Maritime Visions
Investigation on Mega Floating Leisure Island

A contribution to the idea:
"L3-06: Module Based Mobile Leisure Islands"

March 11, 2008

Abstract

This paper is a contribution to the European Maritime VISIONS Academic Contest 2008. We investigate the feasibility of building a Very Large Floating Structure (VLFS) and using this as a floating island offering tourists accommodations such as apartments, ports, dining and activities. To narrow the scope the concept was narrowed down to building of a single MFLI (Mega Floating Leisure Island) with fixed apartments and ports for standard yachts.

The MFLI is pictured as a pontoon type that lies like a plate in calm water. Because of the large horizontal dimensions, stability of the intact VLFS structure is not a problem. Different kinds of forces will influence the island. Wind, wave and drift forces can be mentioned. The elastic deformations are more important than the rigid body motions, because the pontoon-type is very flexible compared to other kinds of offshore structures. Therefore the drift force is the main contributor.

In addition to investigate the technical feasibility the economical model for such a structure have been assessed. The original plan was to sell apartments on the MFLI, but after consideration of different business models we found that rental apartments would generate more income and is therefore a better economical model for the MFLI. The current plan envisions a total of 250 apartments on the MFLI, ranging in size from 400 m^2 to 1000 m^2.

We also considered the geographical location of such an island. Using a GIS-analysis we conclude that the Mexican Gulf or the areas surrounding Indonesia seems like appropriate places for the MFLI.

In addition to the technical issues addressed there are quite a few areas that are outside the scope of this project, but they are nevertheless important to assess if the MFLI is to become a reality. Among these are areas

such as on-shore infrastructure, security, safety and environment and various technical issues not addressed. These issues are described in general and ideas to what we think are appropriate solutions are given where applicable.

In the end we conclude that though this concept needs future research, our preliminary results indicate that neither technical, geographical or economical constraints precludes this concept from realization in the future.

Preface

This report is a contribution to the *European Maritime VISIONS Academic Contest 2008*, for the Think Tank of the European Shipbuilding Industry.

The report investigates the economical and technical feasibility, sustainability and explores the concept of a MegaFloating Leisure Island, a Very Large Floating Structure serving as a leisure island.
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- Odd M.Faltinsen
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- Andreas Velgaard

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Acronyms

- BA - Business Area
- FEM - Finite Element Method
- GIS - Geographical InformationSystem
- GODAE - Global Ocean Data Assimilation Experiment
- MF - MegaFloat
- MFLI - Mega Floating Leisure Island
- MOB - Mobile Offshore Base
- LFS - Large Floating Structure
- SWOT - Strengths, Weaknesses, Opportunities and Threats
- TRAM - Technological Research Association of Megafloat
- VLFS - Very Large Floating Structure

List of Tables

List of Figures

Contents

1 Introduction

The leisure and tourism market is an ever changing market, driven by the need for new and exciting destinations to visit and new things to explore. People want to get away from their daily life and get the feeling of exclusiveness. At the same time they want it to be convenient and spend as little time as possible "getting there". One of the major leisure markets is the maritime leisure market. It can be divided into three major branches: Cruise ships, personal yachting and on-shore apartments and hotels.

Cruise ships are heavily limited by their shape and design. Guests live rather close to each other and the destinations are more or less fixed. Yachting invloves a lot of work if you prefer to sail the yacht yourself. Some see these tasks as the essence of a holiday, but others want such things to be taken care of. For those wanting others to take care of these things the cost of a full-sized crew for and the maintenance of a yacht yachting is an expensive form of leisure. On-shore apartments come in a variety of standards, and are located at various places, ranging from cheap hotels on the Greek islands and party-hotels on Ibiza to the exclusive castles in Nice and Saint-Tropez.

The problems with these on-shore destinations are that the best places are already developed, the cost of developing an infrastructure is high and many countries tries to limit the number of these places, to preserve the site for the locals.

Meanwhile, the area of Very Large Floating Structures are being researched. The Japanese have been researching floating airports over 1000 meters in length, and other countries like the USA are working on large floating structures for use as naval bases and an extension to the aircraft carriers of today. The main advantage of a VLFS is the fact that is doesn't take up valuable and maybe even limited area on the shore-line, they can be placed in a number of locations (given acceptable weather and wave conditions) and have a small environmental impact compared to land-fill projects such as the Palm Islands and "The World" off the coast of Dubai.

In this paper we will look on the possibilities of using a VLFS as a floating Leisure-Island. We call this concept "Mega Floating Leisure Islands" (MFLI). We envision this as a structure capable of providing it's visitors with high-end apartments, located off the coast of some of the worlds best marine leisure venues. These islands will cover an area of approximately 450 000 m^2, with a total of 250 apartments, ranging in size from 1000 m^2 to 400 m^2. The islands will provide all the necessary services, together with a wide variety of activities and facilities like restaurants, shopping areas, boat rental and sports to mention a few.

Seeing that the field of VLFS rather new, that no operational VLFSs of this size have been built and that the research on habitable VLFSs is almost non-existing, this paper will focus on the feasibility of the concept as a whole, with emphasis on the construction of a VLFS of this size, an assessment of the market potential of a MFLI and the overall arrangement and possible locations of such an island. We will therefore not focus on the building of the individual apartments apart from the assumptions needed to perform economical calculations, nor will the design and construction of such things as restaurants be assessed. We assume that if this concept proves technically and economically feasible the task of designing the "top-layer" of the island will be much similar to building and maintaining a similar complex on-shore.

The fact that this project is a work of students with limited time, budget and experience makes it impossible to do all the proper calculations and get hold of all necessary information. In these cases we will however try and do our best by looking at the works of other, making assumptions and try to sketch a general plan for the execution of these calculations. As a consequence of these limitations this project will work mainly as a "proof-of-concept", making simplified assumptions and treating several aspects as problems to be solved at a later stage. However, we hope that the general conclusions of this project will be accurate enough to decide whether the concept is feasible.

This report starts with a literature survey, giving an overview of the research that has been done in the field of VLFSs. The intention of the survey is not to give the reader a deep understanding of the area, but to serve as a state of the art introduction on what has been done as of today and what we can assume will be done in the next 10-20 years. It will also point the reader to additional sources of information, and hopefully provide enough background to understand the terms and assumptions used throughout this paper. Following this we explain how and why we have chosen the Business area(s) in the Visions Contest we have, and our understanding of them. This is useful for the reader to have in mind when reading the rest of the report.

Then, after describing our idea and concept more in detail, including the process of coming up with the idea in the first place and how it evolved, we get down t the technical part. The section named "Detailed design description" takes a closer look at most of the things that needs to be solved to make our vision a reality. We try our best to come up with plans, assumptions and detailed description on each of the areas critical for the concept. This covers the fundamental calculations regarding size, sea-keeping and stability, as well as cost analysis and marketing plan. In addition to this we look into the task of finding a suitable geographical location for such a structure, using a GIS-analysis.

As with any new technology or concepts, there are a number of issues and technology gaps that needs to be addressed. This is done in the "Issues and technology gaps"-section. This section has focus on identifying the issues and gaps, not on solving them. However, we will point to possible solutions wherever possible. The issues and gaps in this project arise from several sources, ranging from our limited time and experience to the fact that we are looking at a scenario several years in the future.

At the end of the report we point out what further work that will have to be done in order to make the MFLI a realizable concept, as well as a discussion of things brought up throughout the report. We will also try to asses the probability of the vision ever becoming a reality, discussing the pros and cons of the suggested solution and the validity of the assumptions made.

2 State of the art in VLFS

Although the area of (V)LFS [1] / MegaFloat is a rather new one, there have been some research in the field the last couple of decades. In this section we will try to give an overview of the research that has been done, and the existing literature on the subject. By doing this, we hope to give the reader an understanding of the area, the research that has been conducted, and insight in some of the terminology used.

2.1 What is VLFS?

The term VLFS is very loosely coined, although the name itself carries some meaning, it is in general a large structure floating on the sea-surface. It is used as a substitute for landfill, as this can be expensive and even impossible in some places. An overview of the history of VLFS's and application areas are given by Watanabe et al. (2004). They use the term MegaFloat, and as they explain:

> Large pontoon-type floating structures have been termed Mega-Floats by Japanese engineers. As a general rule of thumb, Mega-Floats are floating structures with at least one of its length dimensions greater than 60 m.

Another description of MegaFloat is given by Suzuki (2005):

> Megafloat consists of a floating structure, a mooring system, and access. If necessary, breakwater construction is considered.

In this quote we also see that it exists several types of VLFS's, one of them being pontoon-type VLFS, this is quite simply a large pontoon-structure, and to quote Watanabe et al. (2004) again, these are only;

> ... suitable for use in only calm waters, often inside a cove or a lagoon and near the shoreline.

The other type is a semi-submersible type, these

> ... are raised above the sea level using column tubes or ballast structural elements to minimize the effects of waves while maintaining a constant buoyancy force. Thus they can reduce the wave-induced motions and are therefore suitably deployed in high seas with large waves. (Watanabe et al., 2004)

[1] (Very) Large Floating Structures

While the Japanese have concentrated on the Pontoon-type MegaFloats, especially in the TRAM[2]-project, (Suzuki, 2005), the semi-submersible type have been researched mainly by the Americans.Their interest is for use as a MOB [3], being described by Remmers et al. (1999), cited in Girard et al. (2003) as:

> As presently envisioned, a MOB is a self-propelled, floating, prepositioned base that would accept cargo from aircraft and container ships, and discharge resources to the shore via a variety of surface vessels and aircraft.

