.2 Floating island as a flotel

Another possibility is to use input from the existing regulatory framework for occupational use of floating structures like cruise ships or offshore hotel structures, called flotels (see Appendix 3). The passenger ships have an extensive leisure functionality combined with occupational function by the crew. The vessel owner and operator in have the obligation to provide a proper health and safety management for the recreational passenger.

The same principle as with ships and offshore structures however will apply with respect to the value of the floating asset from point of view of investors and insurances. It will have to be classified as fit for purpose by an independent classification society. The specific requirements such as local environment, envisaged lifecycle duration etc., will have to be taken into account. And the impact of the floating structure on the surrounding marine and coastal environment will be evaluated by the national authority under which the structure will fall. That in turn will raise specific requirements on waste control, emissions etc..

[1] Francesca Galea (2009) ARTIFICIAL ISLANDS In The Law of the Sea

[2] Spijkers, O. (2019, April 2). Personal interview.

3. Regulatory framework for Living@Sea: shipping/offshore industry

This chapter gives a succinct overview on the key conventions that set minimum standards for design, construction and operation of ships/offshore structures regarding safety. Parties involved in the shipping operation and their correlations have been illustrated. Moreover, the importance of having offshore assets classed and insured has also been described. Requirement of comfort and reference examples have been given as well.

3.1 Key conventions & stakeholder groups

Regulations defining the framework for shipping environments has a prime focus on safety. Safety of marine operations in shipping is addressed by the International Maritime Organisation (IMO). IMO formulates and maintains a multitude of conventions that are ratified by the member states. A more general and legal framework to ensure not just the value, but also the safety of life at sea, was adopted after the disaster with RMS Titanic in 1912. This was the SOLAS or Safety of Life at Sea convention (1914-01-20). SOLAS states minimal requirements for construction, equipment and operation of merchant ships. It has a focus on principal safety. In particular, the structural integrity of the ship structure and the equipment on board to be fit for purpose with respect to the sailing environment. SOLAS has been ratified by 164 member states in IMO and has been maintained by IMO since 1948. SOLAS is nowadays regarded as the most important of the international treaties concerning the safety of merchant ships.

Over the recent history, IMO introduced further conventions, STCW, MLC and MARPOL. STCW focuses on the required level of training for crew in order to maximize reliability of man-made decisions and minimize hazard of human error related incidents. MLC has a specific focus on the rights and wellbeing of seafarers on board ships. It is by origin from the International Labour Organisation but is organized by IMO. MARPOL has a focus on the preservation of the marine environment with a specific interest in limiting oil and exhaust emissions by ships. Together with the SOLAS convention these are referred to as the four pillars of the international Maritime Regulatory Regime. They affect the basic safety of operations at sea by:

- Requiring a structurally sound structure
  → ***SOLAS*** *(International Convention for the Safety of Life at Sea)*
- Have properly trained and certified staff operating them
  → ***STCW*** *(International Convention on Standards of Training, Certification and Watch keeping for Seafarers)*
- Making sure the on-board crews have good secondary terms of work
  → ***MLC*** *(Maritime Labour Convention)*
- Ensuring that risk of damage to the environment is minimized
  → **MARPOL** (International Convention for the Prevention of Pollution from Ships)

Instead of implementing safety related agreements between the various parties, it is internationally agreed to design, build and operate ships in accordance to the IMO conventions. The IMO conventions are implemented in the national regulations of each IMO member state or flag state. A part of these are mandatory. In fact, every time after a disaster, more regulations come into force. Despite all conventions and regulations, disaster still happens. The first who is more likely to add additional regulations are regions like EU (e.g., wheelmark at safety equipment). The principles of these key conventions are the backbone of international design principles that are imposed on new designs to have similar safety regimes and working environments for seafarers worldwide.

In the offshore industry, operations take place in a working environment with strong oil and gas process plant similarities. They are treated like facilities on shore added with extra hazards due to their remote operation in sensitive and hostile environment. In European settings, the regulations are usually referred to as Health and Safety. Health and Safety considerations are typically regulated by the HSE Health and Safety Executive. There are dedicated guidelines dealing with oil and gas, and with renewable energy type of concepts. Many of the rules and regulations regarding HSE have been collected and are available in the report from Work Package 2 within Space@Sea.

As soon as offshore platforms become mobile, or should be considered ships, the guidelines would then refer to the shipping related SOLAS and MARPOL regulations, or the specific IMO category labelled as Mobile Offshore Drilling Units (MODU). The value of offshore assets is typically higher than that of ships. In general, offshore energy production, as well as oil and gas production are hazardous. The call for quality insurance and classification of design and process details is thus typically stronger than on board ships.

In terms of the implementation of the regulatory framework, it is usually done by a group of parties that enforce mandatory requirements. This group includes flag states, the port state authorities where vessels call, and the financial stakeholders of the maritime enterprises who own and operate ships. The design, building and operation of a ship involves many parties each with different roles and interests. In order to depict such complicated synergy in the shipping/offshore industry, an illustration of stakeholders in the functioning is shown in Figure 3.1.

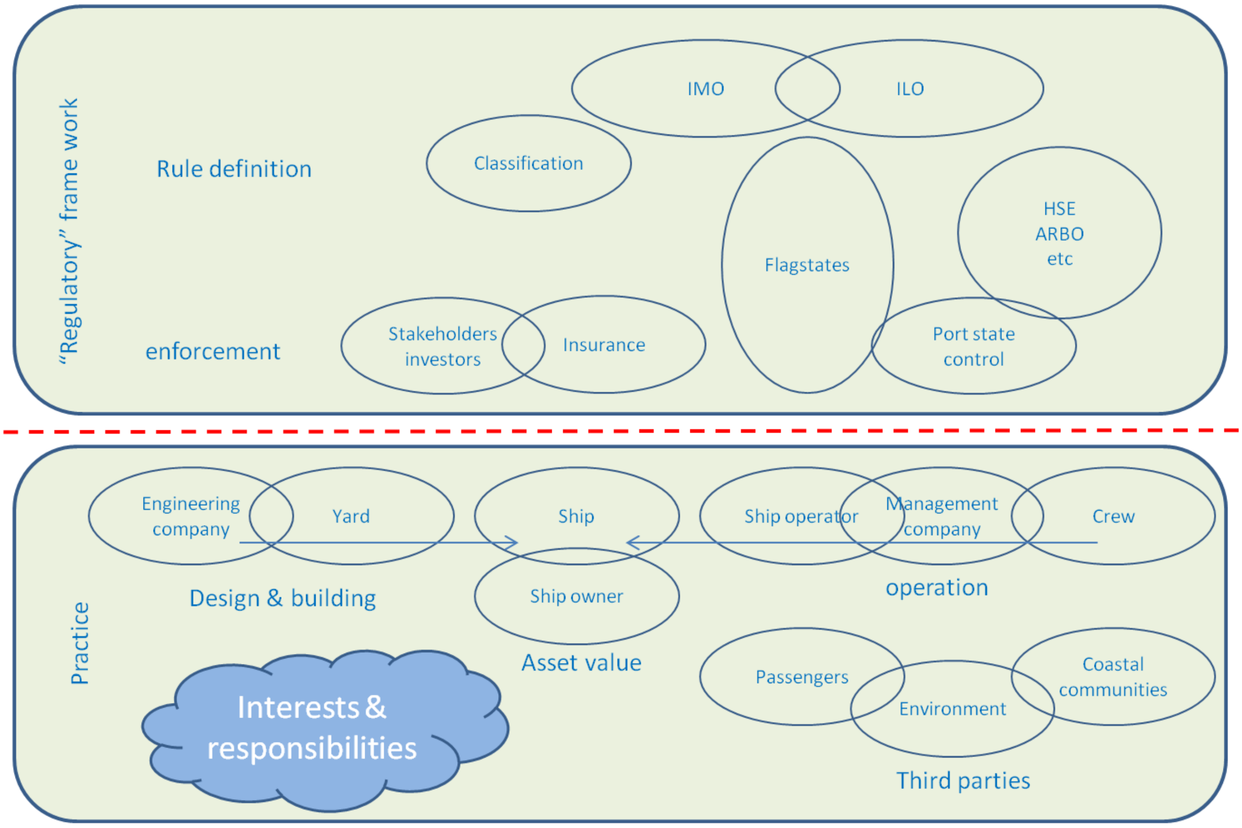

Figure 3.1 Parties and relations involved in Shipping Operations

1.	Engineering companies	Need to conform to class defined rules and standards
2.	Yard	Need to conform to class defined building standards & materials
3.	Shipowner	acquire, charter, sell,
4.	Ship operator	operate ship& maximize cashflow within flagstate regulations
5.	Management company	Minimize running costs within flagstate regulations
6.	Crew	Operates the ship within constraints by management company
7.	Passengers	Travelling or leisure.
8.	Stakeholders	Require ship and crew -> fit for service -> rely class
9.	Insurance	Require ship and crew -> fit for service -> rely class
	a. Hull	structural integrity
	b. Machinery	proper maintenance
	c. Cargo	incidents
	d. P&I	liability
10.	Underwriter	Specialist in maritime insurance -> is all covered?
11.	IMO	Provides framework for flag states
12.	Flag state	Provides framework for operators and class
13.	Classification	Independent party / technical conscience for all

The regulatory framework as mentioned in upper part of the diagram is in place to represent and safeguard the interests of the following parties:

- ***Financial stakeholders and insurance*** make sure that minimal standards are maintained such that incidents and damages remain inside acceptable limits.
- ***Classification societies*** define and oversee the rules and conformation to these rules by ship owners in order to make sure that ship structures are seaworthy and fit for service. Classification societies have their own set of rules (about construction, maintenance, inspections), and will add next to their technical rules, also regulations on top of this (e.g., CO2 bottles, fire extinguishers, construction regulations, electrical safety at tankers).
- ***IMO and ILO*** define further rules requiring minimal safety and wellbeing standards from personnel point of view and the minimization of maritime operational impact on the environment.
- ***Flag states*** implement these rules in national legislation and enforce them onto their own vessels. Examples of such implementations are Health and Safety Executive- and ARBO-rules, etc.. Flag states will add their additional regulations (e.g., quantity of survival suits, life vests, electrical emergency steps, etc.)
- ***Port State Control*** entities are empowered to evaluate conformity of foreign vessels in their port according to IMO conventions and regional regulations.

The bottom part of the diagram represents (some of) the various parties that are typically involved with the design, construction and operation of a ship. Different entities design and build the actual ship for an owner. A vessel operator runs its actual business with management companies and crews as *direction stakeholders*. Passengers, the local environment and coastal communities are involved as *third parties* but have no direct impact on any of operational aspects of shipping. Further parties not shown in the picture are for instance, those owning, packaging and handling cargos.

3.2 Insurance & classification societies

Modern ships are high capital assets. They often are not ordered one at a time, but in a limited series as needed to setup a new transport logistics line, or to replace vessels on an existing line. They are, however, designed and built as “one off” products. The feasibility to fund, build and operate a series of new ships relies on ensuring all involved parties that the end results will meet the expectations. Under the assumption that the outline design will meet the economic prognosis for profitability, the question then remains:

- if the vessel can be operated until its design lifetime,
- if crews will be willing and able to operate it, and
- if no unexpected catastrophe will occur that leaves all with empty hands.

The formal concept of insurance was developed in shipping for exactly this purpose. First formal mention of an insurance is said to originate from the 1300s in Italy, which was related to a shipping issue. Wider application and weaving with financial world started in the 1600s-1700s.

Ship owners recognized the value of shared risks and formalized these in mutual insurances. These later became specialised work by insurance companies. To obtain an insurance, ship owners had to prove that the ships were designed and built in compliance with minimal safety standards. The technological assessment of ships was then delegated to the so-called “classification societies”. The minimum standards were and are defined by the classification societies in “Class Rules”. The various class societies maintained the validity of their rules and standards along with the changes and innovations in ship design, construction and operation over time. Once the ships passed the evaluation and became certified by a classification society, the ships could be accepted inside the insurance “Ship Register”. Vessels in the register would then be accepted under the insurance policy. Evaluation of actual insurance claims typically was done in specialised maritime court cases.

The evaluation of the ship designs and their structural integrity is delegated to independent classification societies. The documentation of that process is mandatory even though the classification of ships is formally not required. Since investors and insurances require class notation as “fit for service”, this practically makes class approval mandatory from business point of view. Class role includes:

- Design, building materials, building procedures, ship integrity during operational lifetime and eventual repairs implemented, these all must be surveyed and approved by a classification society.

- The proper classification of a ship was originally a precondition for the financial parties involved in shipping. That included investors (banks), and insurances.

- Nowadays, the responsibilities of flag states in surveying ships and approving new designs is also often being delegated to classification societies.

It should be noted that the strictest topics for the regulatory framework as imposed by classification requirements are related to the direct safety of ship, crew and passengers from technical point of view. Directly following from that is the safety of the asset value and liabilities for the investors.

3.3 Quality of life: demand and comfort of the crew

The MARPOL and MLC conventions address the impact of ships on the environment and the principal rights for seafarers working on ships. MARPOL has a focus on oily substances but is not restricted to that. It includes ships as well as offshore fixed and floating platforms. MLC addresses the rights of the seafarers. The quality of the accommodation, the recreational facilities, food and catering, health protection, medical care is discussed. Basic approach is that the "competent authority" being the flag state under which the vessel operates, should ensure that quality meets proper demands as defined in national legislation. The compliance to such to be surveyed initially and progressively. There are guidelines quantifying the impact of vibrations and noise on crew (occupational) and passengers at varying locations, (e.g. working areas, accommodations). New build contract specifications can require conformation to specific standards as listed in these rules.

In general, mandatory requirements to the quality of life for passengers, coastal communities and marine environment around the ship do not seem to exist. Comfort related criteria however are defined by various classification societies as mentioned in Chapter 6. These are typically voluntary class notations which are often part of new build delivery contract specifications.

Conclusion

The offshore oil and gas industry introduced new players, technology, hazards and risks to the maritime environment in comparison to merchant shipping. Different procedures were adapted, but the generic concept of regulatory framework remained similar to that in shipping. Both addressed the interests related to "Working at Sea". The offshore industry originates from the (land based) oil and gas world. The asset values and risks that come with handling hydrocarbon energy products are higher than for merchant shipping. Therefore, stricter regulations on health, safety and environment are usually applied than in shipping industry. While the topic of "Living at Sea" may now add another new branch to the scope of the more general "Life at Sea", the outline of a regulatory framework for that new branch will likely be similar, but not identical to that for shipping and offshore

4. Regulatory framework for Living@Sea: urban perspective

This chapter describes different approaches to develop the technical regulatory framework for Living@Sea. Chapter 4.1 shows the necessity and objective for Living@Sea; whereas, Chapter 4.2 gives an overview of documents that could be referred to for several aspects of technical requirements for Living@Sea. Chapter 4.3 shows the complexity of the ownership of the floating structure and shed some lights on the financial concerns of a floating city development.

4.1 Objective and approaches of building regulations for Living@Sea

In Europe, there is no one single unified set of building regulation for all the European Union (EU) countries. Despite the fact that the Construction Products Directive and the EN Eurocodes lead to some harmonisation of the technical building regulations of the EU countries, and that the purpose and subjects covered by the building regulations are identical in these countries, every EU country still has its own building regulations. These building regulations, together with the building control system form the so-called "building regulatory system" (Pedro, Meijer, & Visscher, 2010). To make Living@Sea a reality from the legal perspective, the floating structures must comply with the building regulations for development on water, which are currently still missing (see red in Figure 4.1)

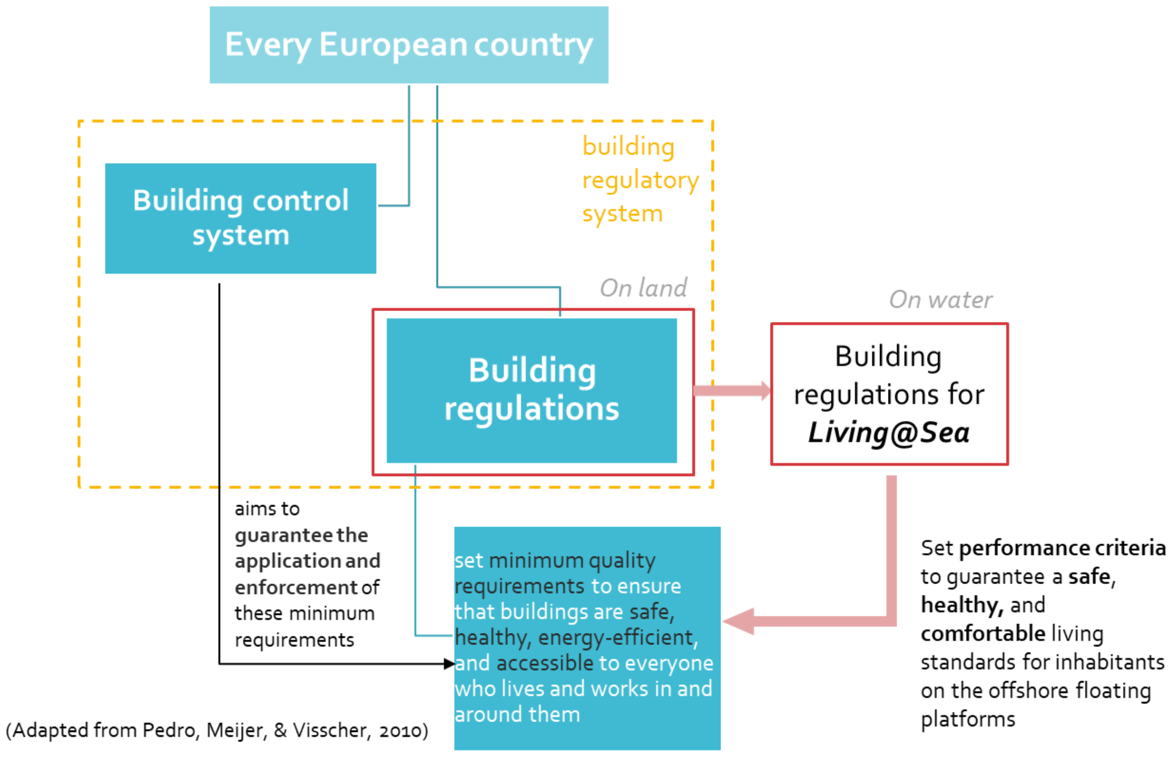

Figure 4.1 Building regulations for Living@Sea and its objective

There are three ways of looking at the potential formation of regulatory framework for Living@Sea (Figure 4.2). Option A is to create a new set of rules and regulations from scratch, taking into account both offshore and urban perspectives. This is the most thorough step; however, the process could take years as it takes much resources and legal procedures to develop, rectified and enact. For instance, most of the building regulations in European countries have been developed based on "Performance System Model (2004)." This was initially a model developed by the International Council for Research and Innovation in Building and Construction Taskgroup 37, Performance based building regulatory system to analyse the formulation of requirements in different countries (Visscher, Sheridan & Meijer, 2005).

While it is possible to develop a new framework based on such model within tasks of Work Package 7 (Figure 4.3), it makes a lot of sense to do everything from scratch as there has been ample knowledge and experiences in the offshore industry. From the urban perspective, countries like the Netherlands have also been working on producing more supplementary information on technical requirements for floating development. Option B takes the offshore rules and regulations as the starting point and adjust them to resemble the urban ones. Option C aims to use the urban rule and regulations as the starting point, taking the hydrodynamic aspects such as stability and buoyancy that are missing in the urban regulations as supplementary ones. It is expected that floating urban extension is mostly likely to take place from the coastal areas, which is closer to the urban environment. Therefore, Option C has been identified to be the optimal approach.

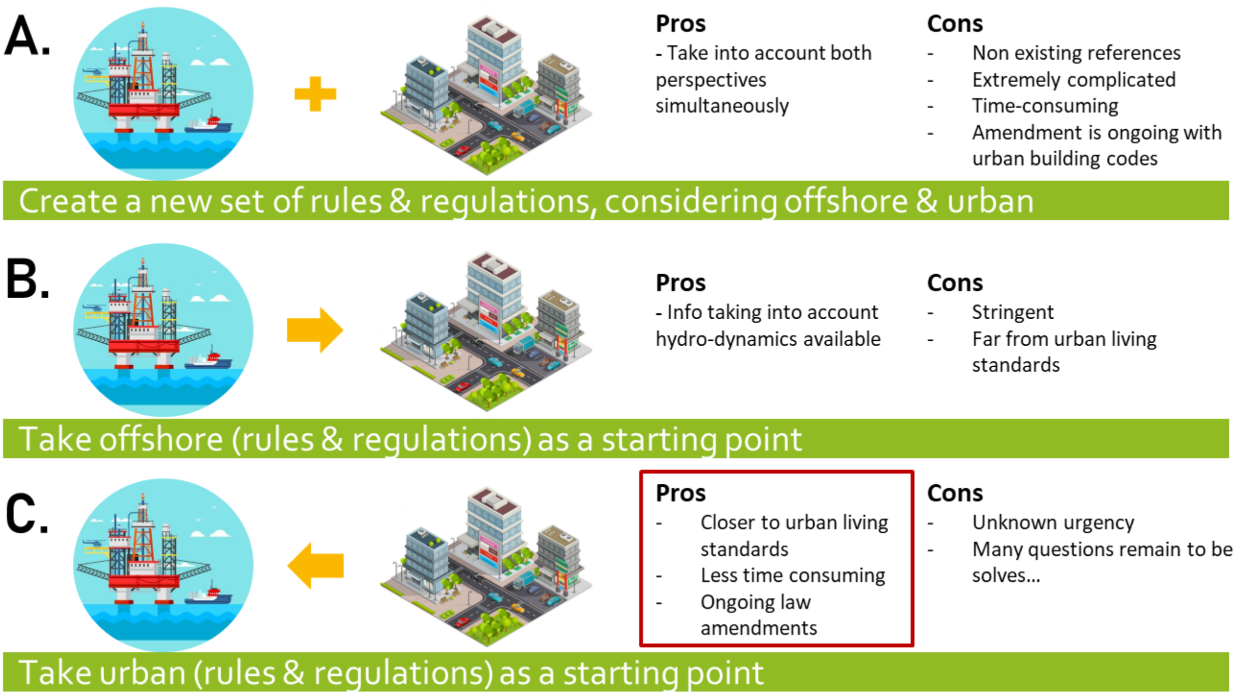

Figure 4.2 Three ways of creating regulatory framework for Living@Sea and their pros and cons

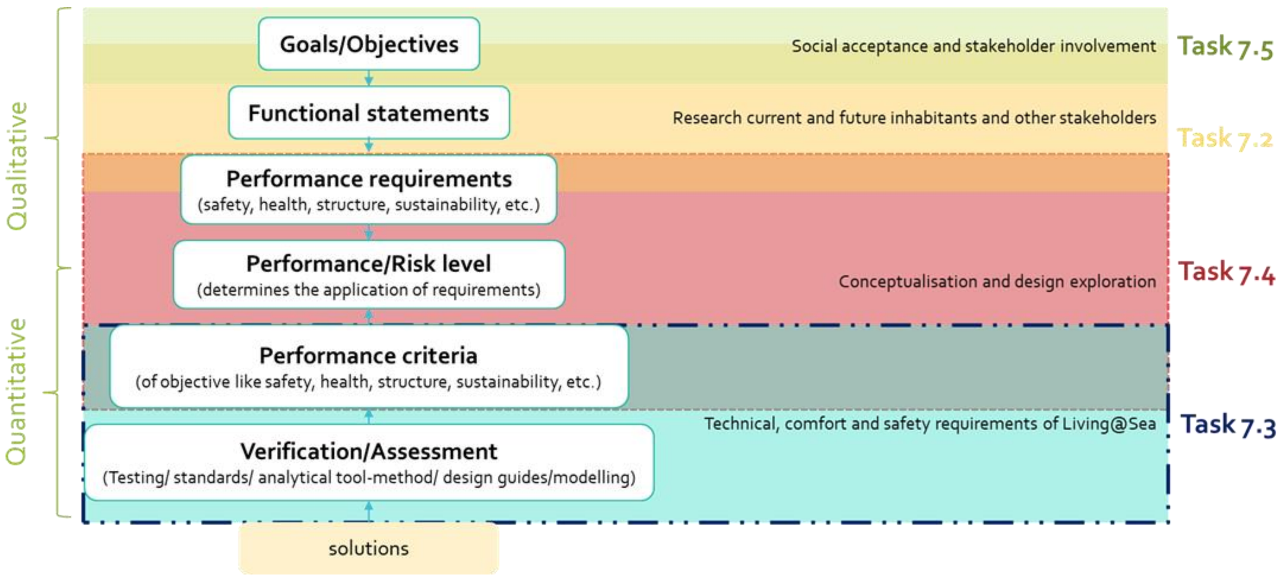

Figure 4.3 Work Package 7 reflecting on the Performance system model

4.2 Reference documents for Living@Sea

One of the major differences between building a living space onshore and offshore is the foundation to build on. In cities, living quarters are constructed on a landform, a reclaimed land or an artificial island; whereas, in offshore environment, living quarters are built on an offshore platform (oil & gas industry) or a ship/vessel. In this section, different perspectives and corresponding rules and regulations have been studied. A brief overview and the pros and cons for applying them can be seen in Table 4.1. Their implications for Space@Sea have been drawn as conclusions.

