Master thesis

Transportation systems for passenger transportation in floating cities.

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By

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Preface

This thesis is written in the framework of the master track transport, infrastructure and logistic (TIL). During this period the author also followed an internship at Blue21. The office of Blue21 was in the incubator of Yes!Delft in Delft. The slogan of the organisation is the following: building tomorrow's leading firms. Blue21 can certainly be considered as one of those.
Because of the land scarcity, floating cities will become necessary in the future. Blue21 researches the development of floating cities and was involved in several projects related to floating buildings and houses, such as the "Drijvend paviljoen" in Rotterdam and floating houses in the Harnasch polder in Delft. Other projects range from measuring water qualities near floating houses to creating visions for floating cities.

I would like to thank Rob van Nes and Jan Anne Annema for their feedback and discussions. Without them this thesis would not have been realised or would at least looked considerably different.
I would also like to thank Bart van Arem, for being the head of the graduation committee and for his questions, input and discussion.
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B. Vreugdenhil
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Executive summary

This thesis analyses transportation systems in floating cities. In 2050, three times the amount of land currently available on earth will be needed if the current lifestyle is maintained. Because most of urbanisation is in delta areas, and because Earth's surface consists of 70% water, floating cities could provide a solution to this problem.
Floating cities, however, require new infrastructure and transportation systems for their inhabitants. One way to facilitate transportation in a floating city is to use the same network, infrastructure and transportation modes that are used in regular urban and transportation planning on the land, but to place them on the water. On the other hand, it may be that building new transportation systems will lead to an improvement, because they would better suit the specific demands. The main research question is how to facilitate passenger transportation in a floating city in a feasible way, and how to evaluate the designs of these transportation systems. With *feasible* it is meant whether it is possible in a technical and economic sense to construct these transportation systems and whether they are safe enough for the inhabitants.

Floating cities of 25,000 inhabitants or more that facilitate the modern-Western lifestyle do not yet exist and it will probably take some time before such floating cities are developed. It is not known how transportation systems will function in such cities.
This has consequences for the research method. It is, first of all, not sufficient to collect data about transportation in floating cities or to analyse existing situations, because current floating settlements do not have the required size and do not offer the required comfort for the Western modern lifestyle.
Collecting data about transportation systems in a contemporary situation is also not sufficient for this research. The behaviour of the inhabitants can be different in the future, so it will be necessary to first translate the data to the specific situation.
Creating floating cities or parts of floating cities for experimental research will probably be expensive and is not possible in the timeframe of the research, so simulating these cities and transportation systems would be the best choice.
It is necessary to focus on a case study, because it is not possible to create thousands of simulations in the short timeframe.
A research-by-design method is chosen for this research. This method generates insight and knowledge by studying the effects of a number of design interventions in an existing situation.(Jong and Voordt) Because of the number of uncertainties in this particular case, it is also necessary to create variants for the future situation of the design, the city. In this report, variants of both the transportation systems and the layout of the floating city are therefore considered.
Although there is always something arbitrary about the choice of criteria, they should fit the characteristics of the research project. The amount of the criteria furthermore should be big enough to be able to create a insight into the situation, but there should also not be too much criteria, because the project could become too complex and not so transparent anymore. The criteria furthermore should differ from each other to create a good overview of the situation.

The criteria, chosen for this research project, are created together with the client. These criteria include keeping the advantages of current transportation systems, improving the drawbacks of the systems and case-specific criteria. The advantages of current transportation systems that should be taken into consideration are: comfort, cost, speed and safety. Though current transportation systems are not seen as fast, comfortable, safe or cheap, they have made it possible to travel distances greater than ever and are more comfortable and safe than transportation centuries ago.
The disadvantages of the current system that should be taken into account are the following: nuisance caused by transportation, a decrease in walkability and the output of emissions. Nuisances can consist of noise and fumes; the deciding factor is whether inhabitants are bothered by the transportation systems. The criterion *emissions* concerns the CO_2 output of the system, so the focus is more on the environment than on the

inhabitants. The decrease in walkability is a bit unusual in that it is not based on the transportation system but on the urban environment.
Case-specific characteristics that should be taken into account are the following: flexibility, scalability, innovation and required space. Floating cities are more flexible than conventional cities. The layout of a city can be changed more easily. Furthermore, floating cities can grow over time in a manner like that in which cities grew historically. *Innovation* concerns how innovative the transportation systems are and whether this would add something to the image of the city. The criterion *required space* has to do with how much space is needed in the city for the transportation system.

Figure 1, Research approach shows the approach developed for this study based on the existing methodology. In the first step analysis, the situation will be analysed and criteria will be created for the design project.
Based on these criteria design variants will be created. In step 2a, design-variants for the scenario are made and in step 2b, design-variants for the transportation systems. In the third step, the 4-step analysis, the designs will be simulated. This sub method evaluates the effects of the combination of the designs of the city and the transportation systems.
The 4-step model will provide information about the capacity, the amount of trips that will be made, the travel time and distances. This model determines whether the capacity of the systems fit the demand. Low capacities could lead to congestion, whereas high capacities are not cost effective. The numbers obtained from this simulation will also be used in the 4rth step, the multi criteria analysis.
Alternatives for a 4-step model are: choice models or activity based models. A 4-step model is chosen because it suits the scale of the design well and because the lay out of the city will be developed during the research project. This can be seen as zonal data on which the model can be based.
Commonly used modelling software (e.g., Omnitrans) was not used for the simulation; instead, a tailor-made model was used. The city will be developed in the future, and the lifestyle could be completely different than the current lifestyle. A new model is easier to fine-tune it to the specific situation and criteria. Using common software also means that workarounds need to be made to model the specific situation.
A multi-criteria analysis is used to evaluate the effects of the systems (step 5) because it allows a certain amount of freedom for selecting criteria and provides clear insight during the decision-making process. Furthermore, the number of uncertainties makes it difficult to make a decision based solely on the monetary value of the effects.