A study described by Rognaas et al. (2001) lists along functional requirements for a MOB a size of 1525.0 m by 152.5 m.

2.2 Why VLFS?

The main reason for building VLFSs are the need for land in areas like Japan, where land-area is limited and expensive. The traditional way of obtaining new land is land reclamation by landfill. This has been done by countries such as Japan, Singapore and the Netherlands. This method has several problems, first of all the method is not cost effective, nor feasible when water depth is more than 20 m, and/or the seabed is soft (Watanabe et al., 2004). The environmental impact is also large, by destroying the underwater habitat and may lead to disturbance in toxic sediments.

2.3 Pontoon-type VLFS and TRAM

Although the semi-submersible VLFS has some advantages, it is a more complex structure. As we focus on a structure in modest weather condition, we therefore focus on the pontoon-type VLFS (also known as MegaFloat). On these grounds the literature survey will focus on research performed on pontoon-type VLFSs, and especially the TRAM-project as described in Suzuki (2005). The TRAM Association was formed in 1995, and was active until 2001. The main goal of this project was to prove the soundness of a VLFS by building an airport. They conducted two research phases, phase 1 and 2. In phase 1, a 300 by 60 m model was built, in phase 2 a 1000 by 60-120 m model was built, and take off and landing was tested (Suzuki, 2005).
The aspects investigated by TRAM where, among others:

- Global hydroelastic response

[2]Technological Research Association of Megafloat
[3]Mobile Offshore Base

- Detailed structural design
- Collapse behavior
- Collision analysis
- Functionality and safety criteria
- Fabrication and towing of units
- Joining of units at sea

The TRAM-projects proved the soundness of this concept, although it left some issues to be solved. Many of the problems encountered by the TRAM-projects have been investigated by Nippon Steel (Tori et al., 2000). The technical report sums up the technologies attained for designing and constructing a VLFS at real size. The techniques include:

- A wave analysis method capable of handling a floating body of any shape as an elastic body
- Displacement reduction mechanisms where worked out
- Methods for analysis and design of mooring system
- Methods for construction of VLFS, including methods for connecting smaller units offshore
- A corrosion-protection method for a lifespan of 100 years

Although these technologies are mentioned, and developed, they are not described in detail. That means that we cannot make directly use of them, but knowing such techniques have been developed makes the construction of a VLFS more probable.

3 Selection of business area

This project falls mostly under business area 5 (BA5), "Floating Infrastructures", but is also influenced by business area 1 (BA1), "Maritime tourism & leisure". It was selected mainly due to this areas being the ones we found most interesting. BA5 can be looked at in many ways, and is, as we see it, the most visionary of the business areas. As we understand BA5, there are several things to focus on, one of them being tourism. This intervene with BA1, which main focus is on tourism and leisure at sea.

We wanted to incorporate tourism and leisure, because we see this as an area where many things can be done, and an area that according to the figures presented in the description of business area 1 is rapidly growing. We take an optimistic look at the future, combining scenario 1 in BA 1 with scenario 1 in BA5. Our idea is therefore based on a high interest in tourism and leisure in general, and maritime tourism and leisure specifically. This is seen in combination with a scenario where the first (V)LFS [4] structures have been built and have proved economically and technically feasible, and the public opinion is positive towards such structures. With these prerequisites in place, the task of building a floating leisure island off the coast of today's more luxurious leisure resorts will be much easier in the future, and possibly even a needed one, as the on-shore resorts will be characterized by high cost and low availability.

3.1 Our understanding of the selected business area and scenarios

As stated, combining two areas and scenarios, we make some additional extensions to the ones described. In the following we will try to summarize our understanding of the scenarios and our additional presumptions:

- In spite terrorist and environmental "threats", the tourism and leisure industry is continuing its rapid growth. As a great number of the population get more money and more spare time, they want to see and explore the world, and have a good time doing so.
- The maritime tourism and leisure industry currently lacks values like; individuality and diversity. Despite this, many want to have a holiday in a marine environment. Currently there are three main possibilities for a holiday in marine surroundings:

    Traditional cruise ships. (Lacks individuality)

[4] (Very) Large Floating Structure

Self owned yachts (costly, requires an individual effort)

Resorts on attractive coast-lines (high cost if you want to be isolated, too crowded in some places, completely stationary)

- The area available for shore-based leisure-facilities is shrinking, due to more places being built, environmental concerns and changing climate. There have already been built artificial (non-floating) islands in some parts of The World (wikipedia.org, 2008).
- We assume that in some years the first MegaFloating structures / VLFSs have been built and proven to be feasible.

4 Proposed solution

Our idea went through several abstraction phases. The final idea that we propose is a very narrowed concept of the preliminary idea. This is mostly due to the limited time frame of the project and to retain an acceptable degree of concrete feasibility. In the following we present our most abstract idea, which should be considered as the main idea, ending with what we actually elaborated further in detail in the report.

4.1 Initial idea

Our vision started as a network of floating islands (MFLI[5]). Each of the MFLIs serving special attractions adapted to different needs posed by the society. The network of MFLIs would have an abstract connection via individual housing-units in the form of more traditional yachts/boats. The housing-units would be able to travel on an individual basis to and from MFLIs and on-shore coasts. When connected to a MFLI the housing-unit would be able to integrate completely, extending the existing unit with the attractions provided by the MFLI for example by using a specialized docking system. Concrete examples on this could be to have a MFLI providing an underwater aquarium/aquacultur which the housing-units could connect to and have their "home" extended with parts of this facility for a period of time. Attractions on the MFLIs could then not be limited to only providing leisure attractions but could support almost any facility, like energy production, food production etc. The network could then pose as a traditional society with the difference being added value from the marine resources naturally available.

4.2 Narrowed approach

As we realized the preliminary idea was very comprehensive with respect to the resources and scope of the project we decided to narrow the approach and to elaborate on this. The focus of the project was narrowed down to a coarse-meshed technical as well as economical analysis of one island as a singular structure with the aim of technical and economical feasibilty. This resulted in eliminating elaboration on the housing-units, integration with these, issues related to networking of the MFLIs and in general narrowing the elaboration to a feasible abstraction level to fit the scope of the project.

The narrowed approach is defined more specifically initiating some specifications on size and form. These were partly set before performing analysis, however

[5]Mega Floating Leisure Island

some are results of the analysis performed during the project. The specifications for the MFLI is listed below. In figure 1 we propose a highly conceptual model of our concept. The model should be looked upon as a reference model, enhancing that it is the main structure that is in focus, not necessarily the houses etc. put on top. The specifications listed are only high-level specifications and is elaborated in the following parts of the report.

- Size and form

  Cross-shaped, modular based form with rounded ends (see figure 1)

  1100x1100 meters equivalent approximately 450.000 m^2

  Total height 6 meters (not including structures in the "top layer")

  Pontoon-type VLFS

  Steel as material

  Conventional production methods

- Economics

  Should be able to house enough customers to be economically self-sustained

  Products provided should be in the high-end luxury market

  Overall goal: Provide individuality and diversity

- Climatic properties

  Significant wave height below 2 meters

  Low average wind-speed

  Comfortable temperatures

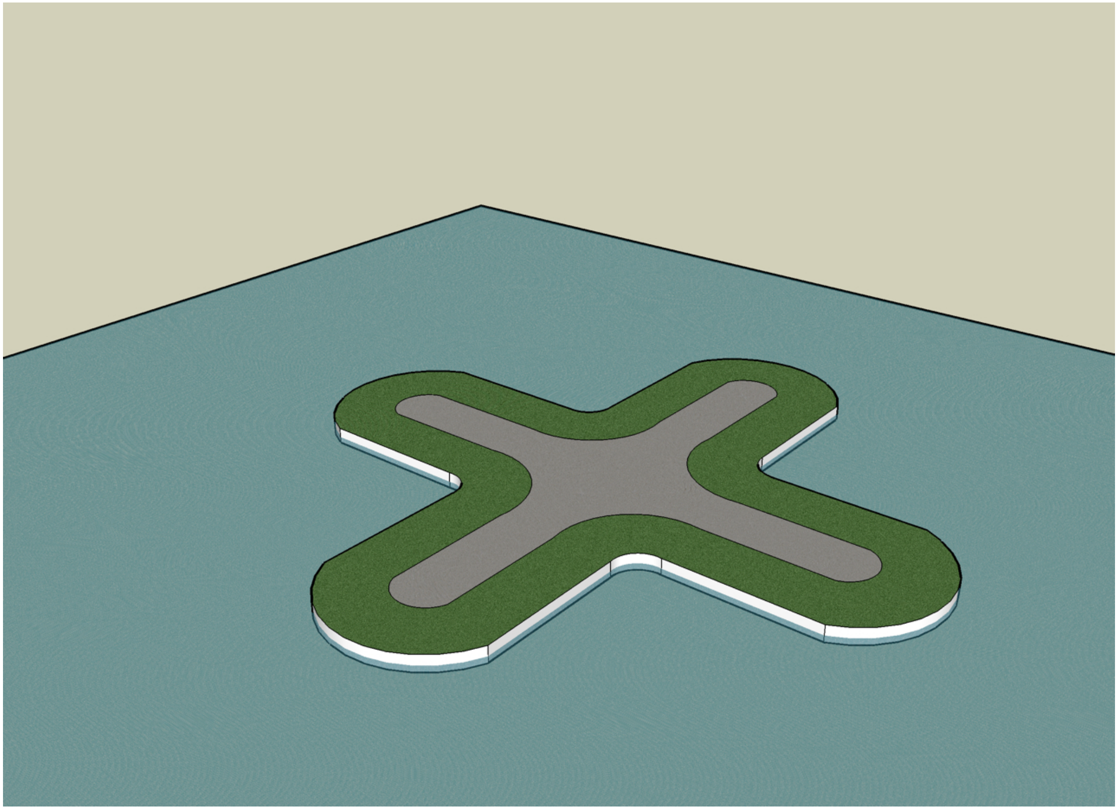

Figure 1: Conceptual model for the idea

5 Detailed design description

In this section we will elaborate on details conserning our analysis of the concept. The section is composed generally into one technical part and one economical part, in addition we present some analysis performed to support the overall analysis.