Table 4.1 Different references for different definitions of the substructure of a floating city

Perspective	**URBAN**		**OFFSHORE**
Substructure	**Land**	**Others: artificial islands, installations, structures**	**Shipping/Installations**
Existing regulations for reference	***Bouwbesluit 2012*** [Building Decree 2012]	***UNCLOS*** (United Nations Convention on the Law of the Sea), ***Bouwbesluit 2012*** [Building Decree 2012]	***SOLAS*** (International Convention for the Safety of Life at Sea), ***MARPOL*** (International Convention for the Prevention of Pollution from Ships), ***STCW*** (International Convention on Standards of Training, Certification and Watchkeeping for Seafarers), ***MLC*** (Maritime Labour Convention), ***HSE*** (Health and Safety Executive)
Pros	Existing rules and regulations already exist and can be adapted for application	***Bouwbesluit 2012*** [Building Decree 2012] can be applied	Existing rules and regulations for living quarters on offshore platforms already exist and can be adapted for application
Cons	Several aspects of floating structures (e.g., stability, buoyancy, freeboard, acceptable resistance) are not taken into account in the current Building Decree 2012, (VROM, 2009) However, amendments are being made at the moment.	There is no official definition of artificial islands in any international conventions, including UNCLOS. Moreover, the legal status of artificial islands remained ambiguous (Galea, 2009).	Stringent rules and regulations, which curbs the development and limits the quality of life offshore to the minimum

Building regulations for floating structures

In the urban context, architects and engineers refer to Building Decree, Building Code or Building Regulations when designing/building on land, as these legal instruments specify the minimum standards for the design, engineering and construction of a safe, comfortable and/or efficient building. In recent years, there is an increasing amount of floating real estate being developed and built. Upon realising the benefits, needs, trends as well as risks of building on water, both the central and local Dutch governments have conducted studies or commissioned third parties to investigate into several technical aspects of floating structures over the course of time. The goal is to come up with standards to regulate the design and construction of buildings and ensure safety and comfort of inhabitant. At the moment, there are more reference documents in the Netherlands than in any other European countries. An overview of these documents is shown in Table 4.2. Moreover, Dutch regulations also deal with European rules. For instance, construction products (e.g., bricks, window frames, concrete piles, etc.) must be tested and assessed in the same way throughout Europe. Moreover, Dutch regulations include a guideline on the energy performance of buildings, which helps to ensure that the energy performance of buildings in the European Union improves.

A catalogue of technical requirements and best practices for the design

It would be recommended to use these references as starting point for the buildings for the purpose of Living@Sea.

Table 4.2 Documents related to regulations of floating structures in Dutch (sorted by Blue21)

Documents in Dutch	Time	Author	Note
Drijvende woningen en de Bouwregelgeving-Handreiking voor ontwikkelaars, bouwers en gemeentelijke plantoetsers [Floating homes and the building regulations-Guide for developers, builders and municipal plan testers]	2009-04	VROM-Inspectie Ministerie van Volkshuisvesting, Ruimtelijke Ordening en Milieubeheer [VROM Inspectorate of the Ministry of Housing, Spatial Planning and the Environment]	
Nederlandse technische afspraak NTA 8111:2011 nl Drijvende bouwwerken [Dutch technical agreement NTA 8111: 2011 nl Floating structures]	2011-11	NEN - normalisatie en normen [Netherlands Standards Institute]	The validity of the NTA has expired and it no longer holds any judicial meaning. It is due for review.
BZK/drijvende bouwwerken in Bouwbesluit (Handreiking drijvende bouwwerken) [BZK/floating structures in Building Decree (Guide to floating structures)]	2015-04	Ingenieursbureau DGMR, Ministerie van Binnenlandse Zaken en Koninkrijksrelaties (BZK) [Ministry of the Interior and Kingdom Relations (BZK)]	
Een dek is geen dak: Ruimtelijke kwaliteit en drijvende bouwwerken; Aanbevelingen voor gemeenten en andere overheden [A deck is no roof: Spatial quality and floating structures; Recommendations for municipalities and other governments]	2015-07	Federatie Ruimtelijke Kwaliteit [Federation Spatial Quality] (Jasper de Haan)	
Drijvende bouwwerken, praktijktoets Bouwbesluit 2012 [Floating structures, practical test of Building Decree 2012]	2016-03	Ministerie voor Wonen en Rijksdienst [Ministry for Housing en Civil Service]; Nieman Raadgevende Ingenieurs B.V.	
Effectmeting wijziging Bouwbesluit 2012: Drijvende bouwwerken, milieuprestatiegrenswaarden en de label C-plicht voor kantoren [Effect measurement change Building Decree 2012: Floating structures, environmental performance limit values and the C-duty label for offices]	2017-05	Sira Consulting B.V.	
Constructieve Veiligheid Drijvende Bouwwerken [Constructive Safety Floating Structures]	2017-09	Rijksoverheid [National government], Adviesbureau ir. j.g. hageman B.V., Ingenieursburo Meijer & Joustra B.V.	Commissioned by Ministry of BZK
Informatieblad Drijvende bouwwerken [Information sheet Floating structures]	2017-11	Ministerie van Binnenlandse Zaken en Koninkrijksrelaties (BZK)	
Wet verduidelijking voorschriften woonboten [Act on the Clarification of Regulations for Houseboats][3]	2018-01	Overheid [Government]	**1.** An overview can be seen in Staatsblad 2017 Nr.494 [State sheet 2017 Nr.494]. **2.** The Act entered into force on January 1, 2018. **3.** More elaborated content will follow after 01-01-2020.

[3] Incl. "floating objects used for residence purposes"

Bestemmingsplan Drijvende Bouwwerken [Zoning plan Floating Structures] (draft)	2018-03	Gemeente Amsterdam [Municipality of Amsterdam]	In general, it is a technical legal amendment to the Houseboat Clarification Regulations, which came into effect on January 1, 2018

Regulations on floating structures before 2014

In 2008, the Dutch Ministry of Spatial Planning and the Environment published a report on "***Drijvende woningen en de Bouwregelgeving-Handreiking voor ontwikkelaars, bouwers en gemeentelijke plantoetsers*** [Floating homes and the building regulations- Guide for developers, builders and municipal plan testers]." This document pointed out that several aspects of water living is not included in the current Dutch Building Decree 2012, such as stability, buoyancy, freeboard, acceptable resistance. It further explained on how the Dutch building regulations should be applied to floating homes It also addresses the topic if floating structures should be qualified as mobility or immobility. Here the connection to the shore or a mooring pile plays a large role. A tight connection and 'loose' connection (Figure 4.5) that make the difference. The shackle leads to a immobile qualification and the cables lead to a mobile. Due to its lack of technical details, the Dutch Standardisation Institution conducted an additional study and published the report of "***Nederlandse technische afspraak NTA 8111:2011 nl Drijvende bouwwerken*** [Dutch technical agreement NTA 8111: 2011 nl Floating structures]" in 2011. NTAs are guidelines that deal with the practical elaboration of a standard from the Buildings Decree. The document provides supplementary information and enables municipalities to examine whether new floating buildings comply with the standards in the Netherlands. Some key categories of how floating buildings have been considered is described in
Table 4.3.

Figure 4.4 Mooring with shackle and mooring with cables

Table 4.3 Key categories of how floating buildings could be regarded in the report of "Drijvende woningen en de Bouwregelgeving-Handreiking voor ontwikkelaars, bouwers en gemeentelijke plantoetsers (2009)"

Category	Structure	Immovable property	Movable property
Definition	According to the Raad van State [Council of State], if an object is anchored and fixed horizontally, but can move vertically, and it is meant to function and stay on the spot, it is considered to be "structure."	In 2007, the Raad van State [Council of State] decided that a warehouse on floating pontoons attached to the quay with steel cables and brackets was also considered to be a "floating structure." From the jurisprudence, the general conclusion is that a floating structure only should be considered an immovable property if it is intended to stay on the spot and anchored to the	As long as the floating building is fixed on *wires*, the general consensus is that it is a movable property. Moreover, according to Article 8 of the Burgerlijk Wetboek [Civil Code]: 1st paragraph, any structure that floats is considered a "ship."

		ground, and that it can be considered as one entity.	
Implications	This implies that Article 40 of the Woningwet [Housing Act] applies, therefore a building permit is needed.	This will automatically be an "immovable property" in legal terms and falls under Burgerlijk Wetboek [Civil Code] Article 3: 3rd paragraph: immovable property.	However, as soon as a houseboat is fixed with steel band or sliding brackets to a mooring pile, it could be considered a fixed connection anchored to the ground, for which the immovable rule applies.
Notes		• The status of whether it is movable or immovable will affect maintenance obligations, rental price, local taxes, transfer tax, sales tax and leasehold. • While some insurance companies or banks assume that floating house to be immovable properties, other insurance companies or mortgage givers might consider them to be mobile and will require them to be registered at the Ship Registry in addition to Land Registry (such as the example of Steigereiland IJburg). • This situation is not clear for potential buyers or developers. Naturally, the developers need to consult with the municipality in advance of the development. Especially if the municipality wants to offer space for houseboats (mobile properties) or immovable properties.	

New floating structures being regarded as building structures

While houseboats have long been a common sight with more than 10,000 of them in the Netherlands to date, recently a growing number of floating houses and even communities have been developed (e.g., Schoonschip in Amsterdam). However, it was not until 2014 that the state decided to amend the building regulations, taking into account floating structures.

On April 16, 2014, the Raad van State [Council of State] faced a case concerning a municipal permit for the renovation of an existing houseboat and investigated into current legislations and regulations that were relevant. This led to the creation of ***Wet verduidelijking voorschriften woonboten*** [Act Clarification Regulations on Houseboats] in 2018, and a proposed amendment to the ***Bouwbesluit 2012*** [Building Decree 2012] and ***Regeling Bouwbesluit 2012*** [Regulations Building Decree 2012]. The Raad van State [Council of State] ruled that a houseboat must be regarded as a building structure within the meaning of the Woningwet [Housing Act] and the Wabo [General Provisions Environmental Law Act]. On the basis of the ruling of the Council of State, floating objects must also be regarded as structures. This does not only apply for houseboats, but also to floating hotels, offices, restaurants and other floating objects that meet the description of a structure. This means that all houseboats and floating structures now need to meet building regulations which are included in the following:

- Woningwet [Housing Act]
- Wabo [General Provisions Environmental Law Act]
- Bouwbesluit 2012 [Building Decree 2012]
- Gemeentelijke Bouwverordening [Municipal Building Regulations]
- Gemeentelijk Bestemmingsplan [Municipal Zoning Plan]
- Gemeentelijke welstandsnota [Municipal Welfare Memorandum]

An environmental permit is required for building a floating structure or placing it at a specific location, with the intention to use (or let it be used) for a long time. This permit is granted by the municipality if the aforementioned building regulations are met as well as fitting into the zoning plan. Municipalities will include spatial rules for floating structures (if necessary) in their zoning plans and management regulations. The same environmental permit may be re-used if the floating structures have to be moved temporarily due to essential maintenance or dredging work on the waterway but returned to the original place. However, if a floating structure is permanently placed elsewhere in the water, an environmental permit for building is required again. In that case, there is the question of placing the building at that location. Depending on the requirements set by the municipality, the province or the water board, a new berth permit may also be required, for example with a view to the efficient use of berth capacity, public order and smooth and safe passage. This is separate from the environmental permit for building a structure. This is apparent, for example, from the judgments of the Administrative Jurisdiction Division of the Council of State.

In 2017, Wet verduidelijking voorschriften woonboten [Act on the Clarification of Regulations for Houseboats] was created with the purpose of amending Housing Act and General Provisions Environmental Law Act in order to make it clear on which rules apply to floating structures (Staatsblad 2017, 37). A distinction is made between sailing ships that are not structures and floating objects that are seen as (existing/new) structures. By amending Article 1 of the Housing Act, it has been clarified that a ship which is used for residence and that is intended and used for sailing navigation, is not seen as a structure within the meaning Housing Act and General Provisions Environmental Law Act. This Act therefore has no consequences for owners of these ships or for enforcement authorities. When the Act on the Clarification of Regulations for Houseboats has entered into force, there are two types of "new floating structures":

1. Floating structures that are newly built, such as new houseboats and water villas.
2. Floating objects that will become a new floating structure due to the change of function, for example a cargo ship that is now used as a houseboat.

With regard to the technical requirements for a floating structure that will be built after the entry into force of the Act, it will have to comply with the requirements set out in the Building Decree 2012. A floating structure that meets these technical requirements may be moved to another location without having to be renovated. The building may be placed elsewhere in the existing technical state, if the requirements are met in areas such as prosperity and spatial planning. This is likely to be the same case for Living@Sea should it be constructed near shore.

Amendment to the Building Decree 2012

The technical requirements of the Bouwbesluit 2012 [Building Decree 2012] only apply to the category of floating structures that are built after the Act comes into force, such as new houseboats, water villas, floating restaurants and hotel boats. Because in practice it has been found that the requirements of a number of building regulations are not always feasible for such floating structures, the Building Decree 2012 for these buildings has eased on a number of points such as safety, health and usability. In addition, provisions on structural safety are included in the Regeling Bouwbesluit 2012 [Regulations Building Decree 2012]. Changes in the Building Decree 2012 are as follows:

Energy efficiency at existing berths newly built floating structures can in principle meet the legal requirements for energy efficiency for new buildings. Problems can arise with new floating structures on existing berths. More flexible requirements apply to this category.

a) The Energy Performance Coefficient (EPC) for a new floating structure on an existing berth, the less severe minimum EPC of 0.8 applies instead of an EPC of 0.4. Achieving an EPC of 0.4 requires solar panels on the roof for new homes. On existing berth locations of floating structures (such as quays in inner cities) maximum building heights can apply and the view of solar panels is not always desirable.
b) Lower values for heat resistance apply to new floating structures on existing berth locations. In order to achieve the current higher requirements for heat resistance (RC values), thick layers of insulating material are required with current techniques. This can lead to spaces that are too small for existing berth locations. Furthermore, it has been decided to apply one RC value for the entire floating body of the floating structure (often a concrete box) and not to use different RC values for the part of the tank above and the part below the water level.

Safety, health and usability

Floating structures can in most cases not meet all the standard new building requirements of the Building Decree 2012. For example, the height, depth, length and width of the berths, which meet other demands from the spatial planning point of view than from the rules and regulations in the Building Decree. In the Building Decree 2012, therefore, floating structures are subject to fewer or more flexible requirements for safety, health and usability.

For floating structures, these lower requirements apply not only to homes, but also to other forms of use, such as floating shops. This means that for floating structures, a few usability requirements are not applicable (the bathroom, outside storage and outside space). The obligation to connect to the distribution network for electricity, gas and heat does not apply, neither. A connection on a voluntary basis is possible. For several safety regulations, more flexible requirements apply, namely those for existing buildings. This concerns the separation of stairs, ramps, bridging of height differences and stairs, as well as the dimensions of an escape route in a floating structure, health regulations (the daylight department) and usability regulations (the accommodation areas and living quarters, toilet space and stabling area). However, this is the case for floating structures in inland water bodies. For Living@Sea in the more open water, these requirements will need to be adjusted based on the offshore requirements.

Accessibility

For floating structures without an accessibility sector, such as a houseboat, no requirements are imposed on a ramp, reachability and accessibility. New floating structures with an accessibility sector, such as a floating restaurant, theatre or shop, must meet the requirements set by the Building Decree 2012 on reachability and accessibility. For the reachability of buildings with an accessibility sector, a jetty can now also be regarded as an accessible route between the entrance of a building and the public road.

For Living@Sea, it would be advisable to try to meet the accessibility requirements on the floating platform. This would mainly be applied to the connections between the islands, making it possible for disabled and elderly to cross safely. Here the standards for floating buildings on inland waters could be applied, that allow to occasionally (with high tide differences for example) to deviate from the regular maximum ramp for accessibility.

Escape route

The jetty between the floating structure and the shore may be regarded as a connecting area. This makes it possible to have an escape route on a jetty. Without this possibility, an escape route at a floating structure would have to end up on shore. Especially when replacing houseboats on existing berths, this could lead to practical problems. A municipality can determine the positions of the floating structures in relation to each other and the dimensions of the jetty in the zoning plan in new berths and water pits in such a way that they can safely escape the jetty in the event of a fire.

In the case of Space@Sea, dedicated platforms would need to be seen as safety compartments / islands, that would serve as safe place to escape to during fire. Here measures would need to be taken, such as a certain distance to the other platform, fire resistant walls or the possibility for decocting so that a fire would not be able to cross over.

Plot boundaries at a berth

The Building Decree 2012 applies to the regulations for fire resistance, daylight and ventilation, and plot boundary. Most floating structures are not on a plot but occupy a berth. So, there is no plot boundary. In this case, the Building Decree 2012 offers the possibility to start from the assumption that the plot boundary is situated 2.5 meters from the floating structure, regardless of whether this is the case. If there is a plot, you can keep the actual distance to the plot boundary.

Living@Sea is of a larger scale housing development. Multiple houses will be built on large floating platforms which occupy water plots. These platforms will be connected to one another by bridges and other connections. The regulations from current Building Decree will have to be reassessed and amended for the application.

Constructive safety

The amended Building Decree 2012 states that additional requirements for structural safety can be imposed for floating structures in the Regulations Building Decree2012. These additional requirements are set out in the Regulations Building Decree 2012 that applies from 1 January 2018. These requirements relate to the stability, buoyancy and strength of a floating structure. In compiling these requirements and the determination methods, the NTA 8111 has been aligned with which the constructive safety of floating structures has been calculated so far. Further information about these requirements can be found in the report 'Constructive safety floating structures'. Nevertheless, such information again focuses on single floating house rather than building complex on large floating platforms as Living@Sea. This document can be used as a reference to further explore the constructive safety of large-scale floating structures.

Spatial quality

With the entry into force of the Act on the clarification of houseboats and the amendment of the Building Decree 2012 for floating structures, national building regulations will now apply to houseboats and other floating objects that are mainly used for accommodation. They are considered as floating structures. Consequently, applications for an environmental permit for placing a floating structure at a certain location must, among other things, comply with the municipal zoning plan and the municipal welfare memorandum. In it, municipal requirements for berths and the appearance of the houseboats can be included. The Spatial Quality Federation has drawn up the 'A deck is no roof' guideline with recommendations for spatial quality criteria on the water, which could be used as a reference document which could be used if the floating island will be placed close to an existing city or other build up environments. On the other hand, when being placed in a large waterbody surrounded by only water, doesn't have any spatial quality reference yet, only water.

4.3 Different scales of legal systems and financial implications

On a broader scope, various issues are touched upon in the development of a floating city at different scales (Figure 4.5). It is vital to have an overview on this as the design, construction and operation of the floating city are regularised through certain regulations, standards and codes such as environmental regulations, zoning plans, etc.. On the international scale, it is important to see how a large-scale floating city as urban expansion of a coastal city (i.e., host by a nation) can be defined legally. Can it be treated as land (i.e., artificial island), so that building regulations from urban (land-based) development can be applied? Will there be a legal problem to develop a floating city as urban expansion of a coastal city within the territorial water of a host nation, if permitted by the authorities of the coastal state? How can a floating city be defined legally outside of the territorial water but within a country's EEZ? What would the legal consequences be? Answers to these questions are important as they are related to not only the administrative law (e.g., construction license and registration), but also fiscal law (e.g., changes, adaptations or exemptions by the tax authorities) and private law (e.g., mortgage issues). The legal definition of a floating city will affect the rights that residents could have on the floating platforms.

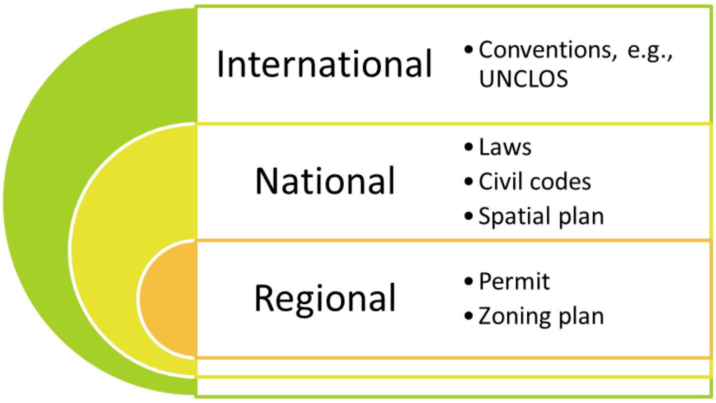

Figure 4.5 Legal status of floating cities at different scales

Spatial planning for floating city development

It is essential and rather helpful for the implementation of floating city as urban extension if floating can be on the spatial agenda of a country. Take the Netherlands as an example, in the urban context, the national government, provinces and municipalities make a structural vision together for infrastructure and space in the Netherlands. Municipalities then further develop it into regional zoning plan (Figure 4.6).

Figure 4.6 Example of spatial planning for urban development in the Netherlands

In the maritime context, a coastal state receives a directive from the European Parliament and Council of the European Union, in this case the Directive 2014/89/EU Maritime Spatial Planning. According to Lisbon Treaty Article 288, a directive shall be binding, as to the result to be achieved, upon each Member State to which it is addressed, but shall leave to the national authorities the choice of form and methods. In 2010, the National Water Plan, also a strategic framework based on the Dutch Spatial Planning Act, replaced certain policy sections of the National Spatial Strategy, including the spatial plan for the North Sea. This National Water Plan was updated in 2015 and approved on 12th December 2015 by the Cabinet of the Netherlands. It includes the North Sea Policy Document 2016 – 2021 that summarizes the Netherlands long term vision (2050) and incorporates a maritime spatial plan which complies with the new EU Directive on Maritime Spatial Planning (Directive 2014/89/EU of July 2014) (Figure 4.7)[4].

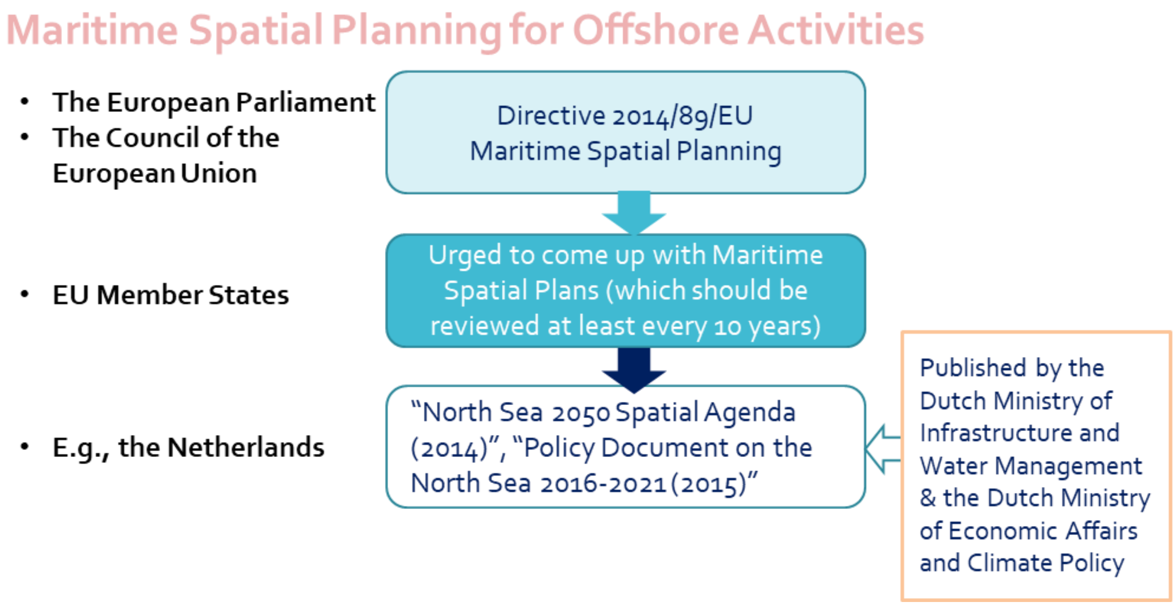

Figure 4.7 Example of maritime spatial planning for offshore activities in the Netherlands

[4] MSP.IOC-UNESCO. Retrieved in May, 2019

Keeping in mind the responsible international organisations and governmental agencies for national and regional spatial planning, the procedure of putting floating development on spatial planning agenda could look like in Figure 4.8. It is important to know that according to Lisbon Treaty Article 188, to exercise the Union's competences, the institutions shall adopt regulations, directives, decisions, recommendations and opinions. Recommendations and opinions shall have no binding force to the Member States. They could be used as suggestions to Member States to take into account living at sea in their national spatial strategies.

Figure 4.8 Spatial planning assumption for floating urban development

Financial implications of building regulations

Floating city development in many ways resemble to urban land and real estate development. Table 4.1 shows the preliminary comparison between costs and revenue components among these two different types of development.