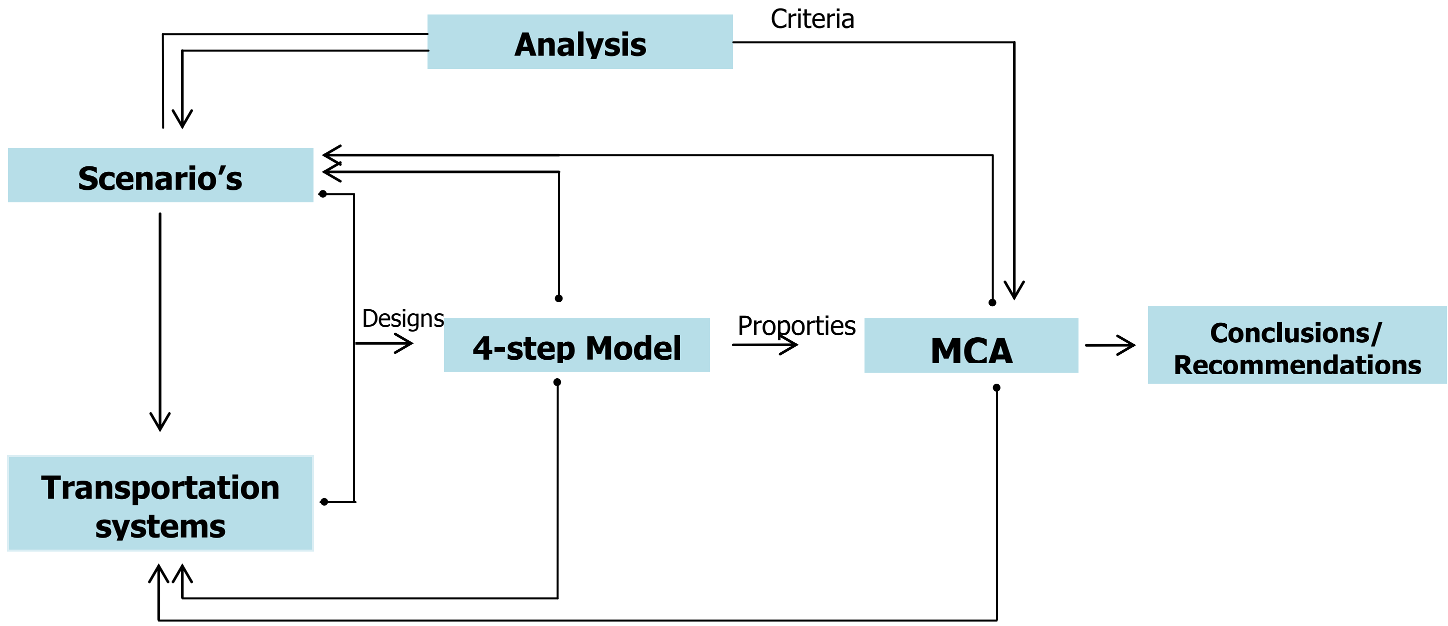

Figure 1, Research approach

The research approach is not necessary a linear method. Sometimes things can be created simultaneously. There are furthermore feedback loops between the simulation and the design period and the evaluation and the design phase. The research will lead to conclusions and recommendations for further research and to criteria for further research. A case study is chosen to test this approach: the Seasteading city. The city is designed for the Seasteading community. This is a group of entrepreneurs from Silicon Valley that wants to experiment with new forms of government. It is therefore assumed that the inhabitants of the city want to be independent as soon as possible and as a consequence will pay for the whole system. The lifestyle of the inhabitants should be similar to Western societies.
The city consists of different modules that can be attached and detached, and is designed so that it can grow organically next to the land and be placed on the sea when big enough. This also means that the city itself can change, because it can grow over time and modules can be added or removed. The focus of the report will be on analysing the transportation of persons.

Scenarios
Two scenarios are developed for the Seasteading city: a concentrated scenario, in which regions are specialized in certain services; and a scenario in which the functions are dispersed over the city like a scrambled egg.
As stated before, it is necessary to develop more than one scenario for the 4-step model. Floating cities are more flexible than current cities and can change relatively easy. The designer has less control over the city. Furthermore, it is clear that a relation between the functionality of the transportation systems and the layout of the city exists, but is not known precisely what the effects of certain planning decisions will be. By evaluating these two scenarios, more insight can also be obtained into this research topic.