5.1 Sizing and principal dimensions

There are two types of Very Large Floating Structures (VLFS); the pontoon type and the semi submersible type. The pontoon type lies in the water like a plate, while the semi submersible is raised above sea level using column tubes or ballast structural elements, like a platform. A semi submersible is preferable in water with high waves. This because the water line area is smaller then for the pontoon type, so the forces from the ocean will not be as huge here. Further more they are also more moveable. The pontoon type structure features high stability, low manufacturing cost and easy maintenance and repair.

When deciding which of these types to use, and also the dimensions, we had to take into consideration the placing of the island and its purpose. The placing is very important due to waves and current. If the waves are too high, one can not use the pontoon type. In this case the island is to be used for tourism, and it is therefore preferable to have as calm weather as possible. By that very fact the pontoon type was the chosen design type.

5.1.1 Approach for sizing

We began considering the area demand. An important criteria was how much space we needed to be able to offer what we specified in the business concept. It is important to provide a certain luxury and individualism together with some attractions like for instance restaurant, shopping and so on. How many units per island and the size per unit is a huge factor in area decision. And this again is very much influenced by the economy. It is important that there are enough units to cover the costs of the island, but on the other hand it is also important that there is certain privacy provided, and that the units are large enough to provide luxury. In this case the shape of the island was very much discussed. We wanted a shape that would utilise the area as good as possible and also give privacy to the different units. The result is a cross-shape design as shown in figure 2

5.1.2 Draught

Second decisions on depth and draught was performed. This is dependant on how much weight the structure has to carry. Since we do not know the exact value of

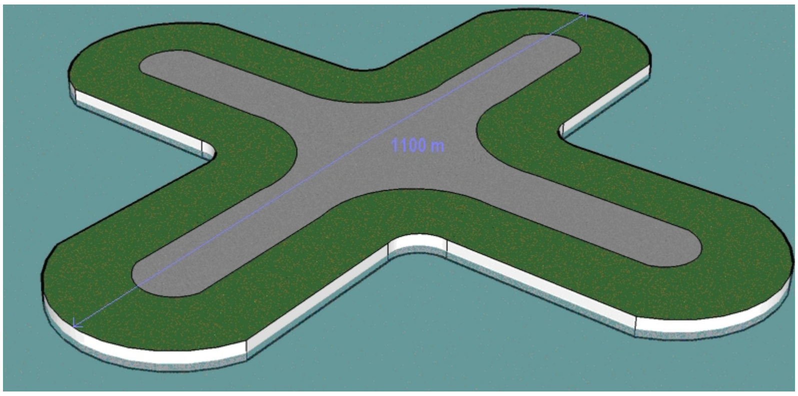

Figure 2: Conceptual sketch with elementary sizing.

this we look at different draughts. When the draught is decided we then determine the final depth of the island.

The island will lie in calm water. Therefore the forces from waves are neglected in the first turn of estimation. It is also assumed even distributed load over all, so the buoyancy will counteract this load, see figure 3. This means that if we find the buoyancy for an actual draught, this will be the load we can carry, according to equation 1

$$\text{buoyancy} = g\rho = A_{WL}Tg\rho \tag{1}$$

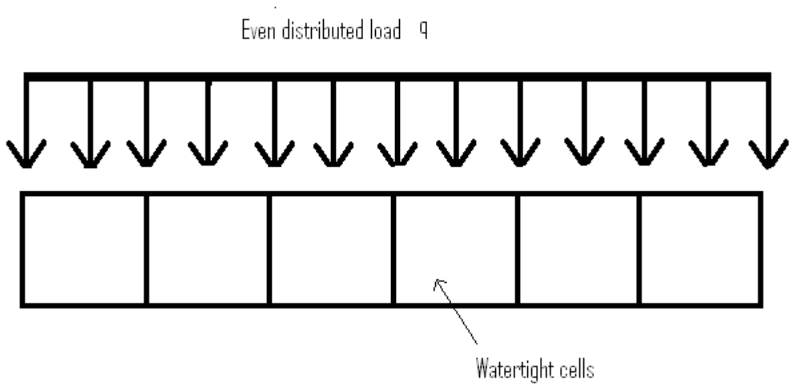

Figure 3: Conceptual view of even distributed load

From table 1 we see that with a draught equal to 3 m, the weight per m^2 is 3.1 ton. This is more than enough weight. Since the island is to lie in calm water we assume that it is enough to have 3 m also over the water line. The result is therefore a depth of 6 m.

Name	*Symbol*	*Value*	*Unit*
Area	A	4500 00	m^2
Draught	T	3	m
Depth	D	6	m
Volume	V	2700000	m^3
Volume displacement	∇	1350000	m^3
Gravity	g	9.81	m/s^2
Dencity seawater	ρ	1025	kg/m^3
Buoyancy	b	13575	MN
Weight	Δ	1383750	Ton
Weight per area		3.1	Ton/m^2

Table 1: Buoyancy estimation

5.2 Weight estimation

In this section we will discuss a few aspects concerning weight estimates. To be able to perform a weight estimate, several tasks have to be carried out first. There have to be executed a plate analysis to decide the thickness of the steel plates, a strength analysis to find out how much steel we need to strengthen the plates enough. The dimensions of the island have to be known.

5.2.1 Plates

The plates lie on an elastic foundation, since we are making a floating island. So there should be performed a "plate on elastic foundation" analysis. How to do this can for instance be found in Timoshenko & Woinowsky-Krieger (1959). When this analysis is executed, estimates of the thickness of the plates can be made, as mentioned earlier. Performing this analysis is very resource intensive, and demand more resources than we have at our disposal.

5.2.2 Braces and bulkheads

Calculating the needed number of steel braces is also a demanding task. To run this kind of analysis a computer program would be needed, and a schematic drawing of the braces and bulkheads placing in the void spaces inside the island. The different braces will be influenced by different moments, strains and stresses. By calculating them, the sizes and numbers of braces and bulkheads can be decided. All of these aspects is on a more specific level than what we focus on here.

5.2.3 Other materials

All of the above deals with the island itself. But the weight of all the material on the top of the island has to be estimated, to decide the full weight of the complete island. Objects like the buildings, soil for lawns and other elements for living comfortable would have to be taken into account.

The different calculations will most likely have to be performed iteratively to get a suitable estimate.

5.2.4 Stability analysis

Stability is important for the floating properties of the structure. Figure 4 explains the basic principle of the stability investigation performed.

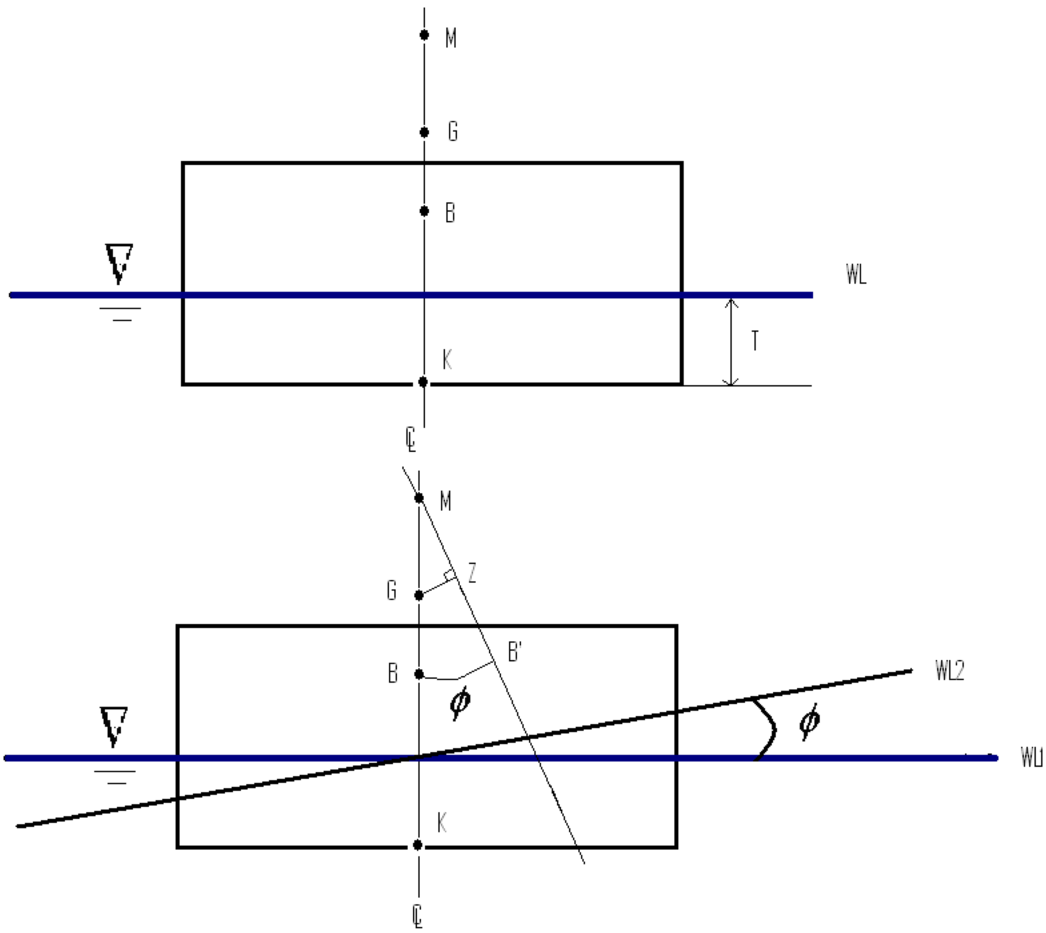

Figure 4: Helping figure for the stability analysis

Where:
M = Initial metacenter
G = Center of gravity
B = Center of buoyancy on WL
K = Keel
T = Draught
WL = Water line