Table 4.4 A preliminary comparison of costs and revenue between land-based urban development and floating city development

	Urban Land and Real Estate Development	Living@Sea Floating City development
Component		
Substructure	Land	Platforms
Superstructure	Buildings (dwellings, apartment buildings, office/warehouses, shopping centers, retail, etc.), public works (infrastructure, public buildings, public services, other assets and facilities)	Buildings (dwellings, apartment buildings, office/warehouses, shopping centers, retail, etc.), public works (infrastructure, public buildings, public services, other assets and facilities)
Costs		
Substructure	**Undeveloped land*:** - Acquisition of (undeveloped) land - Preparing land for housing [Woonrijp maken], e.g., raising/levelling a site, (temporary) construction roads, utility network (water supply, sewage, electricity) installation, permanent roads, bicycle paths, squares, sidewalks, quays, bridges, public playgrounds/sport facilities/art, street lighting, landscape and street furniture, etc. - Plan costs (e.g., for preparation, supervision, advice and studies on e.g., soil quality, traffic and archaeology) **developed land requires additional costs for demolition of structures decontamination of soil*	- Plan costs (e.g., for preparation, supervision, advice and studies on e.g., soil quality, traffic and archaeology) - Designs & engineering - Permit application & inspection - Construction of platforms & transport - Assembly, installation & mooring - Preparing platforms for housing [Woonrijp maken], e.g., roads, utility network (water supply, sewage, electricity) installation, bicycle paths, squares, sidewalks, bridges, public playgrounds/sport facilities/art, street lighting, landscape and street furniture, etc.
Superstructure	Finances arrangement (e.g., mortgage), Plans/designs & engineering, Permit application & inspections, Insurance (during construction and after, for e.g., fire and theft), Site preparation, Construction, Building materials, and Final inspection	Finances arrangement (e.g., mortgage), Plans/designs & engineering, Permit application & inspections, Insurance (during construction and after, for e.g., fire and theft), Site preparation, Construction, Building materials, and Final inspection
Revenue		
Substructure	**Options:** - Sale of the land to private real estate developers, housing associations, or private individuals - Issuing the land under ground lease	**Options:** - Sale of the platform plot to private real estate developers, housing associations or private individuals - Issuing the platform under "ground lease"
Superstructure	**Options:** - Sale of the buildings - Lease	**Options:** - Sale of the buildings - Lease

When buying a house on land, house owners tend to ask the banks for a mortgage so that banks pay for the house, owner of the house pays back to the bank over the years and with interest. However, to obtain this mortgage, banks usually would request that the floating houses are insured. This poses a new market for insurance companies: insurance for floating houses.

National interests (State insurance): NMG (national mortgage protection). In the Netherlands, it is possible for a house buyer to opt to take out a mortgage that includes the Dutch National Mortgage Guarantee (NHG). This means that the mortgage is guaranteed by the Stichting Waarborgfonds Eigen Woningen [Dutch Homeownership Guarantee Fund] so that the risk and interest rate will both be lower.

However, how a floating building is defined (whether immovable or movable) also influences the mortgage one could get. Some banks offer a ship mortgage, and interest rates tend to be higher (yet the term is longer) than those of a normal mortgage. Banks and tax authorities both make their own assessment of whether a loan for a floating house passes for a normal house mortgage or not. The tax authorities may accept the deductibility of interest of a loan that is considered as ship mortgage by a bank and vice versa.

Most mortgages consist of two parts: the part with the plot as collateral, and the part of the ship mortgage for the floating house itself. The result of this is that the floating homes are registered twice in the Land Registry: the plot as immovable property, and the house as movable property (in the ship registry; to do this, the concrete foundation was marked during construction, as is common in shipbuilding).

Moreover, there are questions with “insurance”. Currently there is no regulatory party that will ensure the interests of people who are not working/ moving/ transporting, but actually living. Questions as the following still need to be answered, e.g.,:

- How to deal with different property insurances such as fire insurance, home/land insurance (homeowner’s insurance?
- Is it possible to have shared insurance? How about ownership? Is it possible to share the ownership of a floating platform? E.g., homeowner’s association (VVE) HOA “condominium”, ”common hold” as on land.
- Can risks to financial asset value be insured if classification is in place?
- How to include the risks of the consequences?
- What risks are there for different stakeholders from floating city development? Can communities share risks together? How can we socialize their risks? (e.g., by the whole Dutch nations)
- Can we introduce shared responsibility for a shared platform?
- What is the probability for people to sell their floating houses if the views have changed in a timeframe of 10 years and that a nice view is no longer guaranteed?
- What is the probability that the floating platform will sink? Can this will be ensured by the classification society?

Consequences of treating floating homes as movable properties in the Netherlands

The security right [zekerheidsrecht] of floating homes needs to be established. According to Art. 3:227 BW, there can only be a pledge on movable property. This is only different if the movable property is a registered property as a ship in the Ship Registry (Art. 8:790 BW). During this registration, the establishment of a mortgage on the house is possible as this is not the same as the establishment of a mortgage on a property. Immovable property is verified by the ownership of the land (Art. 3: 3, j ° art. 5:20 paragraph 1). This is a mortgage on the land and established under Art. 3: 227 paragraph 2 BW includes the mortgage law is thus permanently united buildings and works. If the underlying water parcel also owned by the owner of the floating home, a right of mortgage shall be established, and a separate right of mortgage will be established on the floating home. The difference between mortgage and charge can be seen in Figure 4.9.

The right of emphyteusis, or ground rent/lease, is not an option. There is no possibility of a right of easement or a building rights on a movable property. A movable thing can also be established on the basis of Art. 5:106 of the Dutch Civil Code, which cannot be split into apartment rights.

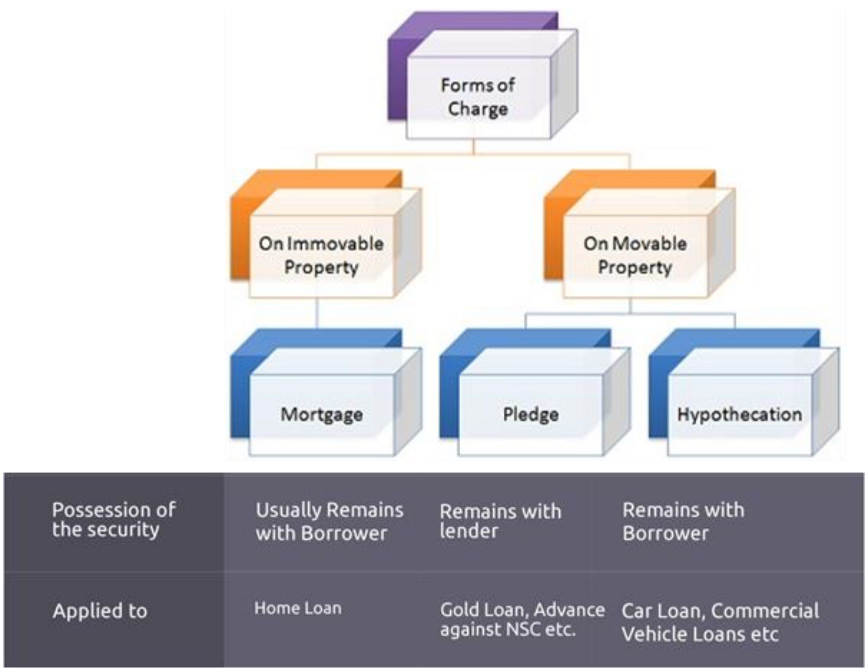

Figure 4.9 Difference between mortgage and charge (adapted from Surbhi S, retrieved in May 2019)

Ownership and registry of floating buildings

According to the Dutch regulation (Art 5.3), it is not possible to divide the ownership of any movable object. The owner of a property should be the owner of all its components. However, if the movable property can be registered in the Dutch land registration, it will then be regarded as an immovable property. In this case, it becomes possible for one to have part of the building (Van der Plank, 2016).

The challenge is that when it comes to a floating neighbourhood, there are roads, bridges and public space, which makes the ownership complicated and difficult to have public space. For instance, if one has one platform with four buildings, it is all legally-binded. If one wants to treat it as land, one would need to register the whole platform. However, currently the Land Registry does not look at land (i.e., platform) over land (i.e., seabed). To be able to do this, it will require a totally different view on how we see land, which requires researches into the consequences that makes it possible. Van der Plank is currently looking into different solutions.

Moreover, Van der Plank has been working on a proposal of amendment in Book 5: rights on land, which aims to introduce a small chapter that treats floating platform as immovable object. Article 3 in Book 3, which holds immovable object will also need to be adjusted. Moreover, Van der Plank would like to introduce change of Article 106 of Book 5 to adjust apartment rights. However, what remains to be found out is "*the best way to have a floating platform registered.*" In fact, when a vessel is registered at the Ship Registry, then it is not a movable object. For the security rights, it is easier to finance a ship that is registered.

3D cadastral registration

If the structure is very complicated, one would have all different land uses. What is sometimes done for land-based development is to make a 3D drawing of all the rights in these land uses (and with notarial acts). It is possible then to register the 3D drawing. However, to make the whole 3D land registration system, it will take a lot of time, money and resources. Consequently, it will not happen. At the moment, the Dutch government does not find it so interesting to do it. If the Netherlands manages to have all water parcels registered, we can see what is floating and where.

Having floating structures outside of territorial sea will change the whole legal structure. For banks this is scary, because as soon as they move, banks will lose their entitlement to this platform.

Solutions to give floating cities a legal form

According to van der Plank (2015), in terms of property law, three major steps need being taken in order to give floating cities a legal form (Figure 4.10):

1. Give a floating platform an "immovable legal entity". The legal law amendment process might take 1.5 years

2. When floating platforms will be qualified as an immovable object, on the one hand, you can divide it into apartment rights and make floating platforms as land. But when it comes to involving public space, 1 &2 will be used together. The amendment will focus on the consequences of 1. & 2. They will be one step and can take up to 2 years

3. To make a floating platform equivalent to land. This might take 5-10 years.

a) For this to happen, firstly, the Dutch land registration needs to be changed entirely. As it will be land (i.e., platform) above land, a way to survey water areas and to be able to register these platforms will need to be set up. If this becomes possible, it will expand the Netherlands and other countries a great deal. Currently in the Netherlands, it is only possible to register per single floating building unit. Moreover, rules on the kind of people that can build and introduce the platforms need to be established.
b) We will also need to think about the consequences that we will have. For instance, for the building rights, regulations assume that they will always be there. Assuming that the floating platforms will be built using concrete, and such structures are likely to last 50-100 years, what will happen afterwards? Change of the building rights and other consequences after this period will arise. There are legal, political and practical questions that need being investigated and answered.
c) Solution to register a floating platform on water
    a. If we do not introduce 3D land registry, we will need to think of an alternative solution.
    b. If we do, at least for the water parcels, we will need to research and ask cadastral registration on what it will look like, and how it will work in real life.

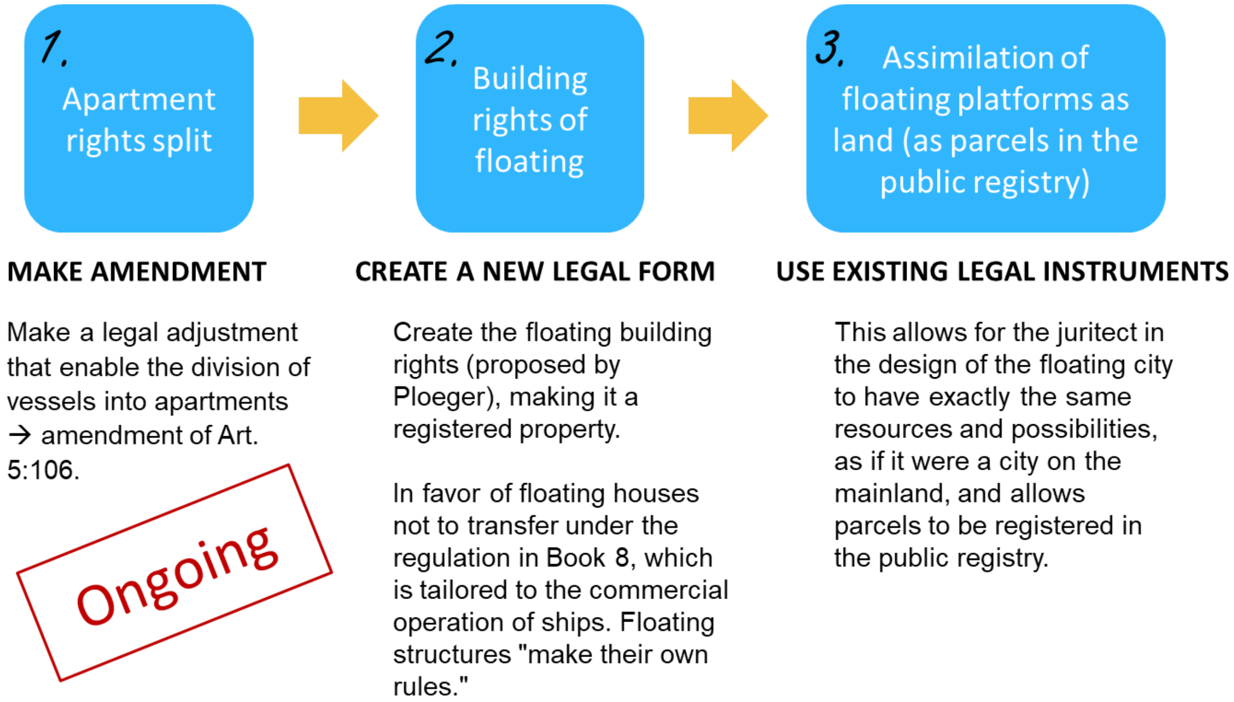

Figure 4.10 Three steps need being taken to give floating cities a legal form (source: based on article of Van der Plank, 2015)

Law amendment on apartment rights

Law amendment can contribute to solving the problem of floating apartment rights. Van der Plank will continue to work on this in summer of 2019, finish it in September and send it to Den Haag in the same year. The evaluation procedure of this will take least 1.5 years, depending on the priority of Den Haag. Current momentum and international attention on floating urban development might help accelerate the procedure. If creating platforms that assimilate to land is possible, it will be a huge step. The Netherlands will be able to expand in such a huge way, for example. A lot of researches will need being done then we can see what consequences there will be.

5. Safety

In order to provide the other work packages in the Space@Sea research with the relevant technical requirements for designing the part for Living@Sea, safety and comfort have been studied based on the offshore and shipping industry. In Appendix 2, key organisations and institutes that are commonly engaged in setting technical requirements are elaborately described. In Appendix 4 a long list, an inventory of rules, regulations and standards which have all been used for creating the chapters on safety and comfort is shown. This chapter focuses on the safety requirements that could be used for the floating city, with an emphasis on fire safety.

5.1 General safety

Most of the oil and gas production in Europe take place offshore and is currently installed in European waters (see example of Figure 5.1). Based on this and considering the accidents (some of them even disasters) that occurred during their lifetime, there is a need for mandatory safety measures for offshore operation.

Therefore, according to the Directive on Safety of Offshore Oil and Gas Operations (2013/30/EU), the EU (European Union) has put in place a set of rules to help prevent accidents, as well as responded promptly and efficiently should one occur.

Figure 5.1 Offshore oil platform (source: Petro-online, retrieved in April, 2019)

Not all the safety standards from oil production are applicable. The following require additional attention because of the presence of the floating islands on the sea. The ones that can apply to floating islands, are the followings:

- Providing a report on Major Hazards for the system. The company (platform owner) that is involved in the operation of the platform, is obliged to identify and assess these hazards before the structure will be installed. The report needs to contain a risk assessment and emergency response plan.

- Technical solutions which are critical for the safety of operators' installations must be independently verified.
- Platform owners are fully liable for environmental damages caused to protected marine species and natural habitats.

5.2 Identification of hazards

A hazard is defined as a potential source of harm. The potential harm may relate to loss of life, or damage to health, the environment or assets or a combination of these. Risk is the combination of the probability of occurrence of harm and the severity of that harm[5].

The main hazard for offshore units (which extract, process and stock hydrocarbons) is the presence and handling of liquid and gaseous hydrocarbons which can generate explosions followed by fire. The main hazard contributors for cruise ships (passengers ships) are stability related (the large height narrow width ratio), based on accident frequency statistics. Both of them are not so relevant for the floating island, because of the absence hydrocarbon manipulation or like with the cruise ships.

Hazard identification is usually a qualitative exercise based primarily on expert judgement. Often the HAZID (HAZard IDentification) methodology is used to identify the hazards and risks and the possible means of eliminating and controlling these (Figure 5.2). This is a high-level, systematic study of the hazards, used for early identification of hazards and is typically made at the conceptual project phase and carried out to the detailed design stage.

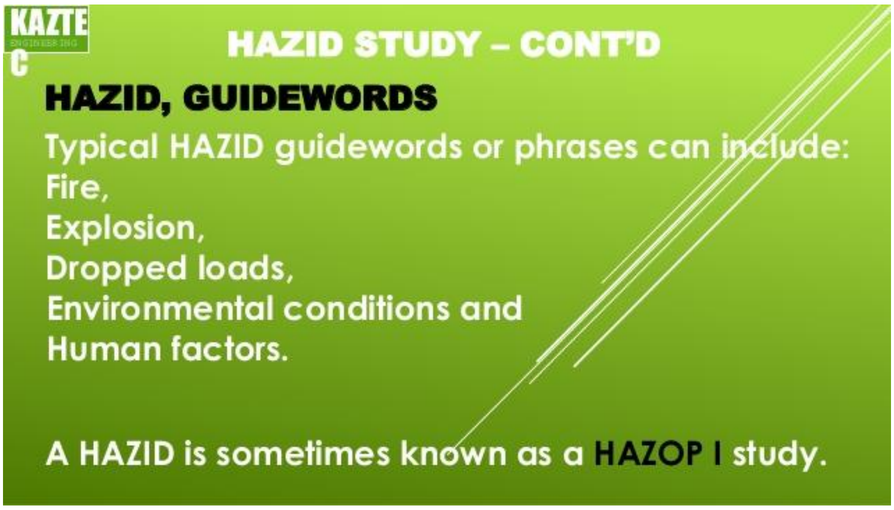

Figure 5.2 HAZID study example

The HAZID approach was also used to identify the potential hazards for the floating islands. The offshore and shipping industry served as input and inspiration. The HAZID study started out with identifying in which stage the of the life span of the floating islands the hazards can occur. Here it was decided to focus on the operation and maintenance phase. It is assumed that Work Package 5, handling the topic of installation, will focus on installation and manufacturing. Afterwards the system, subsystem, and component on which the hazard relates to. The qualification of the hazard within the risk register, the cause of the hazard, the name of the hazard, a detailed description, the typology of the hazard and the consequent it will have.

Examples of causes of hazards events (established by a HAZID) are the following:

- Fire/explosion;
- (Ship) collision

[5] NORSOK Z-013 standard: "Risk and emergency preparedness assessment"

- Loss of power generation;
- Extreme weather or other environmental conditions;
- Assault by terrorism/pirates;

These events can lead to hazards like:

- Structure failure → sinking / capsizing
- Mooring failure → drifting / collision
- Uncontrolled motions, tilt,
- Grounding
- Dropping objects
- Helicopter accidents

A more elaborate overview on all expected the Hazards will be presented in the deliverable of WP2. Appendix 6 shows the summary (work in progress) of this workshops held for the purpose of WP2.

Safety functions

Safety functions are physical measures which reduce the probability of a situation of hazard and accident, or which limit the consequences of an accident. The main safety functions are:

- Temporary refuge, usually in accommodation spaces (safe place to muster whilst the extent of the hazardous situation is being assessed, safety zone around the islands, where only the piloted ships are);
- Evacuation means (lifeboats in principal);
- Main load bearing structure;
- Prevention of escalation for each fire and explosion barrier;
- Escape routes.

For seagoing vessels (not offshore) the approach is similar, except the total risk picture is more relaxed than that on offshore; in fact, the main associated hazard of fire and explosion is referring only to a cellulosic fire (less dangerous than a hydrocarbon one), which is not always the result or followed by explosions.

In case of offshore living spaces (placed on living islands – Space@Sea) because there is no process with hydrocarbons, the only hazards which can exist are the possible occupational accidents, non-process fires, structural failure (quite rarely), collisions with ships and extreme weather. Similar to cruise ships, the number of inhabitants that may not have high training levels might complicate the evacuation in case of emergencies.

5.3 Fire safety

In the offshore industry a large emphasis lies on the fire safety measures. The starting point for fire safety is the awareness of the hazards by the people on board and the adaptation of the correct behaviours and procedures. Building owners and occupiers must carry out a fire safety risk assessment and keep it up to date. It shares the same approach as a *health and safety risk assessments* HAZID system and can be carried out either as part of an overall risk assessment or as a separate exercise. Based on the findings of the assessment, it is needed to ensure that appropriate fire safety measures are in place to minimize the risk of injury or loss of life in the event of a fire. To help prevent the occurrence and development of fire, the risk assessment should identify what could cause a fire to start, i.e. sources of ignition (heat or sparks) and substances that burn, and the people who may be at risk. Once risks are identified, appropriate action to control them can be taken. It needs to be considered whether fire can be avoided or, if this is not possible, how you can reduce the risks and manage them.

Measures to protect people if there is a fire are the followings:

- Carry out a fire safety risk assessment, review and update it when is necessary;
- Keep sources of ignition and flammable substances apart;
- Avoid accidental fires;
- Ensure all times good housekeeping of the devices which can became source of ignition;
- Consider how to detect fires and how to warn people quickly if they start (installing smoke alarms and fire alarms or bells);

- Have the correct fire-fighting equipment for putting out a fire quickly;
- Keep fire exits and escape routes, clearly marked and unobstructed, at all the times;
- Ensure that all persons involved receive appropriate training on procedures they need to follow, including fire drills.

It is recognized that human lives, property and the environment should be given the top priority during a ship fire. The human lives are always the highest priority to protect on board, not only concerning units/ships fire incidents but also other incidents such as grounding and collision. The environment protection comes in second place due to the growing consciousness of protecting environment. Protecting the property (unit/ship) is the third priority. Figure 5.3 shows the consequences of a hydrocarbon fire for an oil platform.

Figure 5.3 Consequences of a hydrocarbon fire (source: Toulouscope, retrieved in April, 2019)

5.4 Fire qualification

A fire on an offshore unit can be cellulosic type or hydrocarbon. A Cellulosic is a fire with a fuel source predominantly of cellulose (e.g. timber, paper, cotton). A fire involving these materials is relatively slow growing, although its intensity may ultimately reach or exceed that of a hydrocarbon fire. A fire fuelled by hydrocarbon compounds, has a high flame temperature achieved almost instantaneously after ignition. A hydrocarbon fire will spread rapidly, burn fiercely and produce a high heat flux.[6] Figure 5.4 shows the consequences of a hydrocarbon fire.

A cellulosic fire reaches 500°C (932°F) within 5 minutes and rises to 945°C (1733°F) over time. Hydrocarbon fire or pool fire, has a high flame temperature to 1000°C (1832°F) within 5 minutes, achieved almost instantaneously after ignition. The heat rises to 1100°C (2012°F) shortly thereafter. A number of test protocols have been

[6] http://www.iadclexicon.org/cellulosic-fire/

established that specify "standard" time/temperature relationships designed to simulate the different types of fire which are shown in heating curves (Figure 5.5).

Also, based on their source and placement, fires on offshore unit/ship can be of type:

- Electrical fires;
- Accommodation fires;
- Heating system fires;
- Machinery fires;
- Workshop fires.

Figure 5.4 Hydrocarbon fire example (source: Stam, retrieved in April 2019 from [VanDam])

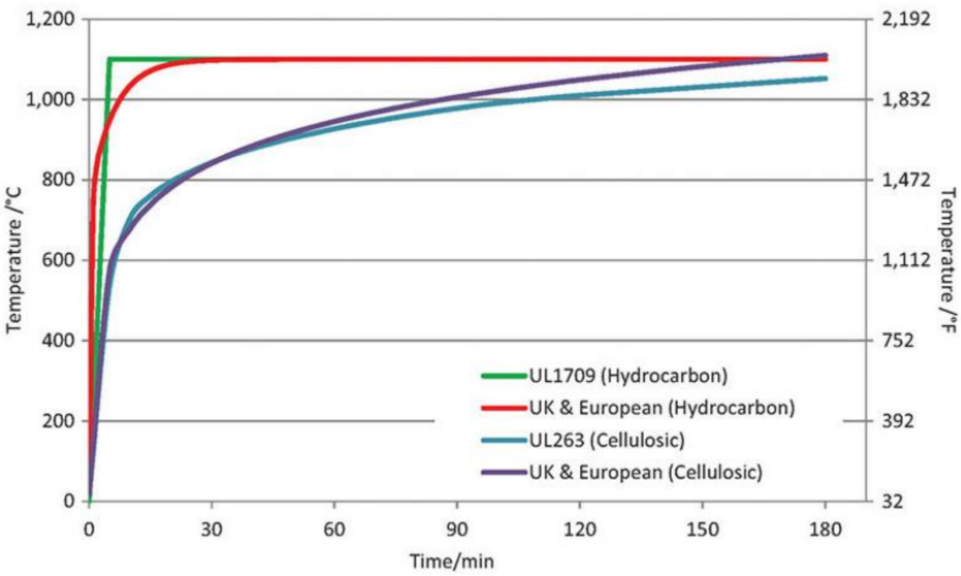

Figure 5.5 Heating curves (source: Williams & Williams, retrieved in May2019 from [Society of Petroleum Engineers])

5.5 Fire protection and management

Fire protective products are divided into two categories of fire protection and based on the fire curves. Cellulosic fire protection materials are tested using protocols, such as UL 263, BS 476-20, and EN 13381. The most common hydrocarbon fire is the pool fire, resulting from the ignition of spilled cargo under normal ambient conditions. The heating regimes used to test fire protection materials designed for hydrocarbon pool fires are set out in BS 476-20 and UL 1709, among others.[7]

Products that provide protection against cellulosic fire receive a fire rating of “A”, “B” and “F”. Products rated according to the hydrocarbon fire curve receive the fire rating “H” or “J”. “J” ratings are based on the extreme hydrocarbon jet fire. Fire integrity is the basic fire-resisting ability of a product to remain intact during a specified period. For cellulosic fire protective products, the fire integrity must be 30 minutes for “B” fire rated products and 60 minutes for “A” fire rated products. For hydrocarbon fire protective products are different. “H” fire rated products need to have a fire integrity of 120 minutes.