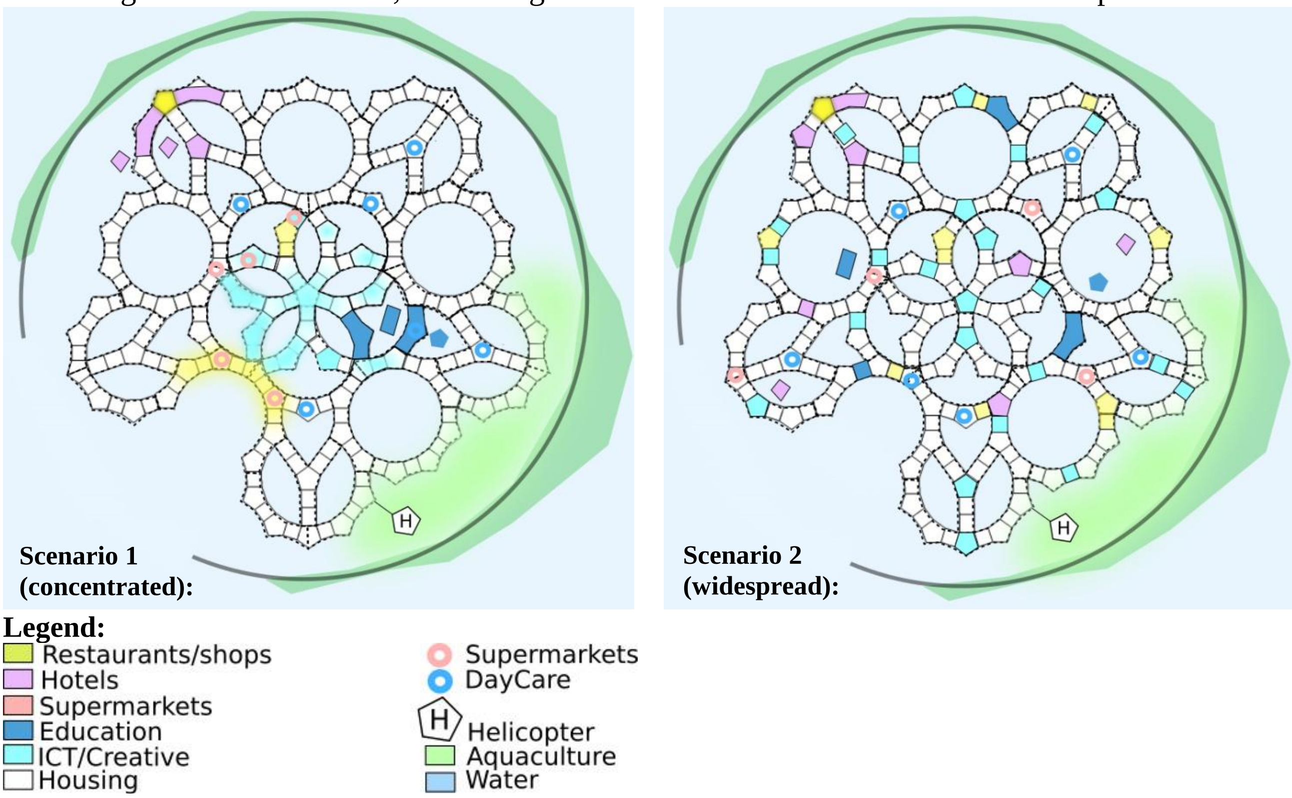

Figure 2, Scenario's

Transportation systems
It is also important to create a number of transportation systems, because it is not yet known which system should be used in the floating cities. Developing and analysing systems that differ significantly from each other will yield the most insight.
Because they differ conceptually, one system is chosen that focusses on personal systems and another is chosen that focusses on collective transportation. A system that focusses on water transportation is also

added, because it is a floating city and there is a lot of water. Both personal and collective transportation is used in transportation system 3: water transportation. All transportation systems also have a slow-mode network.

Transportation system 1 consists of a combination of personal transportation—such as cars or small personal vehicles—and slow mode transportation.

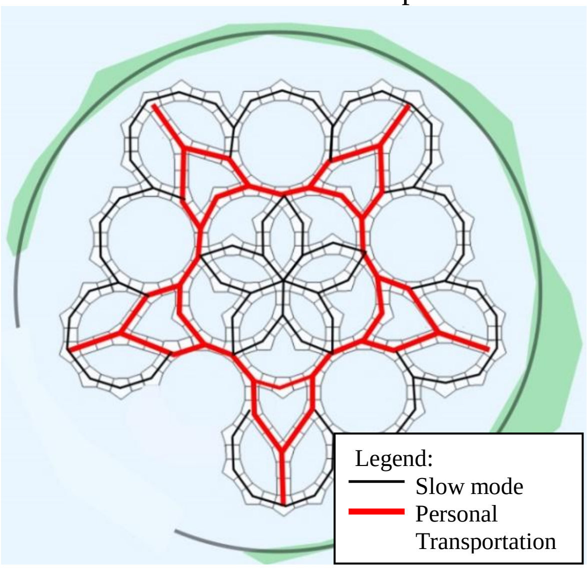

Figure 3, Transportation system 1, personal transportation

The second transportation system consists of a collective system. Because of the scale of the city, an on-demand ULTRA rapid transit system is chosen. This system is combined with slower transportation, such as walking or cycling. Figure 5 shows a network with an inner ring on the left and a wider network on the right. From now on this network will be called collection and distribution.