If the structure should heel, the point M is the rotation point, like shown in figure 4. The requirement is that GM is larger than zero. GM can be found using equation (2).

$$GM = BM + KB - KG \tag{2}$$

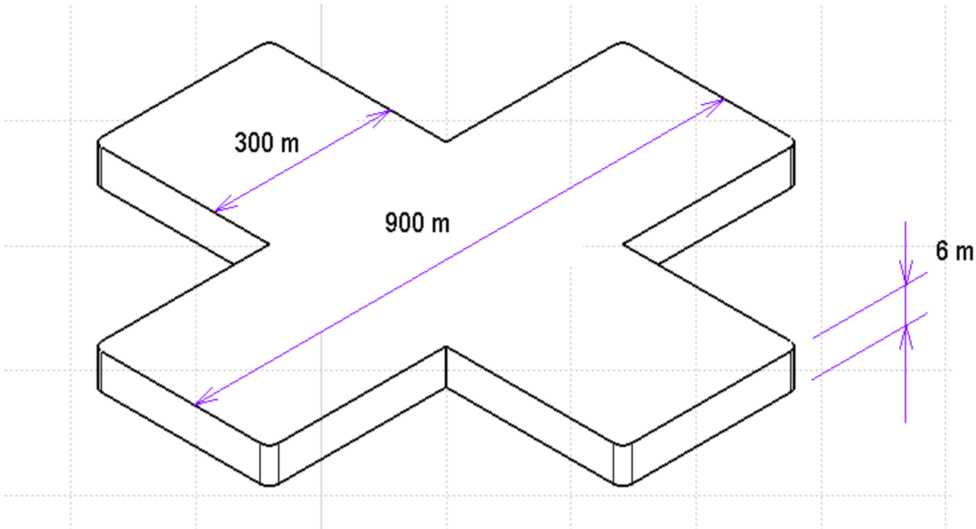

Figure 5: Simplified structure used in stabilty calculations

First we need to find is the moment of area, I. In equations 3, 4, 5, 6 and 7 we deduce the moment of area in an attempt to find BM.

$$BM = \frac{I}{\nabla} \tag{3}$$

$$I_x = I_y \tag{4}$$

$$I = \frac{900 \cdot 300^3}{12} + 2\frac{300^4}{12} + 2 \cdot 300^4 = 19575 \cdot 10^6 m^2 \tag{5}$$

Secondly one needs to find the volume displacement. In our case this is estimated with a draught of 3 metres.

$$\nabla = AT = (900 \cdot 300 + 2 \cdot 300 \cdot 300) \cdot 3 = 450000 \cdot 3 = 1350 \cdot 10^3 m^3 \tag{6}$$

Finally we can directly calculate BM from equation 3 and get the result showed in equation 7

$$BM = 14500m \tag{7}$$

Buoyancy is assumed to be two thirds of the draught, and the point of gravity 1 metre above the water line. Then it is only left to estimate GM. The results can be found listed in table 2.

Name	*Estimation*	*Denomination*
I	19 575 000 000	m^4
Area (A)	450 000	m^2
Draught (T)	3	m
Volume (∇)	1 350 000	m^3
BM	14 500	m
KG	4	m
KB	2	m
GM	14 498	m

Table 2: Results from stability analysis on whole structure

As mentioned the requirement for a structure to be stabile is that GM is larger than zero. The results show that this requirement is more than fulfilled. So stability of the intact VLFS structure is not a problem, this is because of the large horizontal dimensions.

In construction of the island, all the modules have to be stable during transportation to the sight. So in table 3 the stability calculations for a module can be seen. And as shown the GM is also here positive.

Name	*Estimation*	*Denomination*
I	675 000 000	m^4
Area (A)	90 000	m^2
Draught (T)	3	m
Volume (∇)	270 000	m^3
BM	2 500	m
KG	4	m
KB	2	m
GM	2 498	m

Table 3: Results from stability analysis on a single module

5.3 Sea keeping analysis

Different aspects play a role when discussing sea keeping of a floating island. That may be how the island reacts to different forces and loads that influence it and how to keep the island from drifting away from it's original place. There is therefore a need to moor the island.

5.3.1 Forces

Different kinds of forces will influence the island while floating in the sea. Wind, wave and drift forces can be mentioned.

The pontoon-type is very flexible compared to other kinds of offshore structures, because of a large length to depth ratio. Therefore the elastic deformations are more important than their rigid body motions. The wavelengths are very small compared to horizontal size of typical VLFS. Equation 8 indicates small ratio between the wave length and the length of the construction:

$$\frac{\lambda}{L} = \frac{1}{50} \sim \frac{1}{100} \tag{8}$$

This means that the added mass is small. This comes from the acceleration between the construction and the wave particles is little. Thereafter comes the drift forces. They will be the main contributor in this case.

When discussing drift forces they can be divided into two different types: mean drift forces and slowly varying drift forces. The last type is important when choosing mooring type.

To be able to calculate the different forces affecting the island, wave theory is important. When studying wave theory the result is knowledge about the wave motion and velocity, pressure between water and floating subject, and about wave energy. All these sub categories of the wave theory is important. For calculation in wave theory Bernoulli's equation (9) is often used.

$$p + \rho g z + \rho\frac{\delta\phi}{\delta t} + \frac{\rho}{2}|\nabla\phi|^2 = C \tag{9}$$

Where C equals a function of time.

The drift forces can also be calculated out from this equation. The last element on the left hand side of equation 10 is of the most relevance when calculating them.

$$\frac{\rho}{2}|\nabla\phi|^2 \tag{10}$$

This element gives us equation 11 which can be found in Faltinsen (1990):

$$F_1 = -\int_{-\inf}^{0} \rho\frac{\delta\phi}{\delta t}|_{y=0} dz = 2\rho\xi_a\frac{1}{k}\sin(\omega t) \tag{11}$$

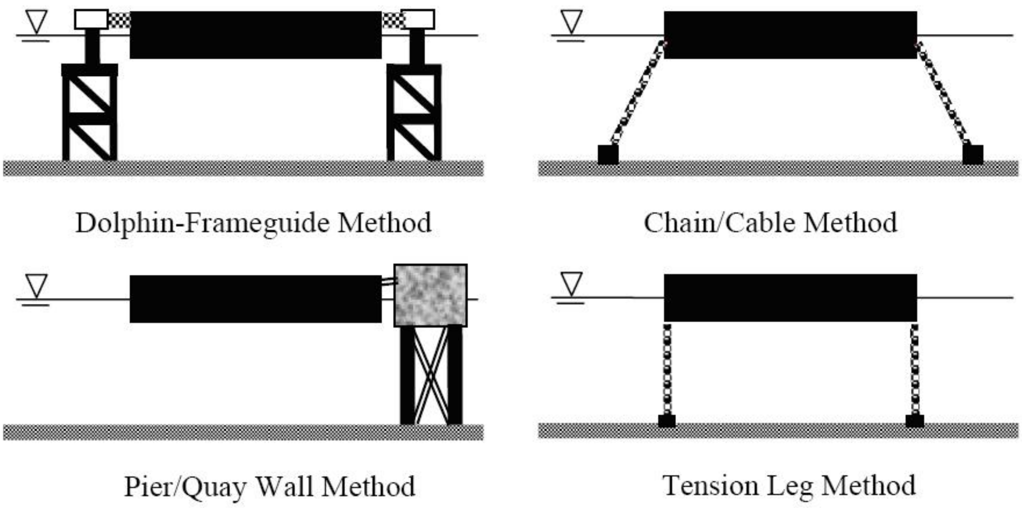

Figure 6: Various types of mooring systems

The notation in this case depends on in which direction one studies a floating object. The MFLI is symmetrical, and the drift force will therefore be the same in the two dimensions.

In order to benefit from this equation there is a need for a wave spectrum. It describes the wave energy with respect to frequency and direction in one given position or area, and is relevant for calculating forces on a floating object. Since we do not have this spectrum we can not calculate the drift forces.

5.3.2 Mooring system

The island can be placed on varying depths ranging from a few meters to several kilometres. Like discussed earlier, forces will influence the island no matter where it is put. And to keep it in place and stop it from drifting away, mooring is required. Mooring can be done in a couple of ways. The selection of mooring system depends on conditions the VLFS has to withstand, and what purpose it will serve.

Like there are different kinds of forces influencing a floating island there are also various types of mooring system, and they have different advantages. Some types can be seen in figure 6.

The two types to the left in figure 6 are very good at restricting horizontal displacements. But they might be more exposed to wind, waves and earthquakes. The last two are less exposed to earthquakes, but especially the cable mooring type is vulnerable to horizontal motion; the longer the chain the larger the motion might be.