A similar approach can be found from the urban perspective where building components and constructions are classified according to their fire resistance. These result in performance criteria followed by a time limit from 15, 30, 45, 60, 90, 120, 180, 240, to 360 minutes. Requirements like load bearing capacity, insulation, integrity etc. are used to measure the performances.

A list of fire-fighting systems and equipment that are usually used on board of (oil & gas) offshore units which can serve as an example for the floating islands, is shown in Appendix 3. Some of the systems and equipment (e.g., fire doors, fire dampers, hydrants, hose and nozzles, extinguishers, fire outfits) will be mandatory found in the living and working areas of the floating islands.

Fire Safety both for ongoing ships and offshore units is governed by the requirements and prescriptions contained in international rules and regulations, a list of these is shown in Appendix 5.

5.6 Conclusion

To provide sufficient safety on the floating island, it is recommended to find out the potential hazards first, using the Hazard Identification methodology (HAZID). After identifying the hazards, adequate solutions to them should be included in the safety management. To be noted that the largest hazard identified for offshore operations is fire. Although the probability of fires expected on the Living@Sea islands is kept low, impact from the fire will be higher as more people will be affected. Therefore, it is of paramount importance to keep the following fire safety objectives in mind:

1. Prevent the occurrence of fire and explosion;
2. Reduce the risk to life caused by fire;
3. Reduce the risk of damage caused by fire to the offshore unit/ship, its cargo and the environment;
4. Contain, control and suppress fire and explosion in the compartment of origin; and
5. Provide adequate and readily accessible means of escape for passengers and crew'

ln order to achieve the fire safety objectives set out above, the following functional requirements are embodied in the regulations of this chapter as appropriate:

1. Division of the floating island into fire compartments with thermal and structural boundaries;
2. Separation of accommodation spaces from fire hazardous spaces
3. Restricted use of combustible materials;
4. Detection of any fire in the zone of origin;
5. Containment and extinction of any fire in the space of origin;
6. Protection of means of escape and access for firefighting;
7. Ready availability of fire-extinguishing appliances; and
8. Minimization of possibility of ignition of flammable cargo vapour.

[7] Rapid Rise Hydrocarbon Fires – An Engineering Perspective Roger Williams, Sherwin-Williams | 21 January 2013 https://www.spe.org/en/print-article/?art=397

6. Human comfort

One of the most important considerations when designing a building is the extent to which it provides an environment that is comfortable for its occupants. Comfort in the built environment is affected by a great number of different factors which can, if not addressed properly, lead to poor levels of comfort, discomfort, or can even cause harm and ill health to its occupants.

Aspects of comfort (Figure 6.1) include:

- Personal factors;
- Health and wellbeing;
- Thermal Comfort;
- Indoor Air Quality;
- Visual comfort;
- Noise Nuisance;
- Ergonomics.

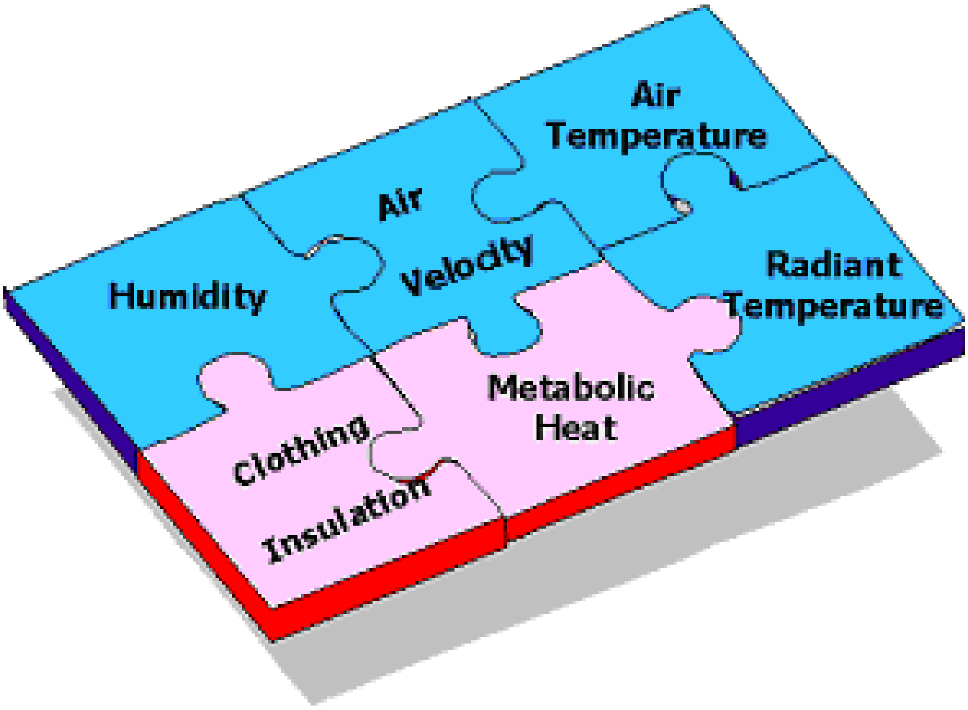

Figure 6.1 Comfort aspects

Personal factors that can affect how comfort in a building is perceived include:

- Age;
- Gender;
- Level of health;
- Clothing;
- Type of activity and level of intensity;
- Access to food and drink;
- Acclimatization;
- Psychological state.

Comfort contributes highly to the feeling of wellbeing, that could be defined as "when individuals have the psychological, social and physical resources they need to meet a particular psychological, social and/or physical challenge". The basic criteria considered in assessing the comfort in dwellings on the floating islands can be summarised as follows:

- The available space (dimensions) and the interior configuration of the dwelling to be provided;
- The level of illumination (natural and artificial);
- Drinking water and sanitary (cold and hot);
- Heating, ventilation and air conditioning (HVAC);
- Electricity/other energy sources;
- Noise and vibration level;
- Protection and safety systems;
- Alarm systems;
- Sound and thermal insulation for the dwellings;
- Facilities for people with disabilities.

Whereas above mentioned comfort requirements are quite general for residences, the more specific factors applying to floating structures are mainly: stability (tilt) and movements. This chapter will address human factors, and in particular the ones that are typically related to floating structures. the buoyancy, stability and acceleration.

Regarding crew habitability and human comfort in general, guidelines from the 7.1 DNVGL-OS-A301 "Human Comfort" (Offshore Standard), and 7.2. ABS Guide for Crew Habitability on Offshore Installations can be used as design references. However, the preference is to use the standards from urban development as much as possible as it is the aim of Space@Sea to keep the living conditions as close to urban conditions as possible.

6.1 Buoyancy and stability

Floating islands follow the physics of floating objects. Any floating object must abide by two criteria:

1. Buoyancy: the ability to float
2. Stability: the ability to resist external and internal moments

Buoyancy or floatability is the ability of a floating object to support a given weight (W), by means of the hydrostatic pressure acting on the underwater surfaces, giving rise to the buoyancy force (B) (Figure 6.2). The buoyancy force is equal to the weight of the fluid (water) that is displaced by the floating object. Because the floating islands are made by separate modules interconnected to each other, it is necessary that every module is calculated and designed as to have the same(ideally) or very similar drafts and freeboards. Else, it is not possible to have a functional communication between the modules (the modules decks will have different heights above the waterline), and this will induce huge loads in the connection structure.

6.2 Hydrostatic stability

The first major point in assessing the hydrostatic and stability of the module is defining the floating body type according to the international rules and regulations.

As per the International Code on Intact Stability 2008 (ISC 2008), the module falls closely under category *Pontoon*, which is described in the aforementioned code as follows:

1. non-self-propelled;
2. unmanned;
3. carrying only deck cargo;
4. having a block coefficient of 0.9 or greater;
5. having a breadth/depth ratio of greater than 3; and
6. having no hatchways in the deck except small manholes closed with gasketed covers.

Also, DNVGL notes the following differences between barges and pontoons:

Class notation	*Description*	*Qualifier*	*Additional description*	*Design requirements, rule reference*
Barge	Barges are vessels without sufficient means of self-propulsion for transit. Assistance from another vessel during transit or transportation service is assumed. [1]	<none>		Sec.1 to Sec.5
		Hopper [3]	Barge primarily designed for self-unloading where the port and starboard portions are hinged at the hopper end bulkheads to facilitate rotation around the longitudinal axis when the bottom opens	Sec.1 to Sec.5
Pontoon	Vessels without cargo hold and no means of self-propulsion for transit.	<none>	Vessel specifically intended for carriage of cargo on deck only	Sec.1 to Sec.5

1) Guidance note: For vessels with limited means of self-propulsion an upper limit for barges/pontoons may normally be taken as machinery output giving a maximum speed less than $V = 3 + L/50$ knots, L not to be taken greater than 200 m.

2) Barge made of concrete will be assigned the class notation: **Barge(Concrete)**. The survey related class notation **BIS** is mandatory and requirements given in Pt.6 Ch.9 Sec.1 shall be complied with.

3) **Hopper** is an optional qualifier for barges built for dredging operations, i.e. **Barge(Hopper)**.

Therefore, it is considered that the module shall be categorised as a **pontoon**.

The second important point to be considered is the applicability of the hydrostatic and stability regulations.

The most obvious aspect is the transit of the module from its construction site to the site of installation (island location).

Considering a pontoon, for transit, only intact stability requirements are applicable for this ship type, damage stability requirements are not mandatory.

The other aspect is when the modules are on site and comprises the island. In this case, intact stability should not pose any issues due to the large scale of the floating body (island) in all directions. Damage stability on the other hand could pose a problem for exterior modules that could suffer collisions and sustain inflow of water. When a damage occurs to any of the exterior modules the following risk are identified:

1. Change in the position of equilibrium of the damaged module (possible sinking)
2. Loss of power if electrical equipment/components is damaged
3. Additional strain in the connectors between the damaged module and adjacent modules (possible breaking off)
4. Risk to human life on the damaged module inhabitants. Measures to counteract this is of paramount importance and thus damage mitigation measures and/or adequate lifesaving appliances should be easily accessible.

Hydrostatic stability is the ability of the floating body to return to a state of equilibrium (preferably upright) in still water when disturbed by external (wind and waves) or internal factors (weight shifting) influences. Ship stability is an area of naval architecture and ship design that deals with how a ship behaves at sea, both in still water and in waves, whether intact or damaged. Stability calculations focus on centres of gravity, centres of buoyancy, the metacentres of vessels, and on how these interact.

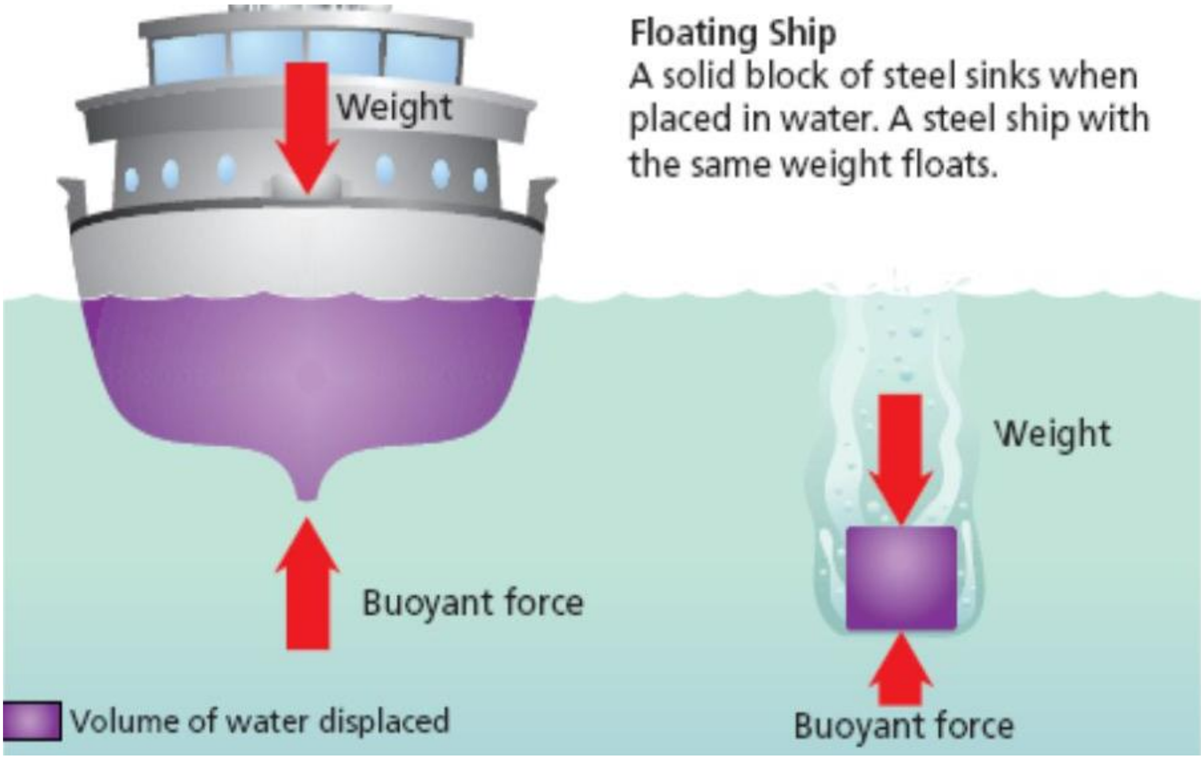

Figure 6.2 Floating body buoyancy

Stability terminology

- Centre of buoyancy (B): The centroid of the displaced volume of fluid.
- Centre of gravity (G): The centroid of the weight.
- Metacentre (M): Whenever a body, floating in a liquid, is given a small angular displacement, it starts oscillating about some point. The point, about which the body starts oscillating, is called metacentre.
- Metacentric height (GM): The distance between the centre of gravity of a ship and its metacentre.

The stability for a floating object is generally split into intact stability and damage stability.

Intact stability

Intact stability deals with the stability of a hull when maintaining intactness (no compartment breach/damage or internal flooding). A brief presentation of the intact stability theory is shown below.

The fundamental concept behind the understanding of intact stability of a floating body is that of equilibrium. There are three types of equilibrium conditions that can occur, for a floating body, depending on the relation between the positions of centre of gravity and centre of buoyancy.

1. Stable equilibrium is achieved when the vertical position of G is lower than the position of transverse metacentre (M) (Figure 6.3). So, when the body heels to an angle, the centre of buoyancy (B) now shifts to B1. The lateral distance or (lever between the weight and buoyancy in this condition results in a moment that brings the body back to its original upright position.

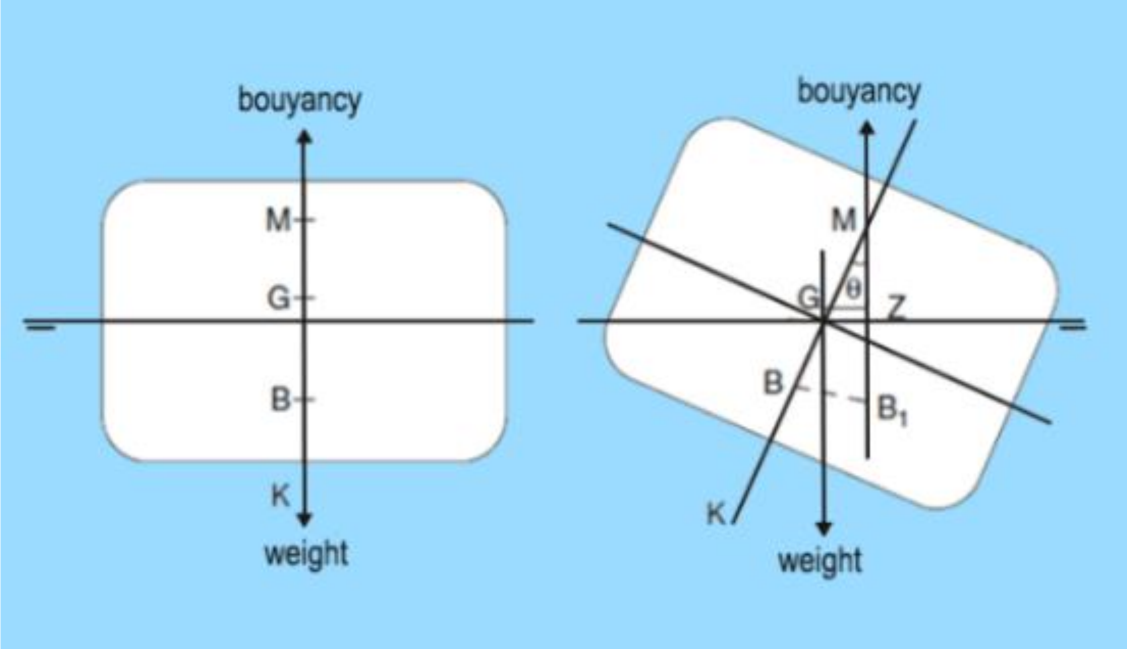

Figure 6.3 Stable equilibrium

2. Neutral equilibrium is the most dangerous situation possible for any floating body, and all precautions must be taken to avoid it (Figure 6.4). It occurs when the vertical position of G coincides with the transverse metacentre (M). As shown in the figure below, in such a condition, no righting lever is generated at any angle of heel. As a result, any heeling moment would not give rise to a righting moment, and the body would remain in the heeled position, if neutral stability prevails. The risk here is, at larger angle of heel in a neutrally stable shift, an unwanted weight shifts might give rise to a condition of unstable equilibrium.

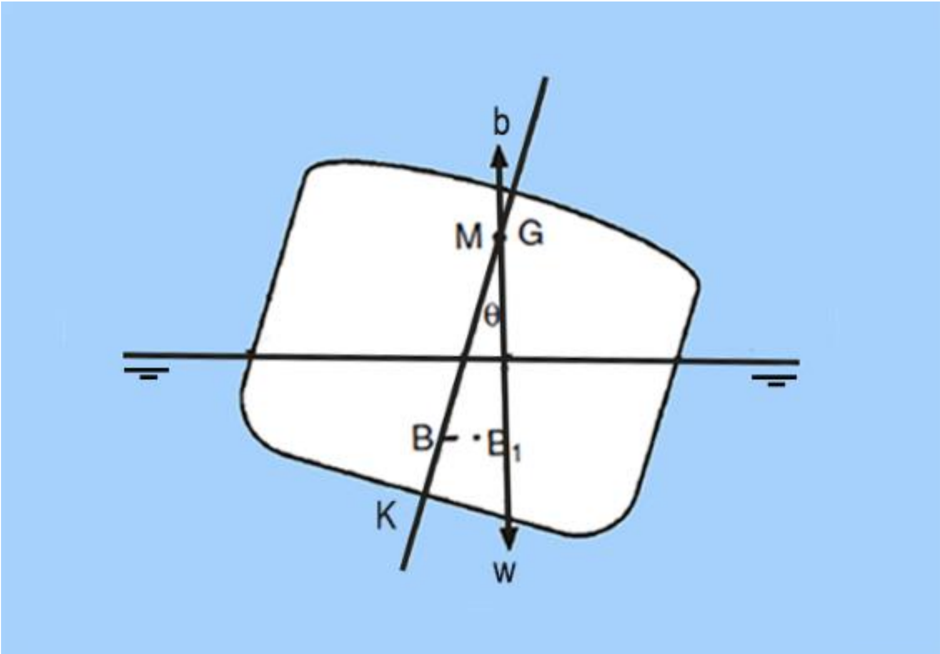

Figure 6.4 Neutral equilibrium

3. Unstable equilibrium is caused when the vertical position of G is higher than the position of transverse metacentre (M) (Figure 6.5). So, when the body heels to an angle, the centre of buoyancy (B) now shifts to B1. But the righting lever is now negative, or in other words, the moment created would result in creating further heel until a condition of stable equilibrium is reached. For ships, if the condition of stable equilibrium is not reached the ship is said to capsize.

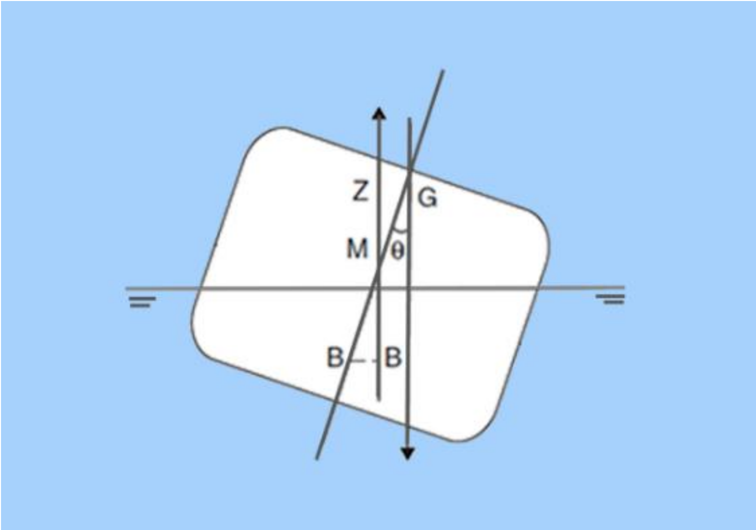

Figure 6.5 Unstable equilibrium

Longitudinal shifts in weights on-board, or any longitudinal trimming moment (a moment that would cause the body to trim), are aspects that are discussed under longitudinal stability.

Figure 6.6 shows the effect of shift of a weight towards the aft of the body, resulting in a trim by the stern. The centre of gravity (G) now shifts aft to a new position (G1), which causes the trimming moment. The body now trims by aft, which means more volume of the hull is submerged at the aft, and part of the submerged volume towards the forward now emerges. This causes a shift in the centre of buoyancy towards the aft (from ‘B’ to ‘B1’). The equilibrium trim angle is reached when the final centre of gravity (G1) lies in line with final centre of buoyancy (B1).

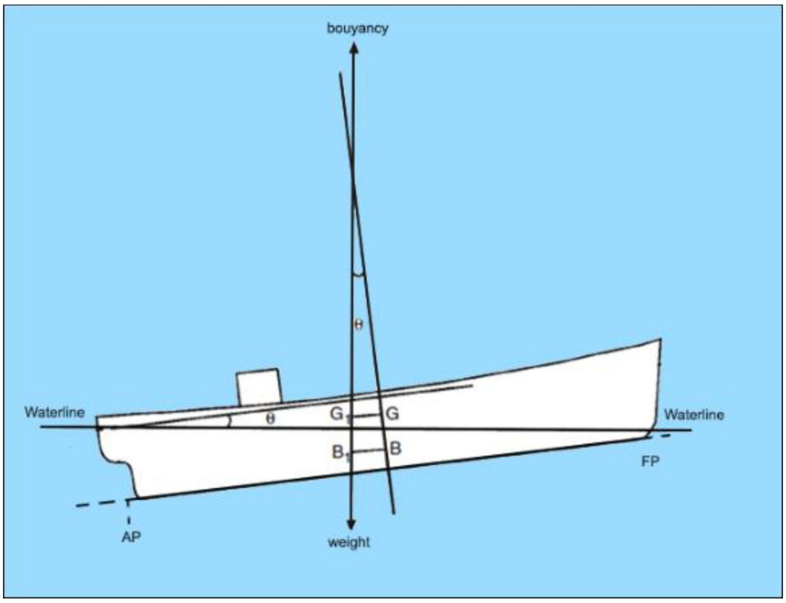

Figure 6.6 Longitudinal stability

Intact Stability Criteria

Based on classification authorities and international regulatory bodies prescriptions, all intact stability criteria of a floating unit and for the specified loading conditions (in each mode of operation) need to be met.

With respect to stability criteria of a vessel in intact state, the requirements of International Code on Intact Stability, 2008 (2008 IS Code) together with IMO MODU Code and MARPOL 73/78 Annex I, Regulation 27 are applicable.