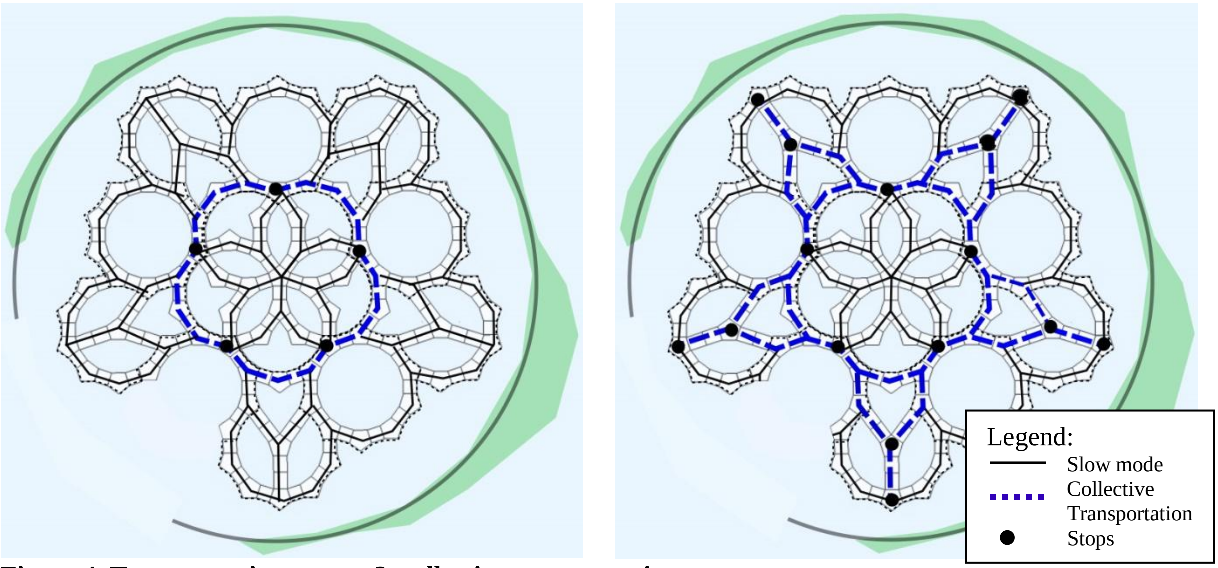

Figure 4, Transportation system 2, collective transportation

The third transportation system combines water transportation and slow modes. Inhabitants can walk everywhere or use collective transportation such as a ferry. It is also possible for inhabitants to use their own boats. It will be necessary to build bridges and harbours on certain locations for this system to function. Roads or dedicated lanes are not necessary.

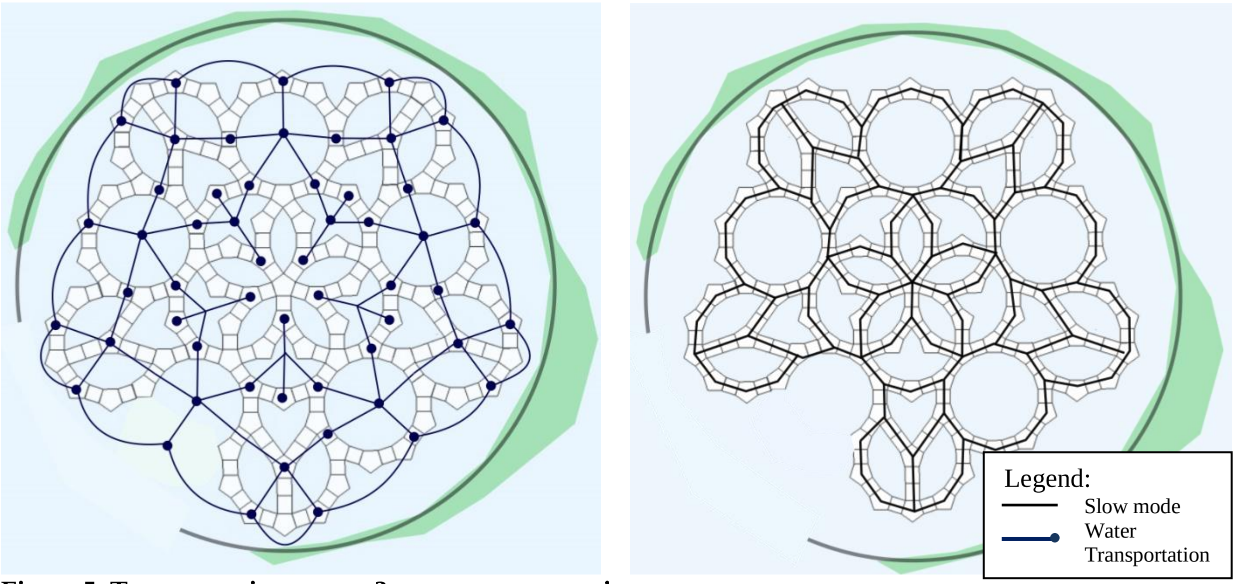

Figure 5, Transportation system 3, water transportation

The 4-step model

The 4-step model consists of four sub-models: trip generation, trip distribution, mode choice, and assignment. The results are shown in and Table 2. Based on the 4-step model, it can be concluded that the transportation systems in scenario 1 have more roads with high travel loads and more regions with a high need for parking places than scenario 2.

In general most travellers will choose to travel with slow transportation. Transportation system 1 (personal) has furthermore the highest share of users. Transportation system 2 (collective) has the lowest modal share. The average distance of the trips is highest for transportation system 3 (water). This is probably because it takes some time before a trip starts. Someone has to go to a mooring place and then wait a couple of minutes before he can travel. This waiting time is higher than in transportation system 2 (personal). Because the system has a lot of shortcuts in comparison to the land based transportation it is faster for the longer routes. The travel time (in vehicle time + waiting time) is therefore also longer for transportation system 3. The in vehicle time is low for transportation system 1 (personal) and transportation system 2 (collective), because more people take small trips.

The average travel time is lowest for transportation system 1 (personal) and longest for transportation system 2 (collective). The reason for this difference is –mainly- due to the fact that more people walk in transportation system 2 (collective). The travel time of transportation system 3 (water) sits in between the other two.