Before choosing either of them, calculations have to be made; both with respect to depth, wind and wave forces, earthquakes and other elements that might influence the mooring.

We would like to use the cable system so that the island can drift a bit in the sea, and be integrated with it. Calculations shoould be done to determine if this is feasible. Motions could affect how comfortable it is to live on the island, and this is a important constraint. All these questions and calculations require much work, time and heavy computations. Therefore they are outside the scope of this project.

6 General arrangement plan

6.1 Arrangement possibilities

With the overall design we have chosen for the VLFS there are an infinite number of possible arrangement for structures. The island can be used for several purposes, but we have studied the possibility for using VLFS as a leisure destination. We have concluded that the shoreline should be used for apartments or living areas, and the center of the island for commercial purposes. We imagine several commercial possibilities:

- Circus, amusement park etc.
- Shopping (tax-free)
- Casino
- Spa

In addition to these "extras" the island must provide necessities like food and other supplies needed for the inhabitants. There is also need for harbours.

6.2 Living areas

There are many possible arrangement for the living areas, but we will now present one solution that can give a large income, and will utilize the space efficiently. The solution will diversify with three different sizes for apartments, all of them largely related to low-price leisure destinations.
The three apartment types are:

- 112 apartments on ground level, with dimensions of 20 x 50 m (20 meters towards the sea, area of 1000 m^2) and a 20x20m garden between the sea and the apartment. These are in the 280x50 m buildings in figure 7.
- 112 apartment on top of the 1000 m^2 apartments. Dimensions of 20x30 m (20 meters towards the sea, area of 600 m^2) and a 20x20m balcony towards the sea.
- 40 apartments on ground level. Dimensions of 13x30 m (13 meters towards the sea, area of 400 m^2). Possibility for gardens, these are in the 130x30m building in the figure.

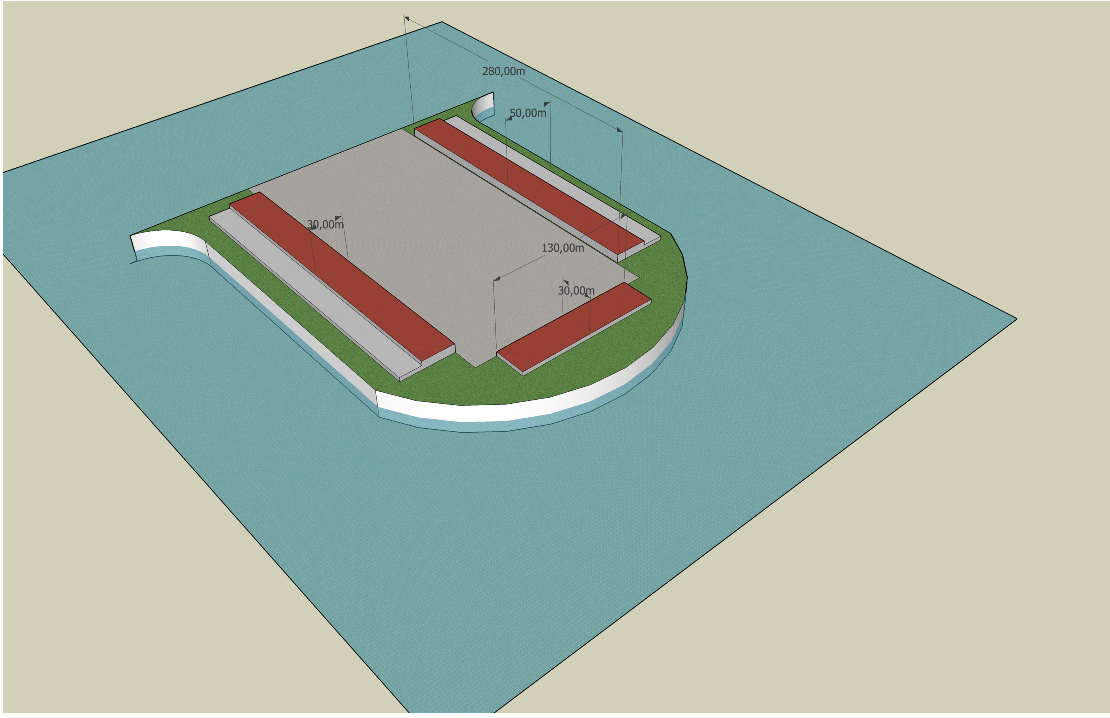

Figure 7: Proposed generic arrangement plan

The sketch in figure 7 shows a concept of these on one part of the island. This arrangement plan leaves 160x300 meters of commercial area in the center, in addition to 300x300 meters in the center of the island. On each side there are 14 1000 m^2 apartments and 14 600 m^2 apartments. On the end there are 10 400 m^2 apartments.

6.3 Geographical location

Geographical location is crucial both for the technical and economical analysis that we exhibit throughout this report. The technical analysis provides requirements for especially climatic aspects. Whereas the economical analysis depends highly on the culture, availability of tourism and so forth. This gives a interrelationship between the technical, economical and the location aspects. We have tried to address relevant requirements in the search of locations that are the most suitable locations given our requirements.

6.3.1 Requirements

Mainly the requirements revolves around climatic areas but also includes land use and socio-demographic sides. We can split the requirements in the two analyses that provides the requirement; technical and economical. Below is the requirements listed, with some rational when needed. Note that the requirements are idealized and not necessarily included in the final geographical analysis, these are reported more thoroughly under the subchapter on analysis.

6.3.2 Technical

The technical analysis of the concept constrains the location mainly on climatic aspects. Listed below are the aspects considered as limitation on the climatic areas.

- Wind speed

  As low as possible.

  Not essential

- Significant wave height

  Lower than 2 meter on annual average.

  Crucial

- Sea depth

  Not exceeding extreme depths

  Possible to anchor

6.3.3 Economical

Economical requirements are necessary with respect to the overall economic feasibility and sustainability. The market plan and the final geographical location

Data set	*Provider*
Coast lines	United Nations Environment Programme
Wind speed	Global Ocean Data Assimilation Experiment (GODAE)
Significant wave height	Global Ocean Data Assimilation Experiment (GODAE)

Table 4: Data sources and providers in the GIS analysis

relates to each other and needs to adapt and collaborate in order to get the best result. Below is the requirements that we propose according to our market plan.

- Proximity to coast line.

  Be within 3 to 20 km from nearest coast line

  The closer the better.

- Temperature

  Attractive average temperature

- Proximity to already attractive tourism areas

  The more tourism the larger potential market

6.3.4 Analysis

n order to find a set of potential locations we performed a GIS[6] analysis. The analysis consisted of traditional overlay operations using logical and mathematical operators. The project had very limited resources available, constraining the amount of data and time available. This resulted in a more proof-of-concept coarse-meshed analysis.

The data used in the analysis consisted of data provided freely from a set of sources, listed in table 4. Software that was used was mainly ESRI ArcGIS 9.1 with ArcINFO licensing and some specialized minor converting software developed especially for the project.

6.4 Results

As mentioned, the overlay analysis was performed using traditional logical and mathematical operations. More specifically we weighted the data in accordance with our requirements and prioritization of these with emphasize on the technical requirements. For the overlay we used the built-in weighted overlay operation in ArcGIS 9.1. This results in weighted areas with weights illustrating prioritization

[6]Geographical Information System

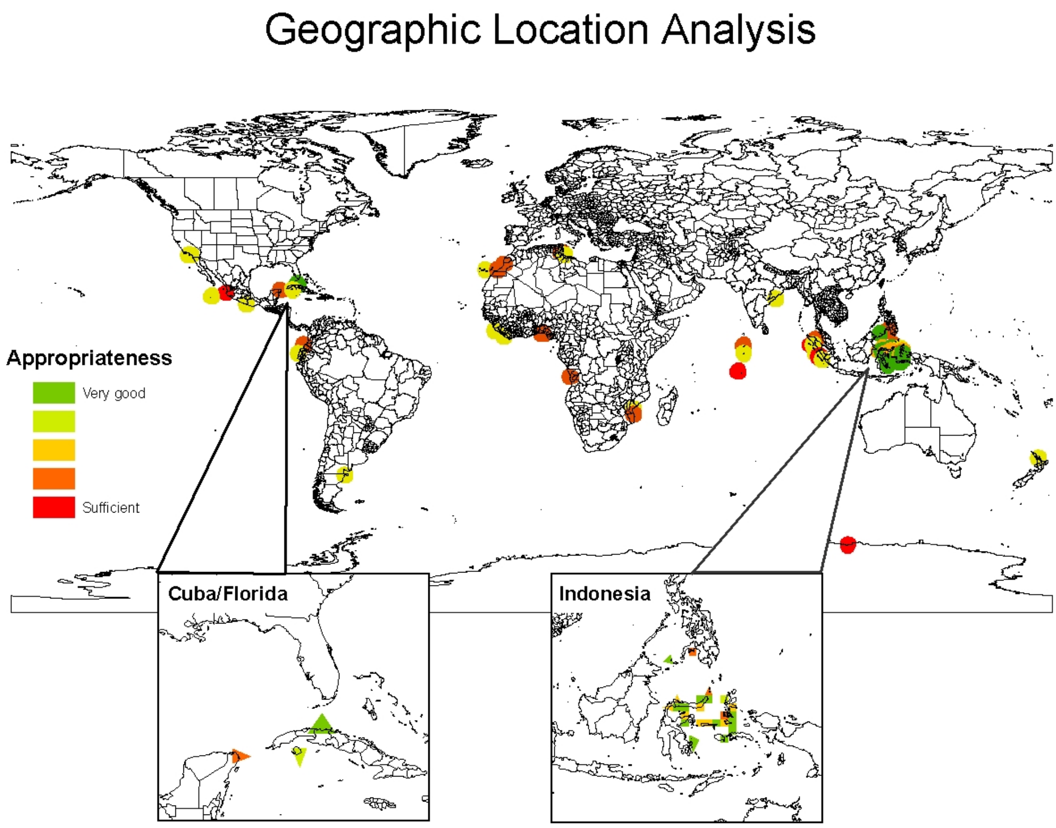

Figure 8: Results from GIS analysis, areas extremely emphasized.