The International Convention on Load Lines (ICLL) gives requirements for the freeboard and openings (down flooding angles) as pertaining to the stability assessment.

Both IS Code and MARPOL 73/78 Annex I, Regulation 27, have the same requirements in terms of intact stability:

- Criteria regarding righting lever curve properties;
- Severe wind and rolling criterion (weather criterion).

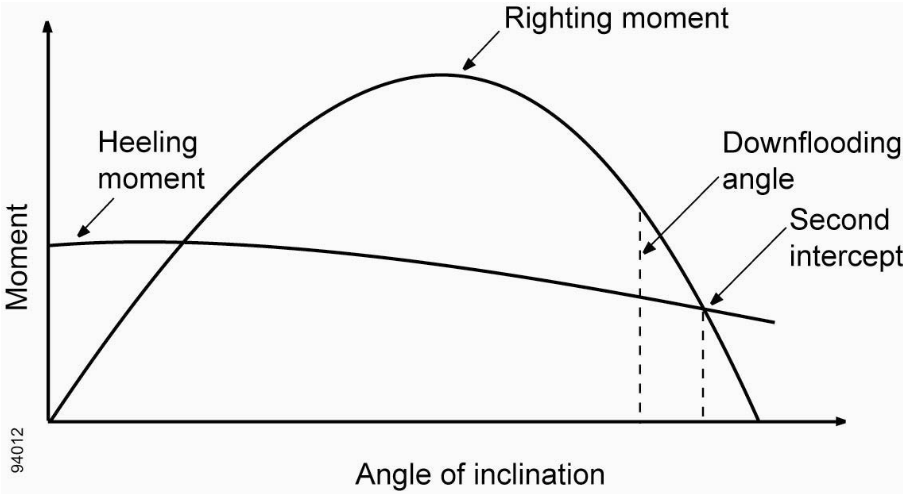

Figure 6.7 Intact stability criteria components

Additionally, according to IMO MODU Code each loading condition should meet the following criteria (see Figure 6.7):

- For surface units the area under the righting moment curve to the second intercept or down flooding angle, whichever is less, should be not less than 40% more than the area under the wind heeling moment curve to the same limiting angle.
- The righting moment curve should be positive over the entire range of angles from upright to the second intercept.

In fact, intact stability evaluation means that loading condition(s) must comply with the intact stability criteria (critical KG[8] curves).

The stability calculations are performed by means of calculating KG limiting curves for intact stability requirements. The calculations are according to classification authorities and international regulatory body prescriptions.

6.3 Damage stability

Another type of stability is the damage stability (see curve example in Figure 6.8).

The definition of damage stability is ship's capability to maintain a stable floating position after a damage. Damage can be caused by; collision (with other ship, structure, iceberg), grounding, blast or enemy action (in case of

[8] KG- vertical centre of gravity

warships). For floating islands, collision is the highest threat. The outcome of such a damage would be the change of draught, trim and heel of the object. To survive after damage, the floating object must be subdivided into several watertight compartments. The study for damage stability of a surface ship includes the identification of compartments or tanks that are subjected to damage and flooded by sea water, followed by a prediction of resulting trim and draft conditions. Damage stability calculations are much more complicated than intact stability. Software utilizing numerical methods are typically employed because the areas and volumes can quickly become tedious and long to compute using other methods.

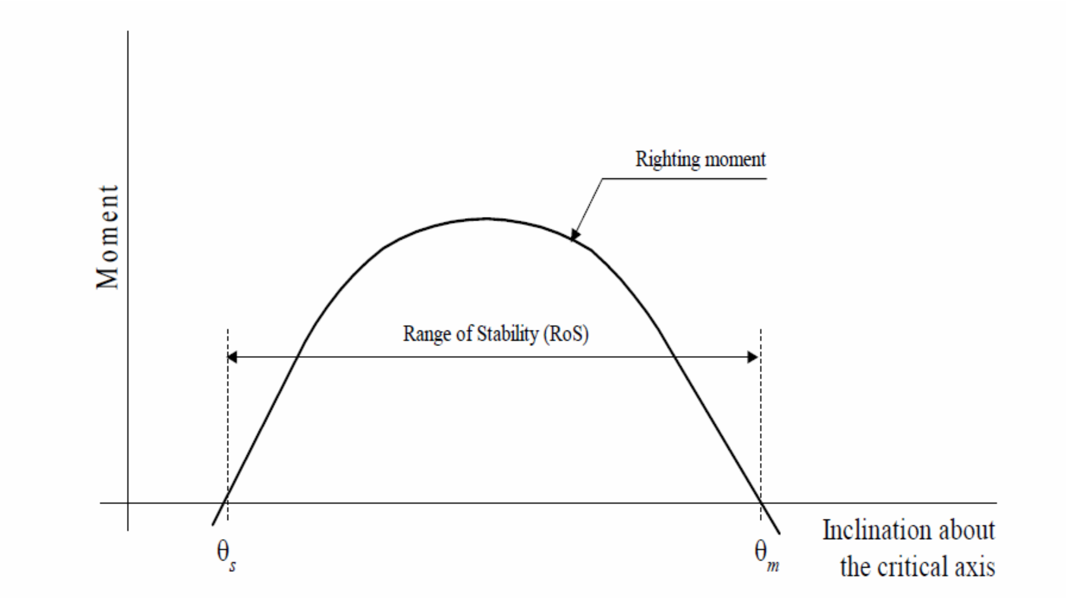

Figure 6.8 Damage stability curve example

The damage stability calculations are developed based on loading conditions within the Intact Stability Evaluation in all damage case assumed by the rules and confirmed to be satisfied the requirement of said rules. The floating unit should have enough freeboard and be subdivided by means of watertight decks and bulkheads to provide enough buoyancy and stability to withstand in general, the flooding of anyone/several compartment(s) in any condition consistent with the damage assumptions. Damage stability rules and damage stability research aims to reduce the risk of damage and to minimize the consequences. Because of damage, the ship will lose a part of the buoyancy, but the biggest risk is the loss of stability. An increasing heel and/or trim may produce a rapid capsize.

The floating islands (platforms) dedicated for living although are not ship shaped, are still floating bodies, having similar dimensions (transverse and longitudinal). Therefore stability (both intact and damage) is of paramount importance (especially for individual modules) also considering their behaviour in site specific Metocean conditions.

6.4 Applicable regulations

The applicable regulations for both intact stability and damage stability are as follows.

Intact stability regulations

- IMO 2008 IS Code presents mandatory and recommendatory stability criteria for and other measures for ensuring the safe operation of ships.
- MARPOL 73/78 Annex I Regulation 27
- MARPOL Annex I details the discharge requirements for the prevention of pollution by oil and oily materials; Regulation 27 is for Intact Stability.
- IMO MODU Code
- The Chapter 3 of the IMO MODU Code is dedicated to subdivision, stability and freeboard.

- DNV GL - Stability and Watertight Integrity

  This offshore standard provides principles, technical requirements and guidance related to stability, watertight integrity, freeboard and weathertight closing appliances for mobile offshore units and floating offshore installations.

  The objectives of this standard are to:

  1. provide an internationally acceptable standard of safety by defining minimum requirements for stability, watertight integrity, freeboard and weathertight closing appliances;
  2. serve as a contractual reference document between suppliers and purchasers;
  3. serve as a guideline for designers, suppliers, purchasers and regulators;
  4. specify procedures and requirements for units or installations subject to DNV certification and classification.

Damage stability regulations

- MARPOL 73/78 – The International Convention for the Prevention of Pollution from Ships, Annex I Regulation 28
- IS Code – Intact Stability Code
- The revised and renamed Intact Stability Code (IS Code) - 2008 consists of two different parts: Part A which include the mandatory stability criteria; and Part B which provides guidance and recommendations.
- Technical Regulation on the stability and buoyancy of house-boats and floating structures (Danish Maritime Regulations).
- Netherlands Regulatory Framework – Maritime 456 Guidelines for the preparation of intact stability information.
- NMA - Regulations of 20 December 1991 No. 878 on stability, watertight subdivision and watertight/weathertight means of closure on mobile offshore units.

6.5 Acceleration and vibration

Ship or floating body motions are shown in Figure 6.9. Transversal accelerations (Roll motions), are closely related to stability such that GM values are inverse proportional to the roll period. This means a very stable ship, also called a “stiff” ship, has a very small roll period as it tends to quickly return to its equilibrium position. On the contrary, a “tender” ship has very low GM values and long roll periods. The sweet spot between these two conditions must be found to give the floating body enough safety against capsizing while also providing motion comfort for its crew/inhabitants. There is no preferred state between the two. The idea is, as stated, to find an equilibrium, not “stiff” nor “tender” as each of these extreme states gives disadvantages: one regarding safety (“tender”) and one regarding comfort (“stiff”).

The general formula that relates the roll period to stability is: $T_{roll}\,[s] = \frac{2\pi k}{\sqrt{gGM}}$; where:

k = roll radius of gyration [m];

g = acceleration due to gravity [m/s2];

GM = metacentric height [m];

Pitch, Yaw, Surge, Sway and Heave motions are mainly related to the ship’s length and block coefficient, and generally the longer and fuller (high block coefficient) the vessel the lower the accelerations for these motions.

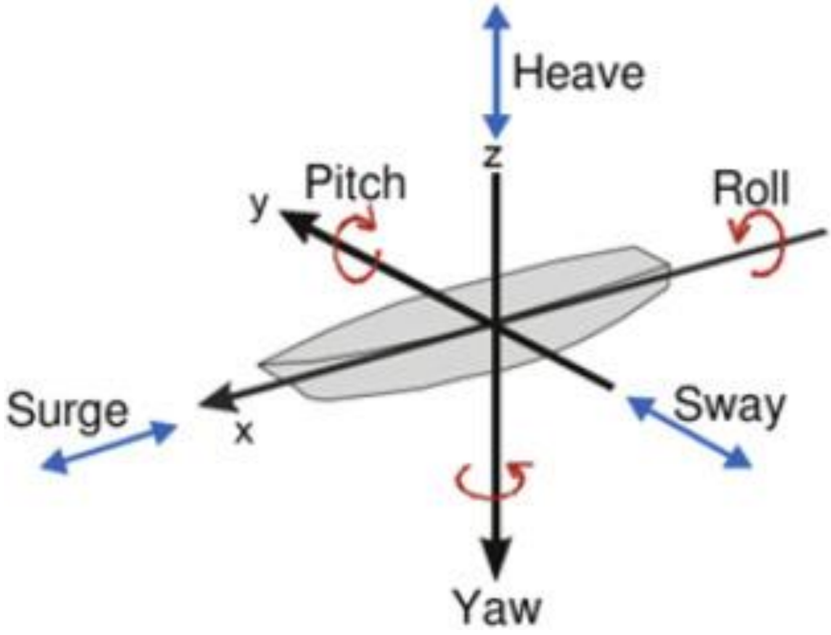

Figure 6.9 Floating body motions

Many structures - and in particular those that are floating – have a dynamic behaviour that is perceived by people on or inside them. Behaviour with low frequencies or long periods are perceived as “motions” while behaviour at higher frequencies is noted as “vibration”. Human perception however is quite different to motions and vibrations. Motions with frequencies from 0.1 to 1 Hz, and in particular at frequencies around 0.2 Hz, are likely to cause disorientation, nausea and result in motion- or seasickness. The sensitivity is illustrated by typical weighing factors as in Figure 6.10 ISO 2631-1997.

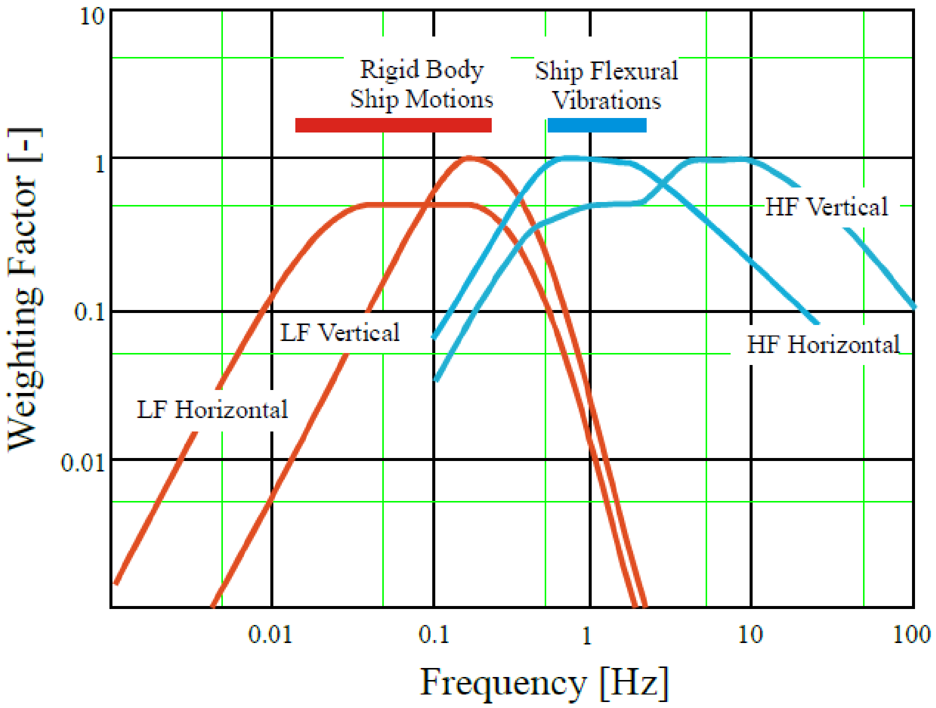

Figure 6.10 Human sensitivity to accelerations (red for motion, blue for vibrations) (source: Dallinga & Bos, 2010)

ISO has developed standards for both the vibration part and the motion dynamics. The latter are often referred to as whole body vibrations. They are typically caused by motions of the global structure. That could be a (high rise) building, a bus or train, or a floating structure. More classic vibrations are often caused by rotating equipment. Relevant standards are:

ISO 2631–1	Mechanical vibration and shock -- Evaluation of human exposure to whole-body vibration -- Part 1: General requirements
ISO 2631-2:2003	Mechanical vibration and shock -- Evaluation of human exposure to whole-body vibration -- Part 2: Vibration in buildings (1 Hz to 80 Hz)
ISO 2631-4:2001	Mechanical vibration and shock -- Evaluation of human exposure to whole-body vibration -- Part 4: Guidelines for the evaluation of the effects of vibration and rotational motion on passenger and crew comfort in fixed-guideway transport systems
ISO 2631-5:2018	Mechanical vibration and shock -- Evaluation of human exposure to whole-body vibration -- Part 5: Method for evaluation of vibration containing multiple shocks

Note that standard 2631 applies in general on human response to vibration. Specific aspects of vibrations in maritime applications are referred to by standards 6954 (older) and 20283 (replacing the previous)

ISO 6954:2000	Mechanical vibration -- Guidelines for the measurement, reporting and evaluation of vibration regarding habitability on passenger and merchant ships
ISO 20283-2:2008	Mechanical vibration -- Measurement of vibration on ships -- Part 2: Measurement of structural vibration
ISO 20283-4:2012	Mechanical vibration -- Measurement of vibration on ships -- Part 4: Measurement and evaluation of vibration of the ship propulsion machinery
ISO 20283-5:2016	Mechanical vibration -- Measurement of vibration on ships -- Part 5: Guidelines for measurement, evaluation and reporting of vibration with regard to habitability on passenger and merchant ships

Vibrations can have a continuous nature, but can also be a mix of a continuous level with sometimes shocks or jerks. The perception of nuisance due to the various vibration/motion effects is nontrivial. Attempts have been made to define specific indicators for various characteristic behaviour. In particular for the lower frequencies this is a not fully developed field of expertise. Some examples of parameters are listed as follows:

Root mean square (RMS) value	mean vibration level typically 1-100 Hz bandwidth
Crest factor	relation of max peak value in comparison to mean level
MTVV	Maximum transient vibration value -> indicative for shock
Vibration dose value (VDV)	Statistical value related to shock
MSI	Motion Sickness Index based on acceleration levels
MSDV	Motion sickness dose value based on low frequency vibrations
IR & CR	Illness and comfort ratings

In general, there are minimal limits in place to safeguard the health, safety and integrity of people and equipment. For maritime applications that has mostly been from occupational point of view. Quite a lot of parameters were defined and are available to quantify the actual behaviour of a structure. But the actual human impact of that behaviour however is less well-defined. It also depends on factors as age, gender, fitness, fatigue and accustomisation.

Fairly clear criteria are available for classic vibration related phenomena. Clear procedures to measure, report and interpret vibrations are available. Classifying results is done based on the location that is reviewed, and the comfort that is requested. Different weighing is done for working areas, recreational, sleeping, dining areas, for crew and passengers etc.

Motion sickness related aspects have been less well represented since crews tend to get accustomed to motion levels. With the rise of cruise shipping there is a need to quantify performance with respect to motion related (dis)comfort. Both for design purposes, as for contract evaluations. The paper "Dallinga & Bos, Cruise ship sea keeping and passenger comfort - 2010" reviews some of the various options with respect to comfort.

According to literature, aspects to consider that have the largest influence on motions are:

- Vertical accelerations
- Wave frequencies

Vertical acceleration limits and wave frequency ranges will be given for each urban function/activity in a floating development. Ranges are determined based on literature (see References).[9]

The acceleration limits from Table 6.1 are considered. The overview is based on Mendis (2007) and Norforsk (1987).

Table 6.1 Human perception levels different functions/activities in a floating development

a RMS (m/s^2)	**Effects**	**Example**
<0.05	People do not perceive motions	Typical house
<0.10	- Sensitive people may perceive motions - hanging objects may show motions	Up in a skyscraper
<0.20	- Motions may affect desk work - Majority of people perceive motions - Similar to cruise liner operability criteria (Norforsk, 1987)	Skyscraper in a storm. Airplane cruising
<0.40	- Desk work becomes difficult - Walking normal is still possible. - Most standing people keep balance - Long-term exposure may cause motion sickness.	Train/metro ride
<0.50	- People strongly perceive motion - Difficult to walk naturally - Standing people may lose balance. - May produce motion sickness	Bus ride, Airplane with light turbulence.
<0.60	- Most people cannot tolerate the motion - Most people unable to walk naturally. - May well produce motion sickness	Train/metro turning or stopping. Airplane with turbulence.
<0.85	- People cannot walk or tolerate motion - Likely to produce motion sickness	
>0.85	Objects begin to fall - people may be injured. - Likely to produce motion sickness	Bus near bus stop, Airplane with heavy turbulence, or landing

[9] An overview of studies that relate RMS acceleration and discomfort, with 2-line summaries summary of each study by March (1998).

Based on the information from Table 6.1, an overview of acceleration limits is compiled for different urban functions (Table 6.2).

Table 6.2 An overview of acceleration limits for different urban functions (source: Deltasync)

	Return period				
a RMS (m/s²)	**Residential**	**Office/retail**	**Streets**	**Park, gardens, outdoor functions**	**Cultural/ leisure**
0.05< a RMS <0.1	**1:1-yr**	**1:1-yr**	**1:1-yr**		**1:1-yr**
0.1< a RMS <0.2	**1:10-yr**	**1:10-yr**	**1:10-yr**		**1:10-yr**
0.2< a RMS <0.4	**1:100-yr**	**1:100-yr**	**1:100-yr**	**1:1-yr**	**1:100-yr**
0.4< a RMS <0.5	**1:1,000-yr**	**1:1,000-yr**	**1:1,000-yr**	**1:10-yr**	**1:1,000-yr**
0.5< a RMS <0.6				**1:100-yr**	
0.6< a RMS <0.85				**1:1,000-yr**	
>0.85 m/s²	**1:10,000-yr**	**1:10,000-yr**	**1:10,000-yr**	**1:10,000-yr**	**1:10,000-yr**

The limits for residential, office and leisure functions were set at lower accelerations. Open space can have higher accelerations. For gardens, parks and other outdoor recreational functions it was set that in a 1:1-year event, which is extremely common and will occur with 100% likelihood any given year, people will perceive motions but will still be able to walk (see Table 6.1). In comparison, the same acceleration limit was set for a 1:100-year event for residential and office functions. In buildings it is more important that people don't perceive motions and that objects are not falling. In gardens and other outdoor functions, the limit is higher, since people are not expected to go to the park or to do outdoor sport in bad weather conditions. For streets, lower limits are set compared to parks and outdoor functions. This is done since the motions for streets should enable safe movement of people/vehicles even during bad weather conditions. In a 1:100-yr event people are still able to walk on street.

6.6 Critical wave frequencies

According to DNV-GL[10], motion sickness is occurring more frequently with frequencies around 0.18-0.25 Hz. Figure 6.11 shows the amount of time that average people can be exposed to certain wave conditions before 10% would develop motion sickness. The graph below shows that with accelerations of 0.4 m/s² and frequencies of around 0.18 Hz, the time 10% people get sick is 8 hours. With lower or higher frequencies if takes longer before 10% of people get sick. It was mentioned that in a 1:100-year storm, the acceleration limit for residential is 0.4 m/s². This means that, in this type of event, which has 1% chance to occur in 1 year, a few people might start feeling sick when the storm lasts over 8 hours. Such storms are statistically rare but could happen. Frequencies between 1 and 0.05 Hz refer to ordinary gravity waves (see Figure 6.12).

[10] DNVGL RU-SHIP (2017), Part 6 Additional class notations, Chapter 3 Navigation, manoeuvring and position keeping.