Table 1, overview characteristics transportation systems

	Transportation system 1 (personal)		Transportation system 2 (network 1)		Transportation system 2 (network 2)		Transportation system 3 (water, personal)		Transportation system 3 (water, collective)	
	Sc. 1	Sc. 2	Sc. 1	Sc. 2	Sc. 1	Sc. 2	Sc. 1	Sc. 2	Sc. 1	Sc. 2
Modal share (slow mode)	76%	76%	89%	90%	84%	86%	75%	75%	75%	75%
Mode share (specific transportation systems)	24%	24%	11%	10%	16%	14%	19%	19%	5 %	5%
Distance (average(m))	900	1,000	740	750	765	937	1,200	1,500	1,200	1,500
In vehicle time + waiting time (minutes)	3.2	3.7	3.4	3.4	4.5	6	7.2	8	9	10
Average travel time (minutes)	11.5	11.9	12.8	13.7	11.8	12.2	11.8	12.6	11.8	12.6

Table 2, Requirement of the parking and mooring places of the transportation systems

	Transportation system 1 (personal)		Transportation system 2 (network 1)		Transportation system 2 (network 2)		Transportation system 3 (water, personal)		Transportation system 3 (water, collective)	
>1500 parking/mooring places	2	0	2	0	2	0	1	0	0	0
1000-1500 parking/mooring	0	0	4	2	4	2	3	0	2	0
500-1000 parking/mooring	2	6	13	19	13	19	12	10	1	3
<500 parking/mooring places	7	5	50	56	50	56	46	52	8	8

Multi-criteria analysis

During step 4, the multi-criteria analysis, the designs are evaluated on the chosen criteria. Weights are used to judge the importance of the criteria. Two sets of weights have been created for the multi-criteria analysis. One set was made by the employees of Blue21; another was made by the author based on what future inhabitants would find important

In Table 3, Results of the multi-criteria analysis the scores for the transportation systems are presented as a scorecard. This scorecard is based on the combination of the scores of the different criteria and the weights, as chosen by the author. The transportation system with the highest score is shown in the darkest shade of blue and the system with the lowest score in the lightest shade. The three transportation systems are evaluated in this step. The second transportation system (collective) is evaluated in combination with the two networks. Transportation system 3 (water) consists of two different modes. This however does not lead to different scores, so a total of four systems is evaluated in this step.

The total *costs* of the transportation system is lowest for transportation system 2 (collective) in combination with network 1 and highest for transportation system 3 (water). Transportation 2 (collective) combined with network 2 scores less good than transportation system 1 (personal). Transportation system 2 (collective) scores best on the criterion *safety*, this is mainly due to the fact that the amount of casualties is low for automated systems. Transportation system 1 (personal) on the other hand scores best on the criterion *travel time*, because it has –as stated before- the lowest average travel time. Transportation system 1 (personal) offers most *comfort,* because people walk least in that transportation system.

The difference in scores for *walkability* is low for the different transportation systems, but transportation system 2 (collective), scores best. Transportation system 3 (water) scores best on the criterion *nuisance*. The transportation system 2, (collective), has the lowest emissions.

Transportation system 1 (personal) scores highest on *flexibility*. Transportation system 2 (collective) scores best on *flexibility* and s*calability*. Transportation system 3 (water), requires the least space in the city and Transportation system 2 (collective) is the most *Innovative* system, while transportation system 3 (water) scores highest on *required space.*

The transportation system 2 (collective), in combination with network 1 scores best on both weight sets, followed by the combination of the system with network 2. This transportation system also scores best on the subsets keeping the advantages and improving the drawbacks, while transportation system 3 (water) scores best on the criteria specific for floating cities.

It is likely that these criteria are also important to other future floating cities, so collective transportation and water transportation can be considered good systems for floating cities. It is however possible that due to certain characteristics of other floating cities, this will change. If the cities for example grow very large or if the city is very wide-spread and has a very low density, transportation systems with higher speeds might become more important.

Table 3, Results of the multi-criteria analysis

	1, Personal transportation	**2, Collective transportation**		**3, Water transportation**
Criteria:	Final Score:	Final Score:	Final Score:	Final Score:
Keep the advantages of transportation systems:				
Costs:	+/-	+	-	--
Safety:	--	+	+	--
Travel time:	+	--	+/-	+/-
Comfort:	+	--	-	+/-
Improve disadvantages of the transportation systems:				
Walkability:	-	+	+	+/-
Nuisance:	-	+/-	-	+
Emissions:	-	+	+	--
Criteria specific for floating cities:				
Flexibility:	+/-	-	+/-	+
Scalability:	--	+/-	+	+/-
Innovative:	--	+	+	-
Required space:	--	+/-	-	+
Total:	--	+	+/-	-

Conclusions

A collective transportation system seems to be the best option for a floating city with this characteristics and scale. Although transportation system 3 (water) scores best on criteria related to floating cities.
The results of the 4-step analysis show that it is unlikely that problems due to congestion will occur at the links themselves. Problems at crossings are however possible. Whether the transportation systems have too much capacity and are not cost effective enough, is a recommendation for further research. It is necessary to calculate if the robustness of the networks leads to costs that are higher than delays that could exist on these systems. The amount of parking and mooring spaces furthermore has to be taken into account when designing the city, especially the amount of parking space in transportation system 1 (personal) could lead to capacity problems, or problems related to the criteria flexibility and scalability. When functions in the city are placed at other locations, parking space will need to be moved too.
The methodology can be considered adequate, because it has been able to get insight into this subject, while there was little data available and there were a lot of uncertainties. By designing two lay-outs of the city and a number of transportation systems, it was possible to get insight into a situation that had a lot of inconsistencies. One of the advantages was that it was not necessary to know where functions needed to be. The transportation systems were also different enough to give insight into the situation.
Although the research consists of a simple 4-step model, it gives insight into the future situation. The multi-criteria analysis –as was used in this report- made it possible to generate scores about the criteria, even when there was little information about them.
The research approach is furthermore transparent and it is clearly stated how scores on the criteria are given. There are however a number of criteria that could have been researched in greater depth. One of the most important recommendations is doing more research about the behaviour of inhabitants in a floating city. This way the congestion and a number of criteria can be modelled in a better way.
Furthermore it would be possible to generate more designs, different case studies can be chosen or the floating city can be placed at other locations, for example near a big city. The chosen transportation systems on the other hand seem to differ enough from each other to create insight into the situation.
The proposed methodology can be used for the design of a floating city and the transportation systems in such a city. The criteria can be tweaked towards to reflect the important elements of the particular case study.