(eg. usefulness) according to the aggregated requirements used in the analysis. Given our strict requirements, even when not taking all requirements into consideration, the areas in the result set are not that many. Having in mind that the analysis is very coarse-meshed the results could be slightly different when performed with fine-meshed computing. However the analysis should be considered as a proof-of-concept and we consider that it is fully scalable to be performed as a real analysis, given the resources needed. An overview of the resulting areas, with the areas extremely emphasized, can be seen in figure 8.

6.5 Cost analysis

Cost analysis on a very large floating structure is difficult, especially since there has not been many projects in this area. The largest project is the TRAM phase 1 and phase 2 experiments for a floating runway in Japan. Although not directly comparable, we will use the cost from the TRAM phase 2 experiment to give a estimate for the cost of our mega floating leisure island. This, because TRAM phase 2 is the largest floating structure that has been constructed, and it is a pontoon type, the same type that we wish to use for our island. The information on the TRAM experiments is collected from Suzuki (2005) where other sources are not mentioned.

6.5.1 Our island

- Area of about 450 000 m^2
- Height of 6 meters
- Volume: 2 700 000 m^3

6.5.2 TRAM phase 1

- Area of about 18 000 m^2
- Height 2 m
- Volume: 36 000 m^3

6.5.3 TRAM phase 2

- Area of about 84 000 m2
- Height 3 m (ibid)
- Volume: 252 000 m^3
- Budget: 103.6 million USD which includes:

    ILS[7] test

    Landing and take off with aircraft

    Conceptual study

    Juridical aspects

[7] Instrumented Landing System

- TRAM phase 1 incorporated in structure. (Isobe, 1999). Therefore total "new" construction:

  252 000 - 36 000 = 216 000 m^3

6.5.4 Result

Price per m^3:

$$\frac{103.6 * 10^6 \text{USD}}{216000 m^3} \approx 480 \frac{\text{USD}}{m^3} \tag{12}$$

Cost estimate for our Island:

$$2700000 m^3 * 480 \frac{\text{USD}}{m^3} \approx 1.3 * 10^9 \text{USD} \tag{13}$$

With an inflation estimate of 2.5 percent p.a.: Cost estimate, 2008 USD:

$$1.3 \text{ billion USD} * 1.025^7 = 1.5 \text{ billion USD} \tag{14}$$

6.6 Marketing plan

6.6.1 Executive summary

The concept of Mega Floating Leisure Islands (MFLI) is attempting to combine luxury maritime leisure with individualism. We see today that cruise tourism lacks individualism, and luxury based coast-lines have limited area and is rapidly filling up. There is simply not enough coastline to meet growing demand in the long run.

The MFLIs will provide individual docking for yachts and ships. Typically we see owners of super-yachts, with length above 100 feet and permanent crews, as possible customers. The MFLI will provide housing and luxury services that the yacht cannot provide, as well as restaurants, supplies and other requirements of the high-end leisure customers.

6.6.2 Situation analysis

Market summary

Super-yacht market In 2003 it was estimated that there were 1600 super-yacht vessels worldwide (Anon, 2003). The industry was about 4.5 billion GBP (or estimated 6.75 billion EUR, with currency exchange rate of 02/08/2003 (oanda.com)). The market had an annual growth rate of 6%, which would be equal to a 9 billion EUR market in 2008. This is not directly related to our concept, but is a indication that there is a large high-end maritime leisure market.

BA1 - Scenario description The European market is the fastest growing segment in the worldwide cruising market with a current market share of 33%. The US market is the largest market today (64%), while the Asian is the youngest and smallest.

The European market for luxury small ships is approximately 10 000 berths, in USA it is appr. 7 000 berths, and 1 000 berths in Asia and middle east. In USA there is a 1 000 berths luxury sailing vessels market. Traditional luxury is 5 000 berths in Europe and 1 000 berths in USA.

Tourism Trends for Europe The European Travel Commission has in the paper Commission (2006) analysed the market, and following is a brief summary of the report. This report is focused on the European market, but we believe that many of these trends also apply to other markets. Global market information has been difficult to acquire, and therefore we have not been able to obtain more information.

Demographics Pensioners are typical time-rich, with little restrictions on leisure time, while many workers have pressured leisure time. Pressured leisure time is leading to shorter and more trips. At the same time is the trend to save up leisure time and use it for longer trips strong. Traditional packet holidays is decreasingly popular while independent holidays and individualised luxury destinations have increasing demand.

Environmental issues There is a growing concern related to climate change, and this will lead to a competitive advantage for those who can prove environmental and social responsibility. Product sustainability will be important in marketing.

Culture Culture tourism is growing in Europe, and can be connected to the demand for independent and individual holidays.

Consumer trends Tourists have greater freedom to travel, and this may lead to a demand for more niche products. The current boom in health and spa products will lead to new markets.

Transport Destinations should be easily accessible, due to pressure on leisure time. The growing demand in the cruise market is met by new and larger ships but there is a lack for cruise terminals, especially in the Mediterranean.

Second homes - residential tourism This market has been growing and it is expected to grow in the future as long as relatively low-cost property is available.

SWOT-analysis A SWOT-analysis looks on internal strengths and weaknesses and external opportunities and threats with a concept.

Strengths

- Can combine the luxury of cruise tourism (the islands will provide luxury at sea, like cruise ships) with individualistic trends
- Localisation in water provides possibilities for transport (and can have high-speed boats docking)
- Possibility for second homes with coastal view
- Can combine the concept with different pricing models:

  Rent a permanent spot on one island

Rent a spot on multiple islands (travel between with boat)

Visiting an island (with or without boat)

- The large size creates possibility for many attractions, like casino, SPA, water sports, restaurants and so on

Weaknesses

- Will be costly, and therefore limited markets (location will be important, proximity to airports etc.)
- Uncertainty among customers related to floating structures
- Need multiple islands to realize concept with travel between islands and renting of spots on multiple islands. Therefore large starting costs
- Cost of building floating islands versus land based leisure destinations

Opportunities

- VLFS is cost efficient when the water is deep and the sea bed is soft
- Environmental friendly (research shows that it will not harm ecosystems or ocean currents (Suzuki, 2005))
- Mobility, the entire VLFS can be moved
- Exclusivity: there will not be many islands, and these can provide a unique experience

Threats

- Competing projects like The World with artificial islands
- Many laws and regulations.
- Products for high-end leisure markets are vulnerable to economic repression

Competition MFLIs will create its own market. There is no directly comparable products today, but still there are some competition. The traditional land based destinations will stay strong, and large projects like The World Islands in Dubai provide luxury leisure destinations. The MFLI will provide opportunities that these cannot, with regard to location and mobility. Land based destinations is limited because of limited area available while MFLIs is limited only by ocean area.

Keys to success The perhaps most important success criteria for the MFLI is location. Both combining demand for leisure destinations in a given area, and the possibility for short travel time. We see the MFLIs as a global product, and it must therefore be placed near airports or other transport hubs to provide short travel time.

In addition the MFLI must provide services that justify a high price. Very large floating structures have high construction costs and this will lead to high rental prices. Therefore we must provide luxury services that makes the product interesting for our market segment.

Critical issues Critical issues for realizing the concept is:

- To accomplish a business model for income that justifies the costs associated with building mega floating structures.
- Technical challenges related to constructing MFLI with regard to strength, size and possibility for providing a basis for luxury leisure
- Legal issues with regard to location in high demand markets: will we be able to place the MFLI in locations that justify high prices?

6.6.3 Marketing analysis

The key to the marketing strategy is to focus on the uniqueness of the product: Mega Floating Leisure Islands providing luxury leisure on floating islands at high demand destinations. This can provide docking for ships in areas where other docking is expensive and limited.

Mission MFLIs mission is to provide the customer with a luxury leisure destination and docking for ships. With the floating islands we will provide an unique experience for the customer.

Marketing Objectives

- Maintain a high demand for rental, with high occupancy
- Ensure that MFLIs is an alternative for all potential customers worldwide

Target Markets Due to the high cost of construction MFLIs the target markets will be money-rich customers. The villas with docking opportunities will typically interest customers with yachts or super-yachts, while villas without docking will interest other customers and customers wishing an unique experience on a mega floating island. The market for super-yachts have a steady growth, and it can therefore be expected a growth in the market for docking in high demand destinations. One of the customers trends is the wish for experience-holidays providing a unique experience, the MFLIs can provide this.

Positioning MFLI will position itself as the premier luxury leisure concept. This can be achieved by using MFLIs competitive edge: unique experience, destination and environmental friendly. The MFLIs will not harm the ecosystem and ocean currents (Suzuki, 2005), and therefore the product should be marketed as a concept with social and environmental responsibility.