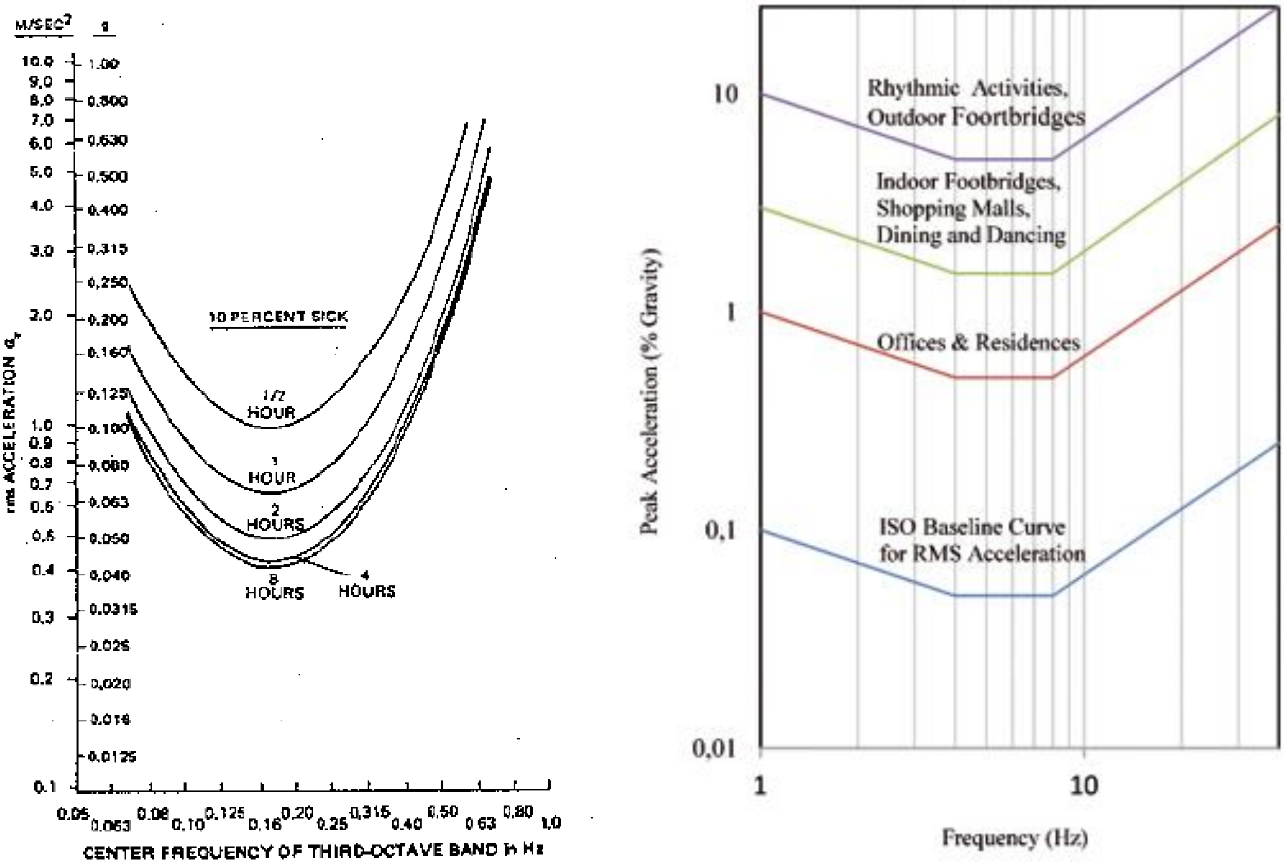

Figure 6.11 The 90% motion sickness protection limits for human exposure to very low frequency vibration (ASTM F1166-94) (left), and evaluation of human exposure to whole-body vibration. Part 2: Continuous and shock-induced vibration in buildings (1-80 Hz) (right) (source: March & Palo, 1998; ISO 2631-2, 1989)

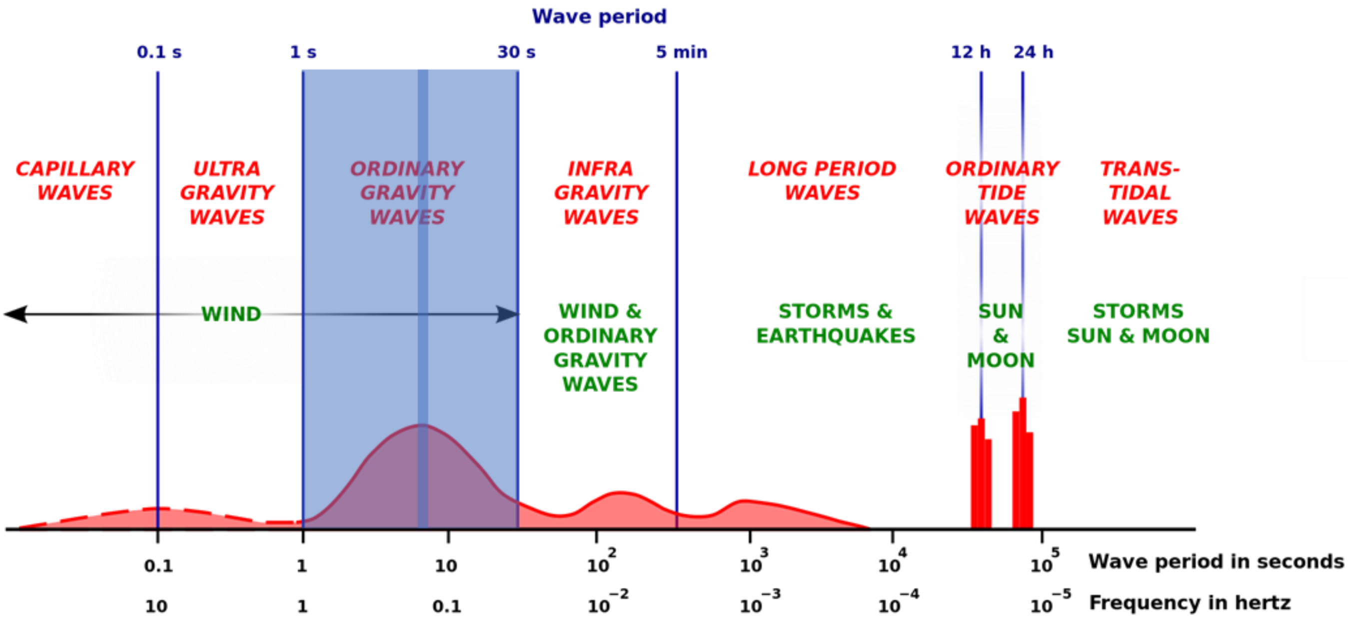

Figure 6.12 Classification of the spectrum of ocean waves according to wave period (source: Munk, 1951)

Overall Acceleration	Consequence
$a_w < 0.315\ m/s^2$	Not uncomfortable
$0.315 < a_w < 0.63\ m/s^2$	A little uncomfortable
$0.5 < a_w < 1\ m/s^2$	Fairy uncomfortable
$0.8 < a_w < 1.6\ m/s^2$	Uncomfortable
$1.25 < a_w < 2.5\ m/s^2$	Very uncomfortable
$a_w > 2.5\ m/s^2$	Extremely uncomfortable

Figure 6.13 Evaluation of human exposure to whole-body vibration. (source: ISO 2631-2, 1989; ISO 2631-1 STANDARD, 1985)

General Operability Limiting Criteria for Ships (NORDFORSK, 1987)			
Description	Merchant ships	Naval vessels	Fast small craft
RMS of vertical acceleration at F.P.P.	0.275 g ($L \leq 100$ m) 0.050 g ($L \geq 330$ m)	0.275 g	0.65 g
RMS of vertical acceleration at bridge	0.15 g	0.20 g	0.275 g
RMS of lateral acceleration at bridge	0.12 g	0.10 g	0.10 g
RMS of roll	6.0 deg	4.0 deg	4.0 deg
Probability on slamming	0.03 ($L \leq 100$ m) 0.01 ($L \geq 300$ m)	0.03	0.03
Probability on deck wetness	0.05	0.05	0.05

Criteria for Accelerations and Roll (NORDFORSK, 1987)			
Description	RMS vertical acceleration	RMS lateral acceleration	RMS roll
Light manual work	0.20 g	0.10 g	6.0 deg
Heavy manual work	0.15 g	0.07 g	4.0 deg
Intellectual work	0.10 g	0.05 g	3.0 deg
Transit passengers	0.05 g	0.04 g	2.5 deg
Cruise liner	0.02 g	0.03 g	2.0 deg

Figure 6.14 General operability limiting criteria for ships (retrieved from Faltinsen, 1990)

NB: those limits are higher, e.g. 0.1 g for intellectual work is 1 m/s² in our overview, which is very high. Objects begin to fall and people may be injured. It is likely to produce motion sickness. Cruise liner limit is 0.02 g (motions may affect desk work; majority of people perceive motions).

6.7 Space@Sea considerations

It can be concluded that for the Space@Sea design, the following considerations regarding buoyancy and stability are of paramount importance.

1. Aspects of buoyancy that must be carefully considered regarding:

- Individual module (stacked or not) buoyancy regarding draft and freeboard while being towed to or from the site.
- Final draft of modules when connected should be within acceptable limits to one another as to minimize high forces in the connection and to facilitate access between modules.
- For the integrated platform, design of each module should try to avoid as much as possible use of ballast (solid or liquid) to bring module edges at the same height. Ballasting (liquid) would probably be necessary while connecting modules together.
- Buoyancy of modules shall be, within acceptable limits, future proof regarding addition or removal of weights.

2. Intact stability regulations shall apply while towing the modules to and from the site, and should consider the following:

- If topsides are built together with the modules in the construction site, wind profile during transit shall be carefully considered regarding stability calculations and possible limits on height of topsides shall be imposed. On a side note, air draft could pose problems regarding actual limitations on the route (e.g. bridges).
- Intact stability should not pose problems for the final integrated platform due to the large final size (island).

3. Damage stability regulations in transit are not applicable for pontoons (which the modules should be considered as per IS Code) but could cause problems for the outer modules or platforms when on site. If these boundary modules sustain damage, the quick change in buoyancy could lead to them breaking off from the platform or cause extreme forces in the connections. The more important result of such damage is the effect on the safety of the modules inhabitants. As such, adequate mitigation measures should be taken to quickly neutralize the danger posed by such damage or, if these aren't possible or are insufficient, appropriate evacuation measures should be in place (lifeboats, escape routes, etc.).

4. Due to the innovative scope of the project, possible exemptions or leniencies from the applicable stability rules and regulations could be attained. As for ships, for designs that do not fall exactly in the scope of existing regulations, regulatory bodies can make exemptions from design regulations that do not have an important impact on the overall safety. These exemptions could only be applicable regarding the stability rules and regulations when in transit as when on site and connect the floating body (i.e. island) shall be, in my opinion too large to suffer any major stability issues

7. Conclusions and recommendations

This study aimed to collect the most relevant requirements for living on floating islands, to guarantee safe and comfortable living environment for future inhabitants. This should have been based on the best practises. However, after literature review and interviews, it has been concluded that currently there is no example of large-scale floating development with the purpose of living. The ones coming closest are from the offshore and shipping industry such as flotels or accommodation units for on offshore platforms; nevertheless, rules and regulations with which these structures comply are confined to oil, gas and shipping industries, that are stricter than ones complied in the urban environment. Current knowledge that is available includes floating offshore accommodation in the offshore and shipping industry, and floating urbanisation on the calm inland and coastal areas; however, offshore and urban environment are completely different worlds and speak different languages. This led to a totally different approach for this task than expected upfront. To find out the most optimal solutions, standards from land-based urban planning will have to be integrated with living and building standards from the offshore industry. This combination should form the basis for new legislation made specifically for floating islands in general and for living purpose. This first attempt should set the baseline for the research and development of the legal part for Living@Sea. The recommendations based on altered rules from both the urban and offshore industry in this report can be used as inputs for the demonstrator design. They will also serve as a starting point for discussions between the urban and the offshore. This chapter gives an overview of the key conclusions and findings.

Existing maritime regulatory framework can be extrapolated to floating islands

The concept of "Living at Sea" on larger scale floating islands is a new kind of human activity on the oceans. Although the existing maritime regulatory framework does not seem to apply directly to "Living@Sea", there does seem to be some structures and principles that can be extrapolated to the marine structures for permanent residential purpose. It is in line with the historical facts that the "urgency" of having marine structures for residential purpose will call for regulatory frameworks to be adjusted, in a way that will meet specific usage conditions instead of imposing a priori restrictions onto them. The development and introduction of the offshore industry in the 20th century brought new challenges with capital intensive assets, highly hazardous operations and combined risks. Consequently, a different regulatory framework was adopted to match the need of the profitable offshore energy industry with corresponding strict safety requirements. The present four main "pillars" that form the maritime regulatory frameworks are related to:

- Safety of the structures,
- Limited impact on the environment,
- Properly trained and educated staff, and
- Wellbeing of workers.

These pillars support the coverage of financial risks by insurances and stakeholders, and operational risks by crews, passengers and coastal communities. They should also be applied on the standards for Living@Sea.

Financial incentive is the key driver that urges standards to be established

The present rules in the offshore/shipping industry have come into place, following the "demands/interests" of the direct stakeholders. Investors in the maritime industry saw large average profits together with lower probability of huge damages. In order to get better prices and coverage conditions from insurers on the offshore assets (platforms/ ships), it was required to have the structural integrity and seaworthiness of these assets classed/certified by classification societies.

Each classification society has developed their own rules to ensure an acceptable degree of stability and safety. Other requirements such as safety to crew, passengers and environment, came later driven by public opinion. For Living@Sea, a similar mechanism to have the floating islands classified is likely to be required in order to obtain insurance for the islands/platforms. The floating platforms are the prerequisite that enables the added value of the service. They are typically one with the rest of the assets on top.

The legal status of a floating island for living purpose remains ambiguous

Such ambiguity undoubtedly hinders the realisation of a city-scale floating island for living and working. Potential developers or investors have no clear idea on the political, legal and practical consequences of treating such a floating platform as land, offshore platform/structure/installation, or a combination of the two. What is the legal framework of a floating island? How long is the design life-time of a floating island, and how long will these rules and regulations apply? Can the ownership of floating islands resemble land ownership? What are the consequences of treating a floating platform as an immovable property? How can the floating island and the property on the super-structure be insured, so that it becomes possible to apply for a mortgage? What is the optimal way to register a floating platform? After literature review and interviews, it has been concluded that currently there are no clear and consistent answers to these questions based on various floating projects in the Netherlands. The legal status of a floating island at different scales still needs being further investigated. Part of these, in particular the financial aspects, will be touched upon in Work Package I for the business case of Living@Sea.

Land registry that allows floating structures to be regarded as an immovable property

The issues about floating houses being registered at land registry still need to be investigated further. In the Netherlands, floating houses are currently considered to be movable properties. However, if these houses can be registered in the Dutch land registration, they will then be regarded as immovable properties. In this case, it becomes possible for one to own part of the floating building. This is significant especially for multi-use and high-rise buildings that are currently investigated in Living@Sea.

While the legislation at local scale is work in progress, the legal status of a floating island on the national and international scales has not yet been investigated. The definition and legal framework of a floating island can shed light on not only the rules and civil codes that can be applied from the urban context, the ownership possibilities of the sub-structure and super-structures, but also financial aspects such as insurance and mortgage issues, which are also vital drivers that power the floating islands development for Living@Sea. Thus, it is recommended to follow the trajectory of current law amendments in the Netherlands and talk with relevant stakeholders that are involved for the next phase of this task.

Many questions still need being investigated, especially the political, legal and financial ones. Some of these questions will be touched upon in Task 7.5 Social Acceptance and Stakeholder Involvement. Stakeholder groups such as policy makers, city officials and potential investors/developers will be interviewed. Their interests in floating island development as a solution to urban city extension will be probed, and their concerns and potential/on-going actions in realising floating urban development will be documented. The outcomes are expected to contribute to the design guidelines of the floating island as well as the development of the business model of Living@Sea.

Current regulations related to floating development are confined to a single floating house

After reviewing building regulations related to floating development from the urban perspective in the Netherlands, as being a pioneering country in floating urban development, it has been concluded that most of the technical requirements for floating structures in the urban context are based on the scale of a single house. Living@Sea looks into larger scale housing and other mixed-use functions, due to the consideration of making a financially attractive business case. For Space@Sea, houses on Living@Sea will need to comply with different regulations than what currently in the Building Decree are, depending on the scale of the development and its visual and environmental impacts. In terms of heat and cold insulation, the use of the right materials will allow floating structures to meet the necessary values from the Building Decree. For other topics, it can be concluded that the building codes allow for more flexibility for floating homes than for homes on land, the same should be the case for the floating islands.

In the following, current existing rules for floating homes in the Netherlands could be applied to Living@Sea:

- There is no obligation to connect to the grid for electricity or gas, this should also be the case for the floating islands. Preferably not using any fossil fuels at all, for heating, cooling or electricity.
- The floating island will need dedicated safety platforms that can be seen as safe place for people to flee to during fire, extreme storm conditions or sinking or platforms.
- The buoyancy should be guaranteed of the modules by applying compartmentation within the structures and monitoring and warning systems in case of damage or leakage.

- Accessibility should be granted. The (maximum) ramp change in the face of specific scenarios (e.g., a very long wave) should be allowed.
- There are no regulations on tilt of floating homes. These topics should be addressed in several stages. First of all, the methodology to measure tilt; if many houses reside on one large platform of 45x45 m or even 90 x90 m, an angle of 1% will have a different effect when measured from the centre or from the side. Moreover, how much tilt will be allowed in what time period also needs to be determined.
- Stability on the platform will need to be maintained. In the case of a large-scale building, the design needs to be considered for the correct distribution of dead loads. On the other hand, limits on the maximum live loads also need to be in place, complimented by a warning system when exceeded.
- The constructive safety: structural integrity and strength, need to allow the constant movement of the floating islands. This movement will not only affect the substructures and their connections (e.g., structural connections, bridges, etc.), but also the buildings on top of the structures. This needs to be considered during the design phase. The blocks exposed to the outside of the island need to have a stronger structure that can cope with ship collision, harsh weather conditions and in some cases even ice shove. Very large vessels (highly explosive) should not be allowed in the proximity of the floating islands, because of the large consequences of collision.
- The platforms need to have fall protection using for instance, fences. If for some reason, someone would still fall overboard, every platform that has an open water connection with at least one side should have the possibility for him/her to climb back onto the top of the platform and to hold onto the sides. Moreover, life vests or buoys should be available at those places. A protection mechanism which prevents the person from being sucked under the platforms.

Preparing future inhabitants of Living@Sea for coping with danger or accidents is recommended

The floating islands can neither be regarded as offshore oil platforms nor ships. These islands will behave differently than oil platforms or ships because of the different shape, mooring design, linkage (bridging), dimensions and characteristics. In comparison to mainly offshore industry (oil & gas), these floating platforms will not face the danger of hydrocarbon fires followed by explosions. Such heavy machinery will not be placed on the Living@Sea platforms. On the one hand, future inhabitants who will live and work on these islands will not have the same training and experience in hazardous situations as the crews on ships and especially those on offshore units. This is not desirable because of the large restrictions that are imposed on the (oil and gas) offshore workers, who are there mainly for work. On the other hand, it is recommended to train, inform and prepare the inhabitants of Living@Sea on how to act in case of danger or accidents. Every inhabitant needs to know how to respond to fire, systems failure, man overboard, sinking, severe storms which lead to extreme movements of the platforms, including the dead loads and live loads on them, etc..

Fire detection and call points

There must be an advanced automatic fire detection system on a floating island. Automatic smoke detection devices must be mandatory installed in all spaces. The detectors can be activated by just a small amount of smoke. It is important to detect as early as possible, so that the exact location of the smoke will be indicated. Additionally, there must be manual call points, installed at strategic points all over the floating islands that are easy for people to reach. In terms of prevention, all interior fittings (e.g., panelling, ceilings, doors, staircases etc.) shall be non-flammable. Soft furnishings (e.g., carpets, curtains, upholstery, mattresses etc.) shall be made of fire-retardant materials.

Rules that must be known and practiced in order to ensure safety

It is the mission of Living@Sea to create a safe environment that allows not only offshore workers but also their families among others to live on the floating islands. While many hazards happening in existing cities on land could also take place on floating islands, it should not be forgotten that every person living on the floating islands should constantly be aware of the applicable rules and procedures regarding fire safety, which is also for everyone’s comfort and safety. Some safety rules that must be known and permanently applied are:

- Study carefully the alarm instruction/escape plan;

- Study the escape route signs in corridors and stairways showing the escape routes and note the main escape routes and the alternative escape routes;
- Should you see smoke from what you think could be a fire, press the nearest call-point button;
- Participate in every emergency drill; you will be instructed and trained in all aspects of fire-fighting, evacuation, communications and use of all safety equipment;
- Smoking in places not allowed is strictly forbidden; please show consideration to no-smokers and refrain from smoking in the no-smoking areas.

A Safety Management System should be developed and implemented

The basic principles, or safety priority, indicated by the International Safety Management (ISM) Code are 1.) Safety of people on platforms/islands, 2.) Safety of all constructions and devices placed on islands, and 3.) Safety of environment. Based on ISM Code prescriptions, every “Company”, namely the administrative authority of the floating island who is responsible for the operations of the platform, should develop, implement and maintain a Safety Management System (SMS) which includes the following functional requirements:

- A safety and environmental protection policy;
- Instructions and procedures to ensure safe operation and protection of the environment in compliance with relevant international and flag State legislation;
- Defined levels of authority and lines of communication between shore and island;
- Procedures for reporting accidents and non-conformities with the provisions of this Code;
- Procedures to prepare for and respond to emergency situations;
- Procedures for internal audits and management reviews.

The procedures required by the Code should be documented and compiled in a Safety Management Manual. In matters of safety and pollution prevention, it is the commitment, competence, attitude and motivation of individuals at all levels that determines the result. In principle, ISM Code Implementation means:

1. Development of plans concerning the safety of the island and pollution prevention. Tasks involved should be defined and assigned to qualified personnel.
2. Emergency preparedness to respond to onboard emergencies. The company should establish programs for drills and exercises to prepare for emergency actions.
3. Reports and analysis of non-conformities, accidents, and hazardous occurrences. SMS should include procedures to report and analyse above. All incidents are to be investigated with the objective of improving the safety and pollution prevention record. Procedures are established for implementation of corrective action.

An overview of potential threats that might occur in Living@Sea and possible mitigation measures have been made (see Appendix 6).

Buoyancy and stability will need additional attention:.

1. Aspects of buoyancy that must be carefully considered regarding:

- Individual module (stacked or not) buoyancy regarding draft and freeboard while being towed to or from the site.
- Final draft of modules when connected should be within acceptable limits to one another as to minimize high forces in the connection and to facilitate access between modules.
- For the integrated platform, design of each module should try to avoid as much as possible use of ballast (solid or liquid) to bring module edges at the same height. Ballasting (liquid) would probably be necessary while connecting modules together.
- Buoyancy of modules shall be, within acceptable limits, future proof regarding addition or removal of weights.

2. Intact stability regulations shall apply while towing the modules to and from the site, and should consider the following:

- If topsides are built together with the modules in the construction site, wind profile during transit shall be carefully considered regarding stability calculations and possible limits on height of topsides shall be imposed. On a side note, air draft could pose problems regarding actual limitations on the route (e.g. bridges).

- Intact stability should not pose problems for the final integrated platform due to the large final size (island).

3. Damage stability regulations in transit are not applicable for pontoons (which the modules should be considered as per IS Code) but could cause problems for the outer modules or platforms when on site. If these boundary modules sustain damage, the quick change in buoyancy could lead to them breaking off from the platform or cause extreme forces in the connections. The more important result of such damage is the effect on the safety of the modules inhabitants. As such, adequate mitigation measures should be taken to quickly neutralize the danger posed by such damage or, if these aren't possible or are insufficient, appropriate evacuation measures should be in place (lifeboats, escape routes, etc.).

4. Due to the innovative scope of the project, possible exemptions or leniencies from the applicable stability rules and regulations could be attained. As for ships, for designs that do not fall exactly in the scope of existing regulations, regulatory bodies can make exemptions from design regulations that do not have an important impact on the overall safety. These exemptions could only be applicable regarding the stability rules and regulations when in transit as when on site and connect the floating body (i.e. island) shall be, in my opinion too large to suffer any major stability issues.

The acceleration is of most influence on human comfort

One of the most obvious differences in living on the sea is the constant presence of movement. This movement can lead to discomfort or seasickness in certain frequencies. Moreover it can influence daily life. In table 7.1 the human perception of accelerations bandwidths is shown. After that, the vertical acceleration limits and wave frequency ranges are given for each urban function/activity that might occur for Living@sea. Ranges are determined based on literature (see References).[11]

Table 7.1 Human perception levels different functions/activities in a floating development

a RMS (m/s²)	**Effects**	**Example**
<0.05	People do not perceive motions	Typical house
<0.10	- Sensitive people may perceive motions - hanging objects may show motions	Up in a skyscraper
<0.20	- Motions may affect desk work - Majority of people perceive motions - Similar to cruise liner operability criteria (Norforsk, 1987)	Skyscraper in a storm. Airplane cruising
<0.40	- Desk work becomes difficult - Walking normal is still possible. - Most standing people keep balance - Long-term exposure may cause motion sickness.	Train/metro ride
<0.50	- People strongly perceive motion - Difficult to walk naturally - Standing people may lose balance.	Bus ride, Airplane with light turbulence.

[11] An overview of studies that relate RMS acceleration and discomfort, with 2-line summaries summary of each study by March (1998).

	- May produce motion sickness	
<0.60	- Most people cannot tolerate the motion - Most people unable to walk naturally. - May well produce motion sickness	Train/metro turning or stopping. Airplane with turbulence.
<0.85	- People cannot walk or tolerate motion - Likely to produce motion sickness	
>0.85	Objects begin to fall - people may be injured. - Likely to produce motion sickness	Bus near bus stop, Airplane with heavy turbulence, or landing

Based on the information from Table 6.1, an overview of acceleration limits is compiled for different urban functions (Table 6.2).

Table 7.2 An overview of acceleration limits for different urban functions (source: Deltasync)

	Return period				
a RMS (m/s²)	**Residential**	**Office/retail**	**Streets**	**Park, gardens, outdoor functions**	**Cultural/ leisure**
0.05< a RMS <0.1	**1:1-yr**	**1:1-yr**	**1:1-yr**		**1:1-yr**
0.1< a RMS <0.2	**1:10-yr**	**1:10-yr**	**1:10-yr**		**1:10-yr**
0.2< a RMS <0.4	**1:100-yr**	**1:100-yr**	**1:100-yr**	**1:1-yr**	**1:100-yr**
0.4< a RMS <0.5	**1:1,000-yr**	**1:1,000-yr**	**1:1,000-yr**	**1:10-yr**	**1:1,000-yr**
0.5< a RMS <0.6				**1:100-yr**	
0.6< a RMS <0.85				**1:1,000-yr**	
>0.85 m/s²	**1:10,000-yr**	**1:10,000-yr**	**1:10,000-yr**	**1:10,000-yr**	**1:10,000-yr**

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Appendix 1: Overview and correlations between tasks within Work Package 7

An overview of Work Package (WP) 7, the relevance of T7.3 with other tasks, and stakeholders which WP7 takes into account are shown in this appendix.

Overview of WP7

The following diagram displays the stakeholders and topics that will be touched upon in different tasks within Work Package 7 (Figure A1.1). Concerns from different stakeholders, research questions that will be answered, and correlations between each of the task are described here. T7.1 focuses on information integration and T7.2 gathers the wishes of offshore workers, namely the functional requirements which they give in order to help achieve a quality living space offshore. These serve as inputs for the living space floor plan used in WP6 as well as for T7.4. The information will also be used in T7.5 indirectly. For T7.3, concerns from policy makers and investors are addressed. As part of the technical community (designers and engineers), in T7.3 we endeavour to answer research questions focussing on the two groups of stakeholders, while integrating requirements from T7.2 and provide useful information to T7.4 as inputs to design guidelines.