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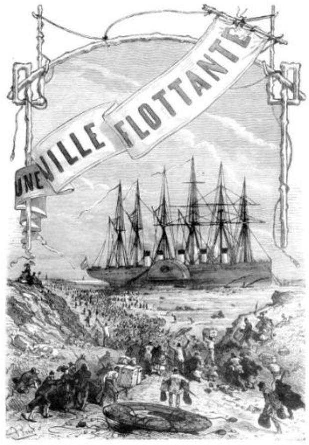
Introduction



Although floating cities have not yet been realised, living on water is something that catches the imagination of people around the world for some while. The first example of a floating city was described by Jules Verne in his book, *Un Ville Flottante*. This book describes a love triangle on board the Great Eastern: a ship the size of a floating city. The book also gives technical descriptions of the ship, images of the landscapes visited and a view of life on board such a ship. Floating cities have since then been researched more thoroughly, and a number of plans have been created.
In this chapter, a small overview of cities with a characteristic relation to water will be given. After this, the context, problem statement and research questions are presented.

1.1. Cities and water from an historical point of view

The existence of cities or empires built on islands goes back as far as the ancient Greeks and is reported in the literature and mythology of the Greeks. One of the more famous myths is the story of the mythical place, Atlantis, which is written about in the dialogues of Plato. Nobody knows if this dialogue was about a real city or about an imaginary place inspired by real ancient empires (ancienthistory, 2015).It could, however, be inspired by the Minoan Empire: a society that emerged in 3500 BC from Crete and grew to become the most important empire on the Eastern Mediterranean Sea. It is also seen as the predecessor for Mycenaean and later on for ancient Greek culture (Watkin, 2000). Although the Minoan society was considered refined and prosperous, it came to a drastic and sudden end, probably due to a combination of wars and disasters (Kunst-en-cultuur, 2015).These two examples are of cities that flourished because of their location in the sea, a location that also, however, caused their downfall. Nowadays, this dichotomy still exists. Cities in delta areas offer many economic opportunities; but there is also always a possibility of flooding or other naturel disasters. Venice is another example of a city near the Mediterranean Sea that is built on islands. This city has around 271,000 inhabitants, of which 62,000 live in the city itself, 35,000 live on nearby islands and 170,000 live on the mainland. The density is 6.42 inh./ha for the entire city. For the old historic city, the density is 124 inh./ha. This is lower than other historic cities in the Mediterranean Sea such as Barcelona and Paris; some parts have densities up to 400 inh./ha (RMIT, 2015).

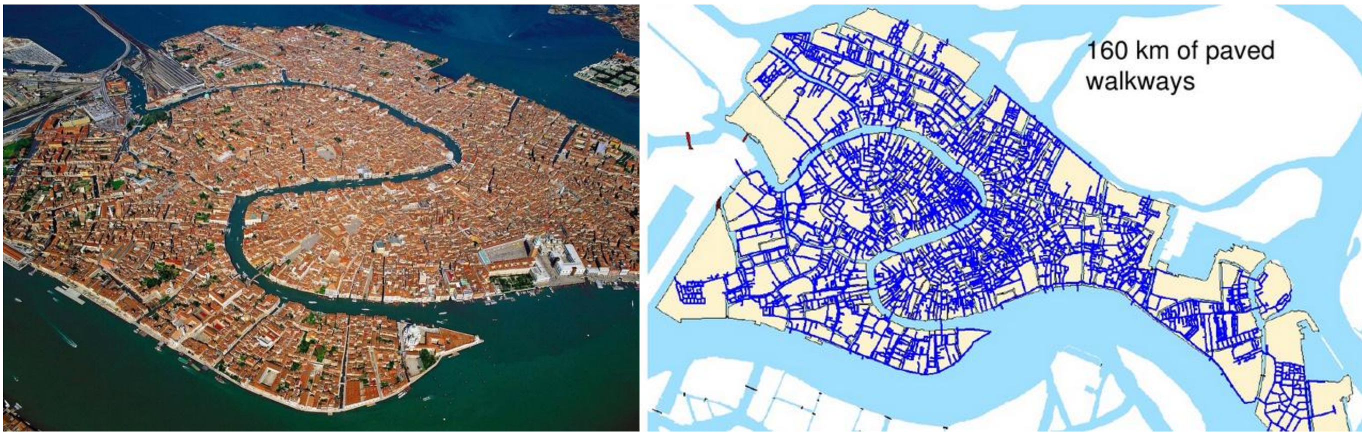


Figure 6 Venice, (google earth (L)), KM of paved walkways(R) (Slideshare, 2015)

From a transportation perspective, it is interesting to note that walking and transportation by water are the most important modes of transportation. Because of how the historic city has grown, there is little space for public-transport infrastructure or highways in the city.

The historic city centre of Venice has around 160 km of paved walkways, and since 1881, the ACTV operates motorized boats and ships on a regular timetable. The city consists of hundreds of islands, and the canals function as ‘roads’ for public transport. The city is enclosed by a railway and a highway. A people-mover also connects the station, a mooring place for cruises and an important parking space with the Piazzolla Roma in the historic centre.