Strategies The marketing strategy must first create customer awareness of the product. Since the product is a unique and new application of mega floating technology this can be achieved via the news media. The message that will be communicated is the unique product and the target markets. A customer trend is that many find leisure locations via the Web and the MFLI will therefore need a web site that can provide information. The first step in creating awareness is to make sure the web site is well known. The third part of the marketing strategy is advertisement. This should be targeted towards the target markets. There is no need for broad advertisement, since the segments that could be interested in the product is limited.

6.6.4 Financial break-even analysis

The break-even analysis for our concept will rely on a specific arrangement plan which we have described earlier. We will attempt to break-even with the estimated investment cost, and find a proposed rental cost for the apartments. This analysis will be based on the following assumptions:

- The cost analysis is correct, and the cost of constructing the island will be covered from rental income from apartments
- The construction costs of living areas and commercial areas will be covered by income from the commercial areas
- The maintenance costs will be covered by income from the commercial areas. (This assumption base itself on that the construction costs for buildings will

be covered early, and commercial income from that point on will be sufficient to cover maintenance costs)

- The structure will have a lifetime of 50 years
- The discount-rate is 5%
- The geometrical decrease of income is 1% p. a. (this means that the income from apartment areas will decrease with one percent per year).

Pricing assumptions:

- The smallest apartments (400 m^2) will have a weekly income of X, and there is a total of 40
- The medium apartments (600 m^2) will have a weekly income of 2X, and there is a total of 112
- The large apartments (1000 m^2) will have a weekly income of 4X, and there is a total of 112
- The apartments will be rented out 45 weeks per year

This gives the following model:
Yearly income:

$$(40 * X + 112 * 2X + 112 * 4X) * 45\text{weeks} = 32040X \tag{15}$$

With 50 years lifetime, 5% discount rate and −1% geometrical increase this gives:

$$\text{Total Income} = \frac{\text{yearly income}}{\text{discount rate} - \text{geometrical rate}} \left(1 - \left(\frac{1 + \text{geometrical rate}}{1 + \text{discount rate}}\right)^{\text{lifetime}}\right) \tag{16}$$

$$\text{Total Income} = \frac{32040X}{0.05 - (-0.01)} \left(1 - \left(\frac{1 + (-0.01)}{1 + 0.05}\right)^{50}\right) \tag{17}$$

$$\text{Total Income} = 505826.81X \tag{18}$$

We have earlier estimated a total cost of 1.5 billion USD. This gives:

$$X = \frac{1.5 \text{ billion}}{505826.81} \approx 2965\text{USD} \approx 3000\text{USD} \tag{19}$$

This gives prices (weekly):

- Smallest apartment: 3000 USD
- Medium apartment: 6000 USD
- Large apartment: 12000 USD

7 Issues and technology gaps

Some areas concerning the development of the MFLI lies outside the scope of the project and our expertice. However, they are still essential to the project and should therefore be adressed. This section deals with these cases, giving an overall description of the problems and how important they are. While the problems presented in this section are not solved we have tried to give pointers to what needs to be done in order to solve them, or how exsisting technologies that can be adopted to the MFLI. It is important for the reader to have in mind that if the issues presented here are not assesed and found a proper solution to the MFLI will most probably not be a reality.

7.1 Technical Feasibility and Design

Our island would need more calculations on several topics, amongst them are: strength, stability, wave response and weight. This section uses material from Ohmatsu (2004).

7.1.1 Strength

In our calculations we have assumed even distributed load, but this is highly unlikely to occur. More calculations would be required, both with regard to buckling, bending, stresses and strains. One way of doing this is by a FEM analysis.

We have also assumed calm water, and no waves. This assumption is not accurate. There will always be some waves influencing the MFLI, and these have to be considered. It could be done by the Mesh Method.

Should the wave forces become larger than our MFLI could take, we could use breakwaters or anti-motion devices to reduce the effect.

7.1.2 Stability

The only stability calculations performed in this report is the initial stability. In this calculation the point of buoyancy and gravity are just assumed. These should be fully worked out to achieve a good picture of the stability. There are several numerical methods for computing these, for instance Simpson's rule.

There should be performed a leakage stability, initial stability for storm conditions and stability for different loads.

7.1.3 Docking system for individual housing units

The initial idea was that the yacht and the living quarters on the MFLI should be fully integrated into one housing unit. For this purpose a suitable "docking"-

solution should be developed.

7.1.4 Energy supply

With regards to energy production the ideal goal is that the MFLI should be self-provided. This can be achived using several existing technologies (wind mills, solar panels), or technologies that are being developed as of today (wave-power systems). One of the largest concerns are noise, the vacationer should not be disturbed by the production of energy. In the light of this solar panels seems like a good solution, but the efficiency and capacity of these should be researched in greater detail.

7.1.5 Waste problems

What to do with the waste? Wealthy people today have a habit of throwing away much garbage. Where should it be put? How to dispose of it? There are several options. For instance a tube down to the sea bed if the island lies in deep waters. Or it could be shipped in to the mainland. Which is the better has to be further researched.

7.2 Production

The realization process of a VLFS can be described as follows (Suzuki, 2005):

- Design
- Approval by government
- Fabricaton
- Towing
- Joining at Sea
- Completion

We have previously described the design part, and approval by government is not in the scope of this project. With regard to fabrication, towing and joining at sea we have seen some issues that need to be researched.

Our design is a module-based approach. The MFLI can be constructed with five modules of 300x300 meters, and if this is difficult the 300x300 modules can be broken down to smaller modules. This is done so that many shipyards can have the possibility to produce the modules, and therefore reduce cost and construction time required. One aspect we have not had time to research is the need for shipyards close to our geographical locations, or at least shipyards that are close enough to be able to deliver modules. In addition to weather constraints on the location, there will also be weather constraints related to towing and joining of the modules.

With regard to the housing and commercial facilities on the MFLI we think that the most feasible approach is to construct this after the island is constructed at site. This approach makes it possible to standardize the island construction so that it can be made more cost efficient when experience in the field increases. In this approach we also assume that the construction of structures atop the island will be rather similar to construction of such structures on-shore. However, specific issues regarding the adaptation of on-shore construction methods to a floating structure will have to be researched further.

7.3 Security

The project revolves mostly on the abstract idea-generation and feasibility-analysis in several dimensions. Hence the project does not focus on security analysis. In this section some of the main issues on security is addressed. We split potential threats to security in three main parts; deliberate attacks, severe accidents and one general part addressing some general security issues.

7.3.1 Deliberate attacks

Attacks with the motivation of destroying construction has become an increasing and real threat to any construction and particularly huge and popular "landmarks". This is not necessarily forseen attacks due to "traditional" environments such as war and conflicts, but is also motivated by other elements often refered to as terrorism.

Due to the size and potential innovative properties of the islands it can be a popular target for deliberate attacks. The potential attacks could be both under- and over-water, thus increasing the complexity of enforcing security. The concept of MFLI is based on a civilian customer mass and aims to promote a leisure-based atmosphere. This property struggles against traditional security models. Similar to an airport where the threats are dealt with in a very strict manner, thus decreasing the leisure-atmospere to a minimum. In this concept such enforcement as on an airport is not a feasible solution since it will break the business model.

The concept is natively supporting some security. Especially is the fact that the business model is built on a restricted client mass, thus enabling security measures on the clients that have approved access to the islands. However it could still be an issue with the approved clients since the security measures on a daily basis should be limited, in contrast with traditional airport security.

Many of marine security issues have been solved by industries like national navy forces and securing off-shore facilities like oil plattforms an alike. These solutions are, however, not natively suited for a civilian mass and will need quite heavy adaption to fit into this concept. We do, however, consider the solutions to be able to adapt and thus fit with the concept and provide at least some degree of security of potential deliberate attacks.

7.3.2 Severe accidents

There are numerous of accidents that could occur with a structure on this size. The most natural parallels are accidents that happens to off-shore oil plattforms and accidents on cruise-ships. In our concept most of the general accidents from both of these domains could be possible. In general there are three conserns for accidents on an island like this. First there are the human sufferings from an accident, second the environmental impacts as the result of an accident and third is damage on the island because of an accident. The human sufferings could be dealt with in having an efficient evacuation structure. We have not focused on this, since we see the problem as an already solved issue, by for example the off-shore oil rigs domain. However the existing solutions may not be sufficient for a structure this size and will require adaption to the domain in this concept and should be investigated further.

The potential environmental impacts from an accident could be huge considering the size of the structure. However the islands are not intended to have a great amount of toxic material, such as oil-tankers and alike, thus reducing the potential toxic waste. We have not concentrated on this issue and have no ready-made solution for the potential environmental impact from an accident. It is recommended to put effort on this in further work.

7.3.3 General security

In this subsection we mention some consideration that could impact security issues. One consideration is legal constraints that occur due to the geographical location of the islands. We have, as earlier discussed, enforced requirements on the location in such way that the islands will be in non-international waters. This introduce several legal issues and should be a parametere in the security analysis. In the project we do not address any legal issues that arise from this fact, since it is considered out of the scope of the project goals.

7.4 Infrastructure and Logistic

In the MFLI being a lot more like an island than a ship, its infrastructure requirements are more like those of an island than those normally applied to a ship. This doesn't mean there aren't a lot of issues to be dealt with in regard to this.