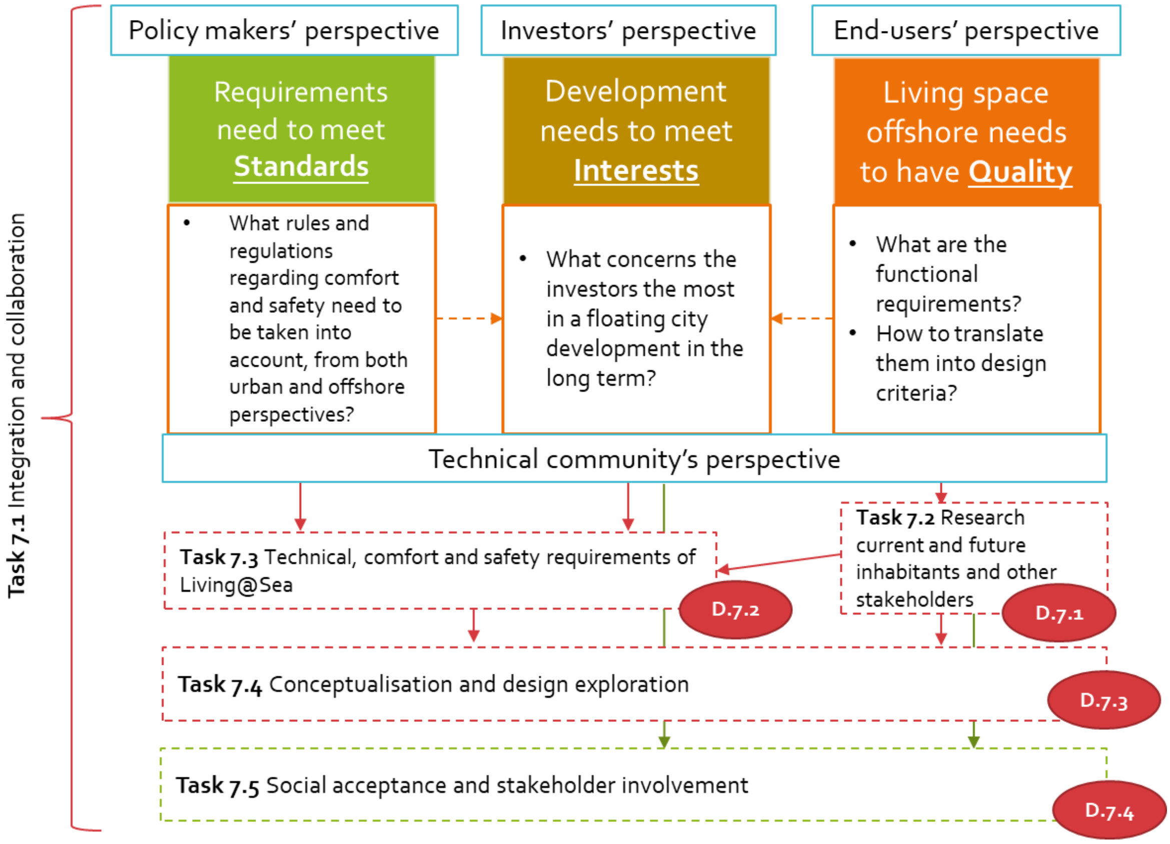


Figure A1.1 The overview and correlations between tasks within WP7

T7.3 relevance to other tasks within WP7

In the report of *D7.1. A list of functional requirements for the design*, which was the outcome of *Task 7.2 Research current and future inhabitants and other stakeholders,* the following ‘wishes’ have been concluded for improving the current offshore living environment by offshore workers, for their physical and psychological wellbeing:

1. Have permission to invite family, friends or even bring pets on board
2. Introduce nature (lawn, garden, park)
3. Create more comfortable furnishings of living quarters, and improvement of leisure facilities (more diversified and friendly to all ages)
4. Make rest areas soundproof
5. Improve sport facilities

Wish #1 would be possible when assuming the inhabitants of the floating city all untrained here. Wish #2, #3 and #5 would also be feasible as they have been included in the key functions in the floating city design of Task 7.4. Wish #4 has to do with comfort requirement, which could be solved via proper design and use of building materials. Task 7.3 provides some guideline for Wish #4. Moreover, the outcomes of Task 7.3 will serve as references for *Task 7.4 Conceptualisation and design exploration*. Important technical issues have been addressed and non-technical issues touched upon this report. These should result in a valid design in Task 7.4, which will be used as interview stimuli in *Task 7.5. Social acceptance and stakeholder involvement*.

Additionally, functions of Living@Sea would require that the daily activities of inhabitants tend towards that of on shore, such as follows. These functions have also been taken into account in the conceptual city design of Task 7.4:

- *Living Residential*: housing complex (height: 3-5 storeys)
- *Business Commercial*: offices, consumer goods and retail (supermarkets, shops, etc.)
- *Business Light Industry*: processing of goods (e.g., food, healthcare products, etc.)
- *Business Research & Development*: innovation testbed
- *Business Catering Industry*: hotels, restaurants
- *Public Community Facilities*: theatres, community centres, sports facilities
- *Public Educational Institute*: schools, libraries, culture centres
- *Public Greenery*: gardens, parks
- *Utilities Electricity*: renewable energy (e.g., solar, wind, etc.)
- *Utilities Other*: wastewater treatment, sewer, drainage, cable/data lines, etc.

These functions have been borne in mind while scrutinising the rules and regulations that ensure safety and comfort from urban and offshore perspectives. In particular, the living and working parts of the functions, such as residential, commercial and R&D. Rules and regulations for Utilities Electricity and Utility Other are less of the focus for this task.

Main stakeholders for Living@Sea

Four main groups of stakeholders have been identified for WP7, as researchers noticed that the concerns from each group have reoccurred over the past couple of years, from both urban and offshore perspectives. This chapter gives a brief overview on the synergies between them as it is rather critical in the process of making Living@Sea a reality (Figure A1.2): ***1.)*** *policy makers,* ***2.)*** *investors,* ***3.)*** *end-users and* ***4.)*** *technical community.*

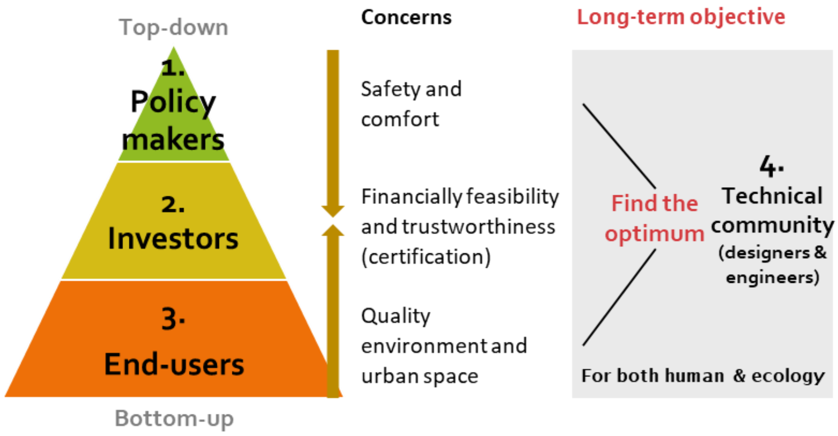


Figure A1.2 Synergies between the four main stakeholders

1.) ***Policy makers*** help to establish the technical requirements that should be dealt with for the new urban development on water. They decide on to what extent these requirements need to comply with the corresponding standards or codes of practice, in order to ensure a safe and comfortable living environment on and around the offshore platforms, not only for humans but also for the environment.

2.) ***Investors/developers*** support the developments financially so that they could be realised. Investors are interested in knowing if the development on water can be financially feasible and interesting; therefore, they tend to pay more attention to the urban fabrics (e.g., building typologies, street network, functions) as these properties determine the costs and revenues for different module options. However, since investors are only interested in low-risk or shared-risk investments, they concern about whether developments comply with safety and comfort regulations and can be insured and therefore trusted. More elaboration on the synergies between investors and other stakeholders can be found in D7.4, done by T7.5 where stakeholder analysis was carried out.

3.) ***End-users*** are the inhabitants that will be living on the floating platforms offshore, referring to workers in the offshore industry (oil and gas) here. From their perspective, the optimal floating modules should enable quality urban space, meaning that they should provide functions in the building/area which meet the demands of the end-users. These are also known as "functional requirements/statements."

4.) ***Technical community*** refers to designers and engineers who serve as a "*linking pin*" that integrates different requirements and needs of other stakeholders. In other words, they ensure that the technical requirements of the floating development will comply with standards and codes of practice requested by policy makers, and at the same time help translating and quantifying the "functional requirements" of end-users into design/performance criteria. The ultimate and long-term objective is to find the optimal spatial planning and urban design for Living@Sea. Nonetheless, since floating development has characteristics and requirements that differ from developments on land, alternative approaches should be explored to define the qualities of built environment on water together with other stakeholders.

Appendix 2: Key organisations/institutes for setting technical requirements

The most relevant organisations and institutes that have been involved in establishing technical requirements and standards have been presented in this appendix. These include *Classification societies*, *Flag (state) administration*, *IMO conventions and codes*, *ISO*, *API*, *NORSOK standards*, *EN/EUROCODES*, *CEN*, *CE and NEN.*

Classification societies

A classification society is a non-governmental Recognised Organisation (RO) that establishes and maintains technical standards for the construction and operation of ships and offshore structures.

Classification societies certify that the construction of a vessel/offshore structure comply with relevant standards and carry out regular surveys in service to ensure continuing compliance with the standards. Classification Society now also looks into design, engineering, and even troubleshooting.

Subsequent to the satisfactory completion of the survey, the RO is empowered to issue the statutory certificate.

This certificate issue will depend on the authorization given to the RO in the Agreement as signed between the RO and the Flag Administration.

Currently, there are more than 50 classification societies (see examples in Figure A2.1), and twelve of which are members of the International Association of Classification Societies (IACS). The IACS publish their common rules, but also their common interpretations of the different regulations.

A classification certificate issued by a classification society recognized by the proposed ship register is required for a ship's owner to be able to register the ship and to obtain marine insurance on the ship. Insurance companies want the ships to be built according to the plan approval by the classification society, who involves in the design and engineering process in the beginning of shipbuilding. In a sense, classification society works for the insurance companies, and need to make the insured value covered. If the requirement is not enough, insurance companies would know and request the classification society to higher their standards/rules.

Classification societies also issue International Load Line Certificates in accordance with the legislation of participating States giving effect to the International Convention on Load Lines (CLL 66/88). They set technical rules based on experience and research, confirm that designs and calculations meet these rules, survey ships and structures during the process of construction and commissioning, and periodically survey vessels to ensure that they continue to meet the rules. Classification societies are also responsible for classing oil platforms and other offshore structures.

Figure A2.1 Classification societies logos

Flag administration

Maritime administrations, or flag state administrations, are the executive arms/state bodies of each government responsible for carrying out the shipping responsibilities of the state (Figure A2.2**Error! Reference source not found.**). They are tasked to administer national shipping, boating issues and laws within their territorial waters and for vessels flagged in that country, or that fall under their jurisdiction.

If the flag state ratifies a convention like SOLAS, MARPOL, etc., then this has to become their law system. The flag state has their national law system on a ship and these regulations have to be followed by the master, crew, owner, managers and inspectors. Flag state inspect according to their regulations. And inspections are often outsourced to a Classification Society. When outsourcing, flag state's quality control consists of: 1.) Auditing the Classification Society and 2.) Port State Report.

The main functions of the flag administration are the followings: Government policy for ships and boating; Marine safety in general; Seaworthiness; Safe construction and stability Policing Dangerous goods being carried;

Navigation safety; Safe manning; Certificates of Competency/licenses for crew Health, safety and welfare of crew; Civil search and rescue Prevention and combating pollution and response; Investigation of Marine accidents Represents country on IMO and other International Conventions.

Some important national maritime organizations are the followings:

- Danish Maritime Safety Administration
- The Directorate General for Sea and Transport (France)
- The Sub-Department WS 2: Shipping (Germany)
- The Navigation, Maritime Transport and Aviation Department (Italy)
- Netherlands Shipping Inspectorate (is responsible for Flag State)
- Dirección General de la Marina Mercante (Spain)
- Maritime and Coastguard Agency, United Kingdom
- Swedish Maritime Administration
- United States Federal Maritime Commission

Figure A2.2 Flag administration logos

IMO conventions and codes

The International Maritime Organization (IMO) is a specialised agency of the United Nations responsible for regulating shipping (Figure A2.3).

The IMO's primary purpose is to develop and maintain a comprehensive regulatory framework for shipping and its remit today includes safety, environmental concerns, legal matters, technical co-operation, maritime security and the efficiency of shipping.

The work of IMO is conducted through committees and these are supported by technical subcommittees.

IMO consists of an Assembly, a Council and five main Committees: The Maritime Safety Committee, The Marine Environment Protection Committee, The Legal Committee, The Technical Cooperation Committee, and Facilitation Committee, and some Sub-Committees support the work of the main technical committees.

The Marine Safety Committee (MSC) is the highest technical body of the Organization (IMO). Over the years IMO has developed and promoted the adoption of more than 40 conventions and protocols as well as over 1000 codes and recommendations dealing with maritime safety, the prevention of pollution at sea and other matters.

There are ten Conventions as: SOLAS, MARPOL, Load Lines, and many Codes as: FSS Code, FTP Code, HSC Code, MODU Code, LSA Code.

Also, there are IMO Resolutions as: Performance Standards, Guidelines, Adoption of Amendments, MSC Resolutions (mainly resolutions for Adoption of Amendments to Convention and Codes) and Circulars for conventions and codes modification.

Figure A2.3 IMO logo

The International Convention for the Safety of Life at Sea (SOLAS) is an international maritime treaty which sets minimum safety standards in the construction, equipment and operation for ships. The convention requires signatory flag states to ensure that ships flagged by them comply with at least these standards.

SOLAS is generally regarded as the most important of all international treaties concerning the safety of the ships. Of interest for the project are Chapter II-1 - Construction – Subdivision and stability, machinery and electrical installations, and Chapter II-2 - Fire protection, fire detection and fire extinction.

International Code on Intact Stability (IMO 2008 IS Code) presents mandatory and recommendatory stability criteria and other measures for ensuring the safe operation of ships, to minimize the risk to such ships, to the personnel on board and to the environment. The Code should be of interest to maritime administrations, ship manufacturers, shipping companies, and others concerned with stability criteria.

This Code prescribes general intact stability criteria for different types of ships and special criteria for certain types of ships (passenger ships, oil tankers of 5000tdw and above, cargo ships carrying timber deck cargoes, cargo ships carrying grain in bulk and High-Speed Crafts).

The 2008 IS Code also describes recommended design criteria for certain types of ships (fishing vessels, pontoons, container ships greater than 100m, offshore supply vessels, special purpose vessels and mobile offshore drilling units).

The International Convention for the Prevention of Pollution from Ships, 1973 as modified by the Protocol of 1978 (MARPOL 73/78, MARPOL is short for marine pollution and 73/78 short for the years 1973 and 1978) is one of the most important international marine environmental conventions. It was developed by the International Maritime Organization to minimize pollution of the oceans and seas, including dumping, oil and air pollution. The objective of this convention is to preserve the marine environment, in an attempt to completely eliminate pollution by oil and other harmful substances and to minimize accidental spillage of such substances.

IMO MODU Code

The purpose of the **Code for the Construction and Equipment of Mobile Offshore Drilling Units** is to recommend design criteria, construction standards and other safety measures for mobile offshore drilling units so, as to minimize the risk to such units, to the personnel on board and to the environment.

International Code for Application of Fire Test Procedures (FTP Code) is used when approving products for installation in accordance with the fire safety requirements of SOLAS. The Code is used by testing laboratories when testing and evaluating products under this code.

The International Code for Fire Safety Systems (FSS Code) was adopted by the Maritime Safety Committee (MSC) to provide international standards for the fire safety systems and equipment required by SOLAS Convention.

Code of Safety for Special Purpose Ships (SPS Code) has the principal purpose to recommend design criteria, construction standards and other safety measures for special purpose ship (e.g. offshore vessels).

International Safety management Code (ISM Code) has the purpose to provide an international standard for the safe management and operation of ships and for pollution prevention.

The Code establishes safety-management objectives and requires a safety management system (SMS) to be established by "the Company".

ISO

The **International Organization for Standardization (ISO)** is an independent, non-governmental organization, the members of which are the standards organizations of the 164-member countries (Figure A2.4). It is the world's largest developer of voluntary international standards and facilitates world trade by providing common standards between nations. Over twenty thousand standards have been set covering everything from manufactured products and technology to food safety, agriculture and healthcare.

Use of the standards aids in the creation of products and services that are safe, reliable and of good quality. The standards help businesses increase productivity while minimizing errors and waste.

Figure A2.4 ISO logo

Some examples of codes for both measurement procedures and evaluation criteria for noise and vibrations are:

- ISO 2923:1996 Acoustics – Measurement of noise on board ships
- ISO 6954:2000 Mechanical vibration – Guidelines for measurements reporting and evaluation of vibration with regard to the habitability on passenger and merchant ships.
- ISO 2631:1997 Mechanical vibration and shock– Evaluation of human exposure to whole-body vibration– Part I: General requirements
- ISO 20283 Mechanical vibration – Measurement of vibration on ships

API

The **American Petroleum Institute (API**) is the largest U.S. trade association for the oil and natural gas industry (Figure A2.5). It claims to represent about 650 corporations involved in production, refinement, distribution, and many other aspects of the petroleum industry.

The association describes its mission as to influence public policy in support of a strong, viable U.S. oil and natural gas industry.

Figure A2.5 API logo

NORSOK Standards

The **NORSOK standards** are developed by the Norwegian petroleum industry to ensure adequate safety, value adding and cost effectiveness for petroleum industry developments and operations (Figure A2.6). Furthermore, NORSOK standards are as far as possible intended to replace oil company specifications and serve as references in the authority regulations.

There are forty years of petroleum experience from the Norwegian continental shelf behind the NORSOK standards.

The acronym NORSOK originally stands for "the Norwegian shelf's competitive position" and was introduced in 1994 to cut costs and improve competitiveness on the Norwegian continental shelf.

Figure A2.6 NORSOK logo

EN/EUROCODES

European Standards are technical standards drafted and maintained by CEN (European Committee for Standardization), CENELEC (European Committee for Electrotechnical Standardization) and ETSI (European Telecommunications Standards Institute) (Figure A2.7). The EN Eurocodes are expected to contribute to the establishment and functioning of the internal market for construction products and engineering services by eliminating the disparities that hinder their free circulation within the Community. Further, they are meant to lead to more uniform levels of safety in construction in Europe. The EN Eurocodes are the reference design codes. After publication of the National Standard transposing the Eurocodes and the National Annexes, all conflicting standards shall be withdrawn.[12]

Eurocode	At room temperature	In case of fire
0 : Basis of design	EN 1990	-
1 : Actions	EN 1991-1-1	EN 1991-1-2
2 : Concrete structures	EN 1992-1-1	EN 1992-1-2
3 : Steel structures	EN 1993-1-1	EN 1993-1-2
4 : Composite steel-concrete structures	EN 1994-1-1	EN 1994-1-2
5 : Timber structures	EN 1995-1-1	EN 1995-1-2
6 : Masonry structures	EN 1996-1-1	EN 1996-1-2
7 : Geotechnical design	EN 1997	-
8 : Earthquake resistance	EN 1998	-
9 : Aluminium alloy structures	EN 1999-1-1	EN 1999-1-2

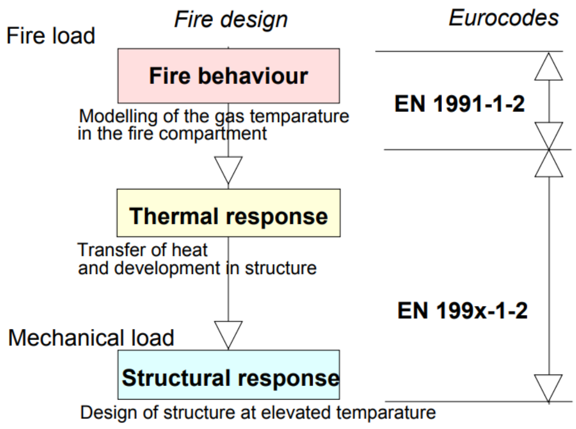


Figure A2.7 EN/EUROCODES related to fire safety (source: https://www.ct.upt.ro/suscos/files/2013-2015/2C10/L1%20-%20Fire%20Safety.pdf)

CEN

The European Committee for Standardization is a public standards organization, whose mission is to foster the economy of the European Union (EU) in global trading, the welfare of European citizens and the environment by providing an efficient infrastructure to interested parties for the development, maintenance and distribution of coherent sets of standards and specifications (Figure A2.8).[13]

Figure A2.8 Logo of CEN (source: European Committee for Standardization)

CEN/TC 72 Fire detection and alarm systems

To prepare standards, harmonised where necessary, to meet the essential requirements 'Safety in case of fire' of the Construction Products Regulation, in the field of fire detection and fire alarm systems in and around buildings,[14]

[12] Eurocodes, retrieved May 2019

[13] https://eur-lex.europa.eu/legal-content/en/ALL/?uri=CELEX:31983L0189

[14] Standards CEN 6055.pdf

CEN/TC 88 Thermal insulating materials and products

Standardisation in the field of thermal insulating materials and products for application in buildings, including insulation for installed equipment and for industrial insulation, covering: terminology and definitions, list of required properties with regard to different applications, methods for the determination of these properties, sampling procedures, conformity criteria, specifications for insulating materials and products, marking and labelling of insulating materials and products.[15]

CEN/TC 127 - Fire safety in buildings

Aims: 1) To develop standards utilizing relevant existing work where available e.g. in ISO, IEC, CENELEC, CEC and EFTA assessing the fire behaviour of building products, components and elements of construction, 2) To develop standards for classification of products, components and elements of construction, appropriate to the fire risks related to their application, 3) To develop standards for assessing fire hazard and for providing fire safety in buildings.[16]

CE

CE marking is a certification mark that indicates conformity with health, safety, and environmental protection standards for products sold within the European Economic Area (EEA) (Figure A2.9).[17] Construction Products Directive (Council Directive 89/106/EEC) (CPD) is a now repealed European Union Directive with the aim to remove technical barriers to trade in construction products between Member States in the European Union.

There are six essential requirements which need to be addressed (by committee) and satisfied, when relevant, by the product prior to being put on the market:

- Mechanical resistance and stability
- Safety in the case of fire
- Hygiene, health and the environment
- Safety in use
- Protection against noise
- Energy economy and heat retention

Figure A2.9 Logo of CE Marking (source: https://ec.europa.eu/growth/single-market/ce-marking_en)

NEN

NEN - Netherlands Standards Institute. NEN manages over 31.000 standards. Those are the international (ISO, IEC), European (EN) and national (NEN) standards accepted in The Netherlands (Figure A2.10).

While the Dutch Building Decree regulates the minimum required building and living quality, it does not regulate everything. No requirements are set by the Building Decree for a number of aspects of floating structures, such as

[15] Standards CEN 6071.pdf

[16] Standards CEN/TC 127- Fire safety in building

[17] Council Directive 93/68/EEC

stability, buoyancy, safety distance or collision resistance. This relates in part to aspects of use. In addition, there are several issues that are encountered in practice, or that require solutions specifically aimed at the development of floating structures. E.g. access to floating buildings, connection of utilities, water level fluctuations, requirements of water managers for water quality, leaching of materials, health and safety requirements related to the safety of firefighters.

The purpose of the Dutch Technical Agreement (NTA) for floating structures is to establish a number of agreements and performance specifications between market and government parties on identified bottlenecks and issues of floating construction that are currently not or insufficiently regulated by building regulations.[18]

Figure A2.10 Logo of NEN (source: https://www.nen.nl/Normontwikkeling/Certificaten/Certificaten-en-keurmerken.htm)

[18] NEN: NTA-8111-2011-nl

Appendix 3: Flotel unit concepts

Another type of floating structures present in the seas that relate to living are the flotel unit concepts (Figure A3.1). These floating hotel vessels, known as flotels, are used to accommodate workers during offshore construction works. These vessel types, have the accommodation facilities for workers correspond to many of the requirements for passenger vessels applicable to them. Like other ships, the flotels must comply with all International Maritime Organisation (IMO) rules, as: SOLAS, MARPOL, COLREG, Load Lines and so on.

Figure A3.1 Offshore flotel example

Regarding the living comfort parameters to be ensured on the floating islands, it was assumed (as a project target) that vertical accelerations should be kept below 0.25 m/s^2, considering cruise ships have an upper limit of 0.2 m/s^2[19].

In fact, the real acceleration value is to be calculated based on Metocean conditions, in accordance with the final location of the platforms/islands. In offshore and coastal engineering, Metocean refers to the syllabic abbreviation of meteorology and (physical) oceanography.

Metocean conditions refer to the combined wind, wave and climate (etc.) conditions as found on a specific locations (Figure A3.2). They are most often presented as statistics, including seasonal variations, scatter tables, wind roses and probability of exceedance. The Metocean conditions may include, depending on the project and its location, statistics on meteorology and physical oceanography.

Metocean data plays an important role when assessing design feasibility with impact across many engineering disciplines and module function. The following locations have been chosen for developing the Space@Sea project:

2. North Sea (ARA region) for the Transport and Logistics hub (Living hub included).
3. Mediterranean Sea for both the Farming and the Energy hubs (Living hub included).