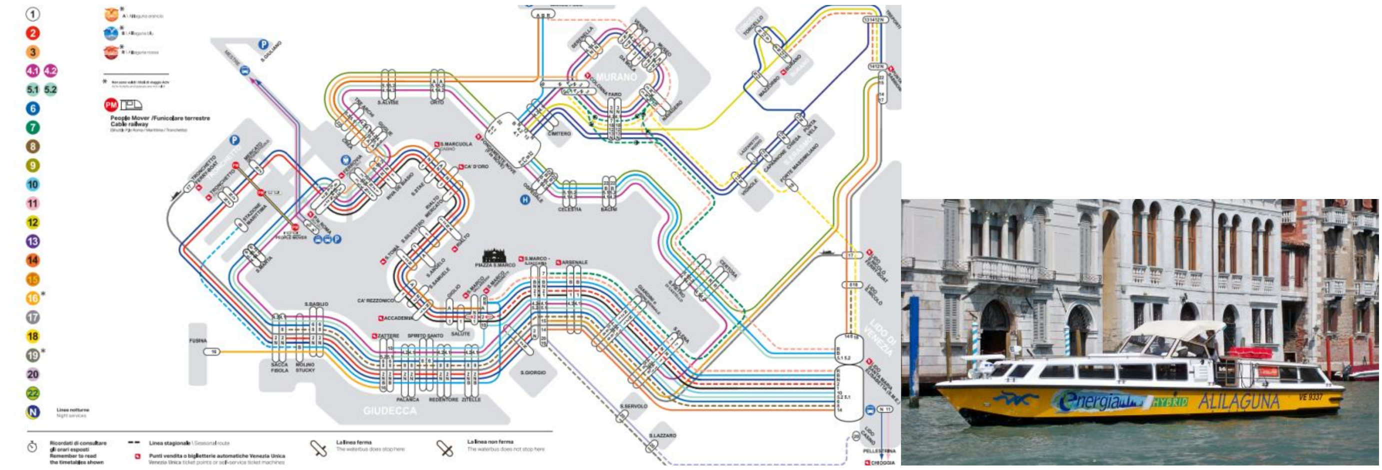


Figure 7; Public transportation, Venice (Slideshare, 2015)

Another example of a city that is built on an island is Male, the capital of the Maldives. It is interesting that this city of 104,000 inhabitants (Male, 2014) (Haveeru, 2015) is a regular city in every other aspect. The city has a density of around 475 inh./Ha. This density is comparable to building blocks in the historic centre of Paris or Barcelona (RMIT, 2015).

From a transportation perspective, the city seems to be similar to other cities. Cars, scooters and motor bikes are considered important modes of transportation in the city. Because of the scale of the city, the public transportation is limited. There is, however, a ferry connection between the city and the nearby airfield. The city is self-sufficient in terms of energy and water production. Waste is transferred to a nearby island.

Figure 8; Male, Maldives (Google earth (l), flickr.com (r)),

There are more examples of cities built on islands or with distinctive relations to water. In South East Asia, floating houses already exist, and a number of settlements are built on water or on pillars. These settlements do not offer the required comfort for a western lifestyle, but they do show a variety of ways to deal with problems regarding water. Most of the transportation is done by walking or by boats.

Another example of houses with a distinctive relationship towards the water can be found in the floating neighbourhood of The Netherlands near IJburg, in Amsterdam. Other examples include projects in Almere and Vancouver. These examples occur on a relatively small scale.

The design of Marlies Rohmer is part of the Steigereiland. This neighbourhood has 3,978 inhabitants. The neighbourhood has an area of 126 km^2 and a density of 32 inh./Ha. The density is low in comparison with other urban areas in Amsterdam, such as Borneo Sporenburg (200 inhabitants).

Figure 9, Floating houses IJburg by Marlies Rohmer (duranvirginia.wordpress.com)

IJburg has a population of 20,000 inhabitants. The area is connected via tram to the central station of Amsterdam and to the rest of the public transport network.

Other famous examples of settlements on water (in this case man-made islands) include the Palm Island and the World Island near Dubai. These projects can be regarded as prestige projects of the Royal family of Dubai. The houses are only available for the super-rich or the happy few.

1.2. Context

Living near the water offers economic and social opportunities, but natural disasters can also threaten the urban environment and the people who live there. This dichotomy already existed in Ancient Greece, with historic examples such as Atlantis or the downfall of the Minoan empire.

Natural disasters can occur everywhere in the world, and at the moment it is estimated that around 200 million people live near coastal areas that are only around 5 metres above sea level (http://worldoceanreview.com/en/wor-1/coasts/living-in-coastal-areas/).

People have been developing ways to overcome natural disasters since the beginning of mankind. One way to do this is to keep the water outside the living areas. A system of dykes provides as an example of this method. The problem, however, is that a lot of damage can occur when there is a flood, because the houses end up under water. Other possibilities include building houses on elevated areas or pillars or building floating houses. This way, the houses stay dry even when the area is flooded.
After hurricane Katrina in New Orleans, other ways to develop a city that adapts to the changes of the environment were proposed. One example is a city that floats on the water. Another involves individual houses that can float when a flood comes or houses on pillars or elevated areas. Experiments in water basins with scale models of floating houses and settlements have also been executed by the University of New Orleans.