7.4.1 On-Shore infrastructure

The vision of the MFLI is that it offers the visitors a complete holiday experience on the island, reducing the pressure on the on-shore facilities. However, there have to be some infrastructure on land in order to get the visitors to and from the MFLI. The crucial part is the travelling time to get to the island. Therefore there should be a port on the coast as close to the MFLI as possible, and an airport nearby, so that the travel time from the airport to the MFLI itself is as low as possible. The easiest solution to this problem would undoubtedly be to place the MFLI close to an existing port/airport with all the necessary infrastructure available. Another option could be to update an existing, but small port facility and/or airport close to the proposed location of the MFLI. Regardless of what solution is chosen there is no new technology needed, the only limited factor here is the price. Existing facilities will be preferred, as this is by far the most cost effective solution. Although issues such as existing on-shore infrastructure is a vital part of the concept of MFLI, it isn't considered to be in the scope of this project.

7.4.2 Port facilities at the MFLI

Small ships/Yachts The initial idea and vision for the MFLI included a yacht-sized "extension" of the island that served as living quarters for the visitors and was extended when connected to the island. This idea relied on the idea of a standardized "docking-system" to connect the "yacht-module" to the island. However, this proved to be difficult to engineer and would made the whole project a lot more expensive, as it requires drastic changes to existing yachts and/or the construction of completely new yacht-modules.

The current idea therefore lets the visitors use their existing yachts (eg: day-cruisers and alike, ranging in size from 20-100 feet) and super-yachts (sized from 100 feet and up), offering a standard docking facility such as those found on on-shore yacht-ports. These will be placed at the "shore-line" of the island, close to the apartments. Although this is a much easier solution than developing a whole new, fixed-docking system that locks a yacht-module to the island still presents some challenges. The technology of shore-based ports for small-sized ships such as yachts have been used and developed for centuries. It can be as simple as a floating raft with ropes holding the boat in place. We envision a more advanced facility, complete with refuelling capabilities and a high level of security, but the basic principle are still the boat floating alongside a fixed raft connected in a flexible way such as with a rope.

Most of the technology required here are already developed and used in marinas all over the world, there are few problems with placing such a port-facility at a floating island. The main challenge is adopting existing technology and integrating them in the overall concept and design of the MFLI. Some issues regarding weather conditions will arise, but the intention is to place the structure in calm water. Other problems present at on-shore ports such as water depth and tides will not be present, as both the boat and the island will be floating.

Large ships As well as providing port facilities for personal boats and yachts the MFLI will have to provide a way for larger ships to dock at the island. In general there are two types of large ships that will dock at the MFLI: Cargo-ships providing the MFLI with all the commodities it is not able to produce itself and transport ships bringing visitors to and from the island. The commodities ranges from food supplies and beverages for the restaurants to furniture and materials needed for maintenance of the structure, as well as waste-handling (if the chosen solution for waste handling is bringing it to the mainland). The transport-ships is to provide all visitors without their own yachts and the staff working at the MFLI a quick, reliable and comfortable transport to the island from the nearest port. These ships can be existing ship types and the design, construction and operation of these lies outside the scope of this project. In general these will typically be transport ships similar to those used in between islands and other short-range goods- and personnel transport at sea. The docking solutions for these larger ships are, similar to those for yachts, rather similar to those used for on-shore ports and only minor changes will have to be made to fit existing technologies to the MFLI. In contrast to the port-facilities for yachts, only one port are needed for large ships, the location of this port on the MFLI is somewhat crucial, as it will generate a rather high level of noise. The location of this large-ship-port close to apartments is not recommended for this reason.

7.5 Safety and Environment

The safety and environmental impact of VLFS is important for two reasons: first it must be safe to be on a VLFS in case of extreme wave conditions, collisions, tsunamis, earthquakes, etc. but it is also important for marketing for two reasons. Firstly, no customers would spend their holiday on a MFLI if they did not think it was safe to be there, and second the environment is a growing trend in marketing. As customers become more environmental aware the products that can guarantee social and environmental responsibility will have a competitive advantage.

7.5.1 Safety

The VLFS needs to be safeguarded from drifting, sinking and collapse. Suzuki (2005) describes some of the research done on mega float in Japan related to safety. In order to secure a mega float from tsunamis there are two approaches: either place the mega float in a protected bay area, or place it with some distance from the shoreline. The mega float will be safe from earthquakes who will only affect the mega float through the mooring system, but the effect can be larger if the earthquake has its center directly below the mega float. A VLFS should therefore not be placed in an area with high probability for earthquakes.

A VLFS is safeguarded from collision by its design. The VLFS contains several watertight compartments, and a collision from a ship would affect only a part of the structure. The compartments should be designed with regard to the largest ship which could collide with it (for example by assumed maximum ship size and speed in the area where it is placed), so that a collision would not lead to catastrophic failure or collapse of the floating structure.

7.5.2 Environment

The environmental study of VLFS is concentrated on two issues: affection on ocean currents and the area of shadow on the seabed cause by the VLFS. Suzuki (2005) says:

> Little changes were observed in various indices of either the physical or ecological environments, except for a small reduction in dissolved oxygen adjacent to the floating structure as a result for the activity of attached organisms.

In comparison with other luxury leisure destinations like the World Islands and Palm Islands in Dubai, the MFLI can therefore be concluded to have a small impact to the environment, and this could be an marketing perspective for the concept.

8 Discussion and Conclusions

8.1 Economical conclusions

8.1.1 Cost analysis

The cost analysis, resulting in an estimated cost of 1.5 billion USD, is connected to large uncertainty. The assumptions that is the basis for the calculation could be wrong, and there is likely to exist deviations between our estimate and an estimate based on more information. We have spent much time trying to find information or cost models for VLFS, but has not found anything. The closest is the numbers from Suzuki (2005), and other estimates that the cost of a Megafloat is 5-15 billion USD. A typical Megafloat is larger than our VLFS, and will therefore be more costly. Several simplifications has been done to make it practically possible to do the calculations within the scope of our project.

We believe that the price for construction of VLFS will decrease as more research and experience in the field is done, and therefore that our estimate is a reasonable first estimate for a brand new concept.

8.1.2 Break even analysis

This analysis is based upon the cost analysis, and will therefore be affected by the same uncertainties. In addition we have assumed a discount rate of 5%, which may be wrong. When we first started our research in the concept we wished to sell the living areas, but have later concluded that a rental model is more likely to be economically feasible. The downside is that a rental model is perhaps not luxurious enough, since the high end customer possibly want to own the apartment, not rent it.

In addition to the discussion of the correctness there is also need to discuss the calculated rental prices. Our estimated price of 3000 USD per week for a 400 m^2 apartment, 6000 USD/week for 600 m^2 and 12000 USD/week for 1000 m^2 shows that our destination will be targeted for the money-rich customers. We believe that our product has an uniqueness and appeal that will justify this price, and there is reason to believe that the final price will be higher due to a required rate of return. Further research should involve market surveys to try to estimate the maximum cost that potential customers would pay for such a resort. Still, we believe that the concept has many possibilities related to arrangement plans so that a realization could be found that makes this concept economically feasible.

8.2 Geographical conclusions

Although the geographical analysis is more a "proof-of-concept" than a full-blown analysis some conclusions can be drawn. According to the results from the analysis two areas stick out. Namely the Mexican Gulf and the Indonesia-area. One should be aware that these areas are the best ones, with regard to the parameters used in this analysis and our weighing of them. Therefore the areas here are by no means an overall best solution, and in order to decide where to place a MFLI a more thorough study with a lot more input data should be made. As stated before this was impossible to do with our limited budget and time.

Nevertheless some useful conclusions can be drawn from the GIS-analysis; First of all we have found that there exists places in the world to place a MFLI with regard to wave heights. Second we have shown that it is possible to conduct a GIS-analysis on the world as a whole, if the data are coarse-meshed enough. We have also found that most of the geographical information needed is available (though it may be at a cost) and we have come up with a set of parameters to include in such an analysis.

8.3 Technical conclusions

In this report it has only been shed light on some of the main technical difficulties regarding VLFS. Because of the large horizontal dimensions, stability of the intact VLFS structure is not a problem. Different kinds of forces will influence the island while floating in the sea. Wind, wave and drift forces can be mentioned. The elastic deformations are more important than the rigid body motions, because the pontoon-type is very flexible compared to other kinds of offshore structures.

These estimations alone are not thorough enough to determine whether the concept is feasible or not. However there has been done much research on the topic, and there are also examples of accomplished projects. This demonstrates that it is possible.

Further calculations might identify some problems with the shape and dimensions. But the idea in total should be quite feasible.

8.4 Overall conclusion

Despite small resources and short time our research have found several conclusions that we believe should prove that our concept deserves future research. We started with a large concept that we later narrowed into three issues:

- Can a VLFS of this size be built and is it technically possible to realize this concept?

- Were could we geographically position the MFLI?
- Is it economically feasible to realize this concept?

It is technically possible to realize this concept, and the technology exists now. Still, future research is needed to determine several variables and uncertainties we have encountered.

The MFLI can be placed in the Mexican Gulf and the Indonesian area. Each market has positive sides: the Mexican Gulf can take advantage of the US market, where luxury is a large segment and the Indonesian area is close to Japan and the large experience and knowledge related to Megafloat and VLFS there.

We were concerned about the economy of the project for a long time. It was difficult to find a model that could analyze the costs of construction a MFLI, but in the end we found an estimate that we believe is a fair starting point in order to decide if the project could be economically feasible. We also found that the MFLI has many opportunities and possible business models. In the end we landed on a rental model, and found through a break-even analysis that the project can be realized with a rental cost that is reasonable to believe could be competitive.

In the end we conclude that though this concept needs future research, our preliminary results indicate that neither technical, geographical or economical constraints precludes this concept from realization in the future.

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