Also, the initial assumptions for platforms dimensions and loads were the following:

1. A minimum edge length of 45 m (for square barge modules of 4 m depth that can be stacked one on top of the other), resulting in an overall deck space of about 2,025 m^2.
2. A minimum module freeboard of 2 m to keep de deck edge out of the water keeping count of a maximum trim/heel angle of max. 5 degrees. This gives a total displacement of each module of abt. 4150 t in saltwater. This should account for the “lightweight” of the module (steel, equipment, etc.) and “deadweight” (superstructures and other topsides depending on specific module function).

[19] Taken from D10.1 Formulation of requirements Chapter 2.4 Platform response.

3. Preliminary estimations of weight/area for different module functions are as follows:
   a. Energy hub - 3.25 t/m2 (abt. 5920 t, deck space factor = 0.9 resulting in a necessary minimum of modules stacked one on top of each other);
   b. Living - 2.00 t/m2 (abt. 3645 t, deck space factor = 0.9);
   c. Farming - 2.00 t/m2 (abt. 3645 t, deck space factor = 0.9);
   d. Transport & Logistics - 5.00 t/m2 (abt. 9110 t, deck space factor = 0.9, resulting in a minimum of 3 modules stacked one on top of each other).

Figure A3.2 Wind, wave and climate conditions

Appendix 4: An inventory of rules, regulations and standards

Four tables are presented in this appendix, with rules and regulations on buoyancy (Table A4.1), stability (Table A4.2), fire safety (Table A4.3) and comfort (

Table A4.4).

Table A4.1 Rules and regulations regarding buoyancy

No.	Rule, Regulation title	Current version	Content of rule, regulation
Buoyancy			
1	Lloyds' Register – Rules and Regulations for the Classification of Offshore Units, Part 3, 4, 9, 11	July 2018	Contains prescriptions and requirements regarding buoyancy for offshore units.
2	DNV GL – OS-C301, Stability and watertight integrity	July 2015	The standard provides principles, technical requirements and guidance related to stability, buoyancy, watertight integrity, freeboard and weathertight closing appliances for offshore units.
3	IMO International Convention on Load Lines (ICLL)	2003 (revised)	International convention dedicated to harmonisation all aspects regarding ships load lines (survey and certification requirements).
4	IMO Convention on the International Regulations for Preventing Collisions at Sea (COLREG)	2003	The Convention prescribes rules to be followed by ships and other vessels at sea in order to prevent collisions between two or more vessels.

Table A4.2 Rules and regulations regarding stability

No.	Rule, Regulation title	Current version	Content of rule, regulation
Stability			
5	Bureau veritas - Rules for the Classification of Offshore Units, Part B, Ch.1	December 2016	Stability calculations
6	Lloyds' Register – Rules and Regulations for the Classification of Offshore Units, Part 1, 4, 6, 7, 8, 10, 11		Contains prescriptions and requirements regarding stability for offshore units.
7	DNV GL – OS-C301, Stability and watertight integrity	July 2015	The standard provides principles, technical requirements and guidance related to stability, buoyancy, watertight integrity, freeboard and weathertight closing appliances for offshore units.
8	DNV GL – RU – SHIP Pt.3Ch.15 Stability	January 2017	Contains technical requirements regarding intact stability criteria and damage stability.
9	ABS Rules for Building and Classing Mobile Offshore Units, Part 3, Hull Construction and equipment, Ch.3	January 2019	Contains prescriptions and requirements regarding stability for offshore units
10	Regulations of 20 December 1991 No. 878 on stability, watertight subdivision and watertight/weathertight means of closure on mobile offshore units	December 1991	Contains Norwegian Maritime Authority (Flag Administration) requirements for stability on mobile offshore units.
11	Netherlands Regulatory Framework– Maritime of the Netherlands Shipping	December 2004	Contains requirements regarding intact stability.

	Inspectorate; Regulation Safety Seagoing Vessels		
12	Netherlands Regulatory Framework– Maritime of the Netherlands Shipping Inspectorate; Ships Decree 2004	2004	Contains requirements regarding damage stability calculations.
13	IMO SOLAS, Consolidated Edition – Chapter II-1, Construction – Structure, subdivision and stability, machinery and electrical installations, Part B – Subdivision and stability	July 2014	Contains requirements regarding intact stability, damage stability and stability management.
14	IMO MODU Code, Chapter 3 – Subdivision, stability and freeboard	2009	Contains requirements regarding intact stability criteria, damage stability and extent of damage.
15	International Code on Intact Stability (IMO 2008 IS Code)	December 2008	The Code presents mandatory and recommendatory stability criteria and other measures for ensuring the safe operation of ships.
16	International Convention for the Prevention of Pollution from Ships (MARPOL 73/78)	October 1983	The convention covers prevention of pollution of the marine environment by ships from operational or accidental causes.
17	Code for Safety for Special Purpose Ships (SPS Code), Ch.2 Stability and subdivision	May 2008	The Code recommends design criteria, construction standards and other safety measures for special purpose ships.

Table A4.3 Rules and regulations regarding fire safety

No.	Rule, Regulation title	Current version	Content of rule, regulation
Fire Safety			
18	Bureau veritas - Rules for the Classification of Offshore Units, Part C, Ch.4, Sec.4, 5, 6, 7, 9, 10, 11	December 2016	Contains the provisions and requirements regarding fire safety for offshore units, as following: - structural fire protection; - fire and gas detection and alarm; - suppression of fire: fire-fighting installations; - suppression on fire: materials to be used; - fire control plans; - additional requirements for helideck structure, helicopter refuelling and appliances adequate for fire protection; - shore connection, fire extinguishers, gas fire-extinguishers, gas fire-fighting extinguisher, foam system, fire-fighter outfits.
19	Lloyds' Register – Rules and Regulations for the Classification of Offshore Units, Part 7, Ch.1, 3	July 2018	Contains the provisions and requirements regarding fire safety for offshore units, as following: - fire and gas detection alarm; - fire extinguishing systems; - additional requirements for means of escape and evacuation; - requirements for enclosed spaces; - boundary bulkheads; - access doors.
20	DNV GL-OS-D301, Fire protection	July 2015	The standard provides principles for design, construction, installation and commissioning of fire protection of offshore units, as following: - passive fire protection (structural, ventilation,

			space protection); - active fire protection (water fire extinguishing systems, hydrants, hoses, local systems, foam systems, deluge, portable extinguishers); - fire and gas detection and alarm systems; - fire-fighter's outfits, recharging and storage spares system, helicopter facilities fire plans, emergency escape breathing devices).
21	ABS Rules for Building and Classing Mobile Offshore Units, Part 5 Fire and safety	January 2019	Contains requirements regarding structural fire protection of accommodation spaces, service spaces and control stations from mobile offshore units, as following: - fire integrity of bulkheads and decks; - structural spaces protection; - active fire protections (systems and dedicated equipment); - helicopter deck protection; - helicopter refuelling facilities; - storage spaces for hazardous materials; - fire and gas detection and alarm systems.
22	Regulations of 1 July 2014 No. 1099 on fire protection on ships	July 2014	Contains Norwegian Maritime Authority (Flag Administration) requirements for fire protection on ships (passive and active systems). The requirements consist of the followings: - structural fire protection (construction details): - fixed fire-extinguishing systems; - fire equipment: hydrants, hoses, nozzles, fire outfit's; - alarm system.
23	Regulation 31 January 1984 No.227 concerning precautionary measures against fire and explosion on mobile offshore units	January 1984	Contains Norwegian Maritime Authority (Flag Administration) measures against fire on mobile offshore units. The requirements consist of the followings: - fire risk analysis; - fire extinguishing systems: hose, hydrants, portable fire extinguishers, fireman's outfit; - spaces fire protection (fire divisions, ceiling, lining, stairways, deck covering, paints, varnishes, furniture, ventilation system, windows, doors); - alarm system; - gas detection.
24	Netherlands Regulatory Framework– Maritime of the Netherlands Shipping Inspectorate; Regulation Safety Seagoing Vessels	December 2004	Contains requirements for the equipment provided and compliances with IMO Conventions and Codes, and Class Register requirements. Chapter 14 Fire safety: ventilation, fire detection and alarm, sauna and thermal suite construction, structural fire protection, main vertical zones, fire integrity for bulkheads and decks, fire appliances.
25	IMO SOLAS, Consolidated Edition – Chapter II-2, Construction – Fire protection, fire detection and fire extinction, Part B – Prevention of fire, Part C – Suppression of fire	July 2014	Contains requirements for ignition, fire growth, smoke generation, detection and alarm, fire-fighting, structural integrity, as following: - fire safety objectives and functional requirements; - space venting; - inert gas system;

			- gas detection; - protection of spaces exposed to gas; - closing and stopping ventilation devices; - fire protection materials; - handling of combustible materials; - furniture in enclosed spaces; - smoke generation; - detection fire and alarm; - living spaces fire protection; - specific requirements for passenger vessels; - thermal and structural boundaries; - spaces fire integrity; - stairways fire protection; - windows and doors in fire-resisting divisions; - ventilation systems; - fire-fighting systems; - equipment (hose, hydrants, portable extinguishers).
26	IMO MODU Code, Chapter 9 – Fire safety	2009	Contains requirements regarding structural fire protection, fire safety systems, fire-fighting equipment and arrangements, fire detection, as following: - fire integrity of bulkheads and decks; - spaces fire protection; - ventilation systems; - emergency escape breathing devices; - equipment (hydrant, hose, portable fire extinguisher); - fire detection and alarm system; - provisions for helicopter deck.
27	International Code for the Application of Fire Test procedure (FTP Code)	2010	The Code is intended for use by Administration and authority of the Flag state for approving products to be installed, in accordance with fire safety requirements on IMO SOLAS. The Code presents: - fire tests procedures; - tests reports; - materials approval; - tests for fire class divisions.
28	The International Code for Fire Safety Systems (FSS Code)	2016 (amended)	The Code provide international standards for the fire safety systems and equipment required by SOLAS Convention, as the following: - emergency escape breathing devices; - firefighter's outfit; - fire extinguisher (fixed and portable) with water, CO_2, foam; - fire detection and fire alarm systems; - smoke detection system; - means of escape (stair widths, stairs, doors and corridor dimensions calculation based on person flow to be evacuated); - inert gas system.
29	Code for Safety for Special Purpose Ships (SPS Code), Ch.6 Fire protection	May 2008	The Code recommends design criteria, construction standards and other safety measures for special purpose ships.
30	ISO 13702 Control and mitigation of	2015	The standard describes the objectives and

	fires and explosions on offshore production installations		functional requirements for the control and mitigation of fires and explosions on offshore installations used for the development of hydrocarbon resources. Among others is applicable for floating systems.
31	API RP 14G Recommended practice for fire prevention and control on fixed open-type offshore production platforms	April 2007	Even if the standard refers to offshore fixed platforms, it contains important recommendations regarding likelihood of having an accidental fire, and for designing, inspecting, and maintaining fire control systems; it establishes methods and procedures for safe evacuation in a fire hazard (offshore domain).
32	API RP 14C Recommended practice for analysis, design, installation and testing of basic surface safety systems for offshore production platforms		The standard covers industry practice for the provision of basic surface safety systems, including active fire protection systems
33	NORSOK C–001, Living Quarters Area	March 2015	Contains requirements regarding fire safety for the architectural design and engineering of the living quarters area on offshore installations in the petroleum industry, as following: - facilities in living spaces; - hot food area; - fire divisions; - fire extinguishing devices required.
34	NORSOK C–004, Helicopter deck on offshore installations	September 2004	Contains requirements regarding fire safety for helicopter decks on offshore installations, as following: - fire preparedness; - helideck fire protection.
35	NORSOK S–001, Technical Safety	February 2008	The standard describes the principles and requirements for the development of the safety design of offshore installations (oil and gas). An important part of this standard is dedicated to fire detection, passive fire protection and fire-fighting systems, as following: - gas detection and alarms; - fire detection and alarms; - ignition source control; - ventilation system; - alarm communication; - fire divisions; - safety critical equipment; - fire-fighting systems; - fire equipment (hydrants, hose).

Table A4.4 Rules and regulations regarding human comfort

No.	Rule, Regulation title	Current version	Content of rule, regulation	Comments
Human Comfort				
36	DNVGL-OS-A301 Human Comfort	April 2016	Contains requirements regarding comfort parameters on board offshore facilities, as following: - noise and acoustics (level limits);	

			- vibration limits; - illumination (area limits); - indoor climate.
37	ABS Guide for Crew Habitability on Offshore Installations	February 2016	This Guide focuses on habitability aspects of offshore installation. These aspects (for personnel accommodation areas and the ambient environment) are the followings: - hull vibration (maximum acceleration level); - noise criteria; - indoor climate criteria; - lighting criteria; - accommodation criteria (area, distances, sanitary spaces, lockers).

Appendix 5: Fire-fighting systems and equipment

The fire-fighting systems and equipment that are usually used on board of (oil & gas) offshore units which could, partly altered, serve as an example for the floating islands are:

1. Fire retardant bulkhead (walls) and decks (floors): different Class of bulkhead and Decks (such Class-H, Class-A, Class-B and Class-C) are used for construction of bulkhead and decks in areas like process, accommodation, machinery space, pump room etc. The main applications of such bulkhead and decks are to contain or restrict the spread of fire in sensitive areas.
2. Fire doors: special doors resistant to fire are fitted in fire retardant bulkhead (having the same fire class as the bulkhead) to provide access from different spaces.
3. Fire Dampers: these dampers (passive fire protection products used in heating, ventilation, and air conditioning ducts to prevent the spread of fire) are provided in the ventilation system of cargo holds, engine room, accommodation etc. in order to block out excessive oxygen supply to the fire.
4. Fire Pumps: as per regulation, an offshore unit must have main fire pump and an emergency power pump of approved type and capacity. The location of the emergency fire pump must be outside the space where main fire pump is located.
5. Fire Main Piping and Valves: the fire main piping which is connected to the main and emergency fire pump must be of approved type and capacity. Isolation and relief valves must be provided in the line to avoid over pressure of the same.
6. Fire Hose and Nozzles: fire hoses are used on units; number and diameter of the hoses are based on classification society requirements.
7. Fire Hydrants: fire hoses are connected to fire hydrants from which the water supply is controlled.
8. Portable Fire Extinguishers: portable fire extinguishers of CO2, Water, Foam and Dry Chemical Powder are provided in accommodation, deck and machinery spaces carried along with number of spares as given by the regulation.
9. Fixed Fire extinguishing system: CO2, Foam and water are used in this type of system, which is installed at different locations on the unit and is remotely controlled from outside the space to be protected.
10. Inert Gas System: this system is to protect Cargo space from any fire hazards, preferably there will not be any gas system present at the floating islands.
11. Fire Detectors and Alarms: fire detection and alarm systems are installed in process area, accommodation, deck areas, and machinery spaces along with alarm system to notify any outbreak of fire or smoke at the earliest.
12. Fire Fighter's Outfit: fire fighter's outfit is used to fight a fire on the ship made up of fire-retardant material of approved type.
13. Means of Escape: escape routes and passages must be provided at different location of the unit along with ladders and supports leading to a safe location. The size and location are designed as per the regulation.

Probability of ignition

To prevent the ignition of combustible materials or flammable liquids, some functional requirements shall be meet:

1. means shall be provided to control leaks of flammable liquids;
2. means shall be provided to limit the accumulation of flammable vapours;
3. the ignitability of combustible materials shall be restricted;
4. ignition sources shall be restricted;
5. ignition sources shall be separated from combustible materials and flammable liquids.

Suppression of fire

The purpose of this activity consists in detection of fire in the space of origin and to provide alarm (for safety escape) and firefighting activity. That is why it is necessary to provide a fire detection and fire alarm system.

The fixed fire detection and fire alarm systems shall be so designed, and the detectors so positioned, as to detect rapidly the onset of fire in any part of the living spaces. Except in spaces of restricted height and where their use is especially appropriate, detection systems using only thermal detectors shall not be permitted. The detection system shall initiate audible and visual alarms distinct in both respects from the alarms of any other system not indicating fire, in relevant places to ensure that the alarms are heard and observed by a responsible person.

For detection of fire in the space of origin and to provide alarm, fire detectors are used. Some of the main types of detectors used on units/ships are:

Flame detectors

Light produced by a flame has a characteristic flicker frequency. The spectrum in the infrared or ultraviolet range can be monitored to give an alarm. These detectors are especially placed near fuel handling equipment or boilers to give an early warning.

Heat detectors

Heat detectors are of various types such as rate of rise type, which has bi-metallic type detecting elements – a thick strip and a thin strip.

During normal temperature rise both strips will deflect about the same amount and thus show no reaction. Normally if rate of rise is low, the detector will not give any alarm. If the rate should quick rise, the two strips come in contact, thus triggering the alarm.

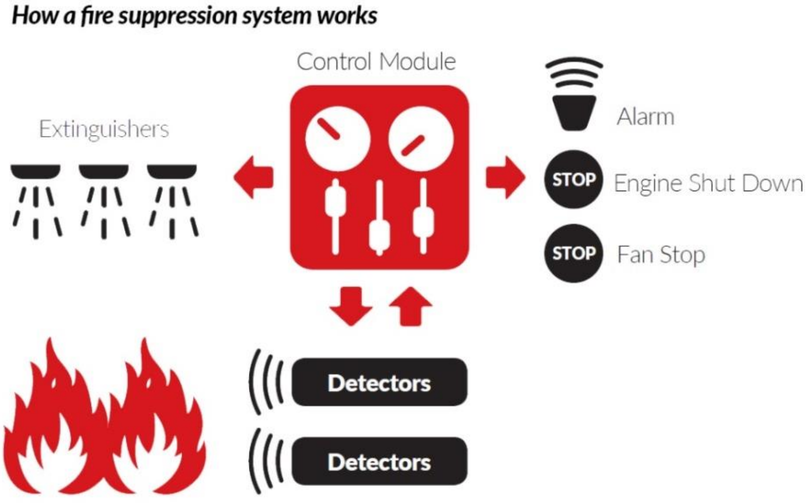


Figure A5.1 Fire suppression system

Smoke detectors

There are two main types of smoke detectors used:

1. Light obscuration type
2. Ionization type

These detectors are mostly used in accommodation areas.

Some points to be considered for fire prevention on board units/ships

- In dedicated places, waste bins used for storing oily rags must have lids (covers);
- High pressure fuel oil pipes should not be tightened to control a leakage while the engine is running. Also, oil shouldn't be taken into turbochargers during operation;
- Short sounding pipes should be kept shut with plugs;
- Exhaust leakages and steam leakages should be promptly attended;
- The electrical equipment from galleys should be careful in good order;
- Fire caused by cigarettes is still one of the most common causes of fire. All care should be taken to dispose cigarettes (using self-closing ashtrays) and never should one smoke in bed.

These are some of the main points one needs to consider for a safe environment.

The priorities of protection measures may be kept as the following order:

1. prevent fire form developing;
2. detect a fire (early);
3. contain the fire;
4. alarm;
5. evacuation;
6. deployment / firefighting / smoke ventilation.

Traditionally fire protection on board can be divided into 3 main groups:

1. structural fire protection;
2. fire detection;
3. fire extinction.

Structural fire protection is also called passive protection due to its passive characteristics. The purposes of structural fire protection are to slow down the spread of fire on board and give people the time to escape or, at the worst situation, reach the life crafts or wait for the rescue vessels. Fire detection and fire extinction are active protection. Their purposes are very clear: to detect a fire and extinguish it.

The passive fire protection systems shall protect personnel and asset by:

- Segregating various areas of the installation by preventing the spread of fire through specific boundaries.
- Protecting critical equipment and structural elements which must retain their integrity.

The active fire protection systems shall protect personnel and asset by:

- Reducing the burn rate, flame temperature and heat fluxes generated by fire.
- Providing cooling of exposed surfaces to reduce the potential for fire escalation.
- Limiting the evolution and restricting the spread of smoke and combustion products to assist with egress and emergency response activities.
- Extinguishing certain specific fire scenarios.

SOLAS gives the basic principles of fire protection on board ships in more details in Chapter II-2, Regulation 2.

Also, fire protection shall be in accordance with statutory requirements of the National Authority having jurisdiction in the waters where the unit/ship is located. The main elements of the fire protection strategy can be as follows:

- Inherently Safer Design;
- Passive Fire Protection System;
- Active Fire Protection System.

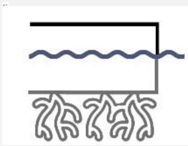
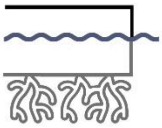
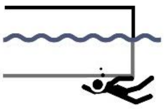
Inherently safer design aims to removes the potential for accident event to occur and if they occur, ensures that there is no risk to personnel or to the environment. The key goals of inherent safety are to reduce hazards, reduce causes, severity, consequences and effective management of residual risk.

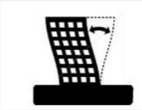
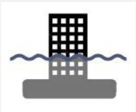
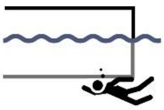
To avoid fire, all required rules and procedures must be rigorously respected; the equipment must be appropriately maintained, troubleshooting (if malfunctions exist) to be provided, detailed technical checks schedule and mandatory maintenance to be respected.

Appendix 6: An overview of threats and concerns for Living@Sea

In Table A6.1, an overview of threats that might occur in Living@Sea has been made. Causes for each threat and their consequences have been enlisted. Examples of potential mitigation measures are also given.

Table A6.1 An overview of threats and concerns for Living@Sea (Source: Blue21, 2019)

THREATS & CONCERNS		CAUSE	CONSEQUENCE	RISK	MITIGATION
	Lightning Strikes.	Extreme weather. Flat /no landscape.	Structural damage. Personal injury. Threat to human life. Fire.		Taller buildings at regular centres with integrated grounding technologies.
	Corrosion.	PH content (Saltwater).	Structural damage. Material fatigue. Ecological threat.		Limit the exposure of joints and corrosive materials. Implement protection for corrosive materials, joints and servicing.
	Extensive marine growth	Natural integration.	Damage to anti-corrosion coatings. Additional weight.		Underwater drone monitoring of marine growth, Marine growth prevention in 'corrosive risk' areas
	Harmful algae blooms	Lack of natural light	Ecological Threat.		Underwater drone monitoring of marine growth, Marine growth prevention in 'corrosive risk' areas
	People falling from platform.	Human error. Poor visibility. Ice formation. Excessive movement. Freeboard breaching wave.	Personal Injury. Threat to human life.		Access at regular centres with emergency life preservers and blankets. Visual indicators of edge (material change, height variance, buffer or railing).
	People becoming trapped below platform.	Human error.	Personal Injury. Threat to human life.		Sufficient draft heights to prevent people swimming below structure. Controlled swimming zones.
	Freeboard breaching waves.	Extreme weather. Nearby passing vessels.	Structural damage. Risk to human life.		
	Snow loads and ice drift.	Extreme weather.	Structural damage. Personal Injury. Threat to human life. Additional weight.		

THREATS & CONCERNS		CAUSE	CONSEQUENCE	RISK	MITIGATION
	Extreme precipitation.	Extreme weather.	Flooding. Additional weight. Structural damage.		
	Fire.	Human error. Mechanical/ Electrical failure. Extreme weather.	Structural damage. Risk to human life. Personal injury.		
	Vessel colliding with platform.	Extreme weather. Human error.	Structural damage. Structural failure. Personal injury. Risk to human life.		
	Excessive movement.	Extreme weather. Poor stability.	Discomfort. Material fatigue. Structural damage. Personal injury. Risk to human life. Structural failure.		
	Excessive noise.	Mooring. Friction of joints.	Discomfort.		
	Sinking.	Severe structural damage.	Risk to human life. Calamity.		
	People being trapped between platforms.	Extreme weather. Human error.	Risk to human life. Personal Injury.		Design out minimal gaps.
	Lack of Accessibility.	Poor planning and implementation.	Risk to human life.		Easy access for emergency servicing.
	Service Failure.	Material fatigue. Human error. Extreme weather.	Ecological damage. Flooding. Structural damage.		
	Falling Objects.	Extreme weather. Excessive movement.	Structural damage. Personal Injury Risk to human life.		

THREATS & CONCERNS CAUSE CONSEQUENCE RISK MITIGATION

	Material Fatigue.	Extreme weather. Excessive movement. Excessive vibration.	Structural damage. Structural failure. Risk to human life.		Monitoring, Maintenance and repair
	Colliding Platforms.	Extreme weather.	Structural damage. Structural failure.		Minimum gap widths, Adequate mooring, regular monitoring of key junctions
	Excessive vibration	Extreme weather. Poor stability.	Discomfort.		Optimizing platform shape (minimizing the perimeter-to-surface area ratio).
	Excessive Wind.	Extreme weather.	Structural damage. Material fatigue. Personal injury. Risk to human life.		Minimise wind-tunnelling effect, robust materials on exposed facades.
	Drift.	Insufficient mooring.	Colliding platforms. Structural damage.		Sufficient mooring in place. Preventative measures to avoid platform collisions.
	People tripping on gaps or junctions.	Human error. Poor visibility.	Personal injury.		Visual indicators of gap (material change, height variance, buffer or railing) Minimum distances between neighbouring platforms.