Another reason to consider floating cities is that land will become scarce in the future. Since 2009, half of the world population lives in cities. This will grow to 75% in 2050. In parts of Asia, this scarcity of land is already apparent. (Graaf)
A project for a floating city - designed by AT Design and commissioned by CCC - uses a self-sustaining community to mitigate the overpopulated areas in Chinese delta metropolises. The different modules are connected to each other with tunnels, and most transportation is done by ships, submarines and electric vehicles.

Figure 10, At Designs vision for floating cities (inhabitat.com, 2015)

The urbanized areas in these delta areas will also use fertile land for food production. The food crisis of 2012 has already indicated the need for more food production. Near the end of this century, however, a fifth of the fertile land will be used for urbanization. New land to produce food can be acquired only by threatening delicate eco systems such as rainforests.
The sea is also the only area in the world in which people still literally hunt for food. Although people still hunt for food in the rest of the world, the biggest part of the food supply is provided by agriculture.
People used to be gatherers and hunters who used the food the environment provided them. Approximately 5000 years ago, humans started farming. Agriculture provided steady food production, which allowed people to build prosperous societies and allowed men to focus on things other than food production.
Agriculture, however, uses a large part of the surface of the world. Aquaculture, fish farming and algae production are ways to use the surface of the seas better. Although aquaculture is an interesting subject, it is not part of the scope of the study.

1.3. Problem statement

The previous chapters provided a broad background of building floating cities and gave an idea of what is needed for a floating city to function. The focus of this report will be on transportation in floating cities. This chapter presents the problem statement of this paper and focusses on the disadvantages of the current transportation system, the problems that could arise with the infrastructure in floating cities and a number of conditions that must be taken into account when analysing the infrastructure in floating cities.

Floating cities require new infrastructure. The need to travel will always exist. People need to go to work in the morning, do grocery shopping in the afternoon or perform other activities. One way to facilitate transportation in a floating city is to use the same network, infrastructure and transportation modes that are used in regular urban and transportation planning on the land, but to place them on the water.
On the one hand, one could argue that this is a safe way to deal with the situation, because such systems have been proven to work. On the other hand, it could be that building new transportation systems will lead to a better situation, because it will better suit the characteristics of the new situation and the needs and desires of the inhabitants. The question is how to make the best of the opportunity to create a new infrastructure without losing the advantages of the current transport systems and by taking the specific characteristics of the floating city into account. Building infrastructure on the mainland means, in most of the cases, that conditions are given and the choice for certain transportation modes, networks and systems are based on the existing situation. Floating cities provide a chance to create new systems.

It would, however, be necessary to note what the advantages and disadvantages of current transportation modes are, what opportunities exist for a new transportation system and what the characteristics of the infrastructure in a floating city will be.

Although a number of negative effects have been associated with the current transportation network (such as car transportation), cars make it possible to achieve speeds that make it possible to travel distances that are greater than ever in history. Furthermore, car transportation offers a certain level of comfort that people do not easily give up, and although safety problems exist with car transportation, the system is regarded as safe enough for travellers. The question is how to take advantage of the opportunity to create a new system while keeping as many of the advantages of the current transportation system as possible. These include the following: travel speed, comfort and safety.
It is however important to note that the distances in the city are not high, so the travel time may not be that important. The safety issues are furthermore also elements that are of less important in the future floating city, because of the scale of the city. Improvements in technology are furthermore likely to make the system safer.
The disadvantages of the current transportation system exist of the nuisance caused by transportation systems, the CO2 emissions and the decrease in walkability.

Nuisances can consist of noise and fumes; the deciding factor is if inhabitants are bothered by the transportation systems. The criterion emissions evaluate the CO_2 output of the system, so the focus is on the global environment and not on the inhabitants. The decrease in walkability on the other hand is a criterion that is not based on the transportation system, but on the urban environment.
Nuisances can consist of noise and fumes; the deciding factor is if inhabitants are bothered by the transportation systems. The criterion CO_2 emissions evaluate the CO_2 output of the system, so the focus is more on the global environment than on the inhabitants.
The decrease in walkability on the other hand is a criterion that is not based on the transportation system, but on the urban environment. Most transportation on land is done by car transportation, which can cause nuisance because of pollutants and noise. Although planners try to promote more sustainable transportation modes, cars are still the most important means of transportation for most countries in the Western world.

Since the publication of Jan Jacobson's *The Death and Life of Great American Cities*, urbanists have been experimenting with dense, mixed use cities.
It is important that these cities are walkable. This means that people can walk to important functions in a region instead of having to take cars. This leads to a more vibrant environment and higher housing prices (Gilderbloom, 2014). Walking is a primary mode of transportation in a number of old historic city centres. Venice is an example of a city in which walking is an important mode of transportation.

New problems could also arise by building infrastructure in a floating city. The amount of infrastructure should for example be minimized in the city so that more space can be used for housing and other functions, such as shops or restaurants. Infrastructure is more expensive in floating cities.
Another possible advantage of the floating city is that it could become flexible. Floating cities are more flexible than conventional cities. The layout of a city can be easier changed. Furthermore floating cities can grow over time similar to how cities historically grew. Innovation focusses how innovative the transportation systems are and is this would add something to the image of the city. The criterion required space answers how much space in the city is needed for the transportation system.

The goal is to use the advantages of a new infrastructural system while compensating the disadvantages. In addition, the floating cities offer certain characteristics and conditions that should be taken into account. A case study will be performed to experiment with different transportation systems, based on a design that will be presented in chapter 2.

1.4. Research questions

The main research question is how to facilitate transportation in a floating city in a feasible way and how to evaluate this in future designs. With feasible meaning that it should be possible to create such systems in a technical and economic sense and that it should be safe enough for the inhabitants. Furthermore, the transportation systems should fit the scale of the design project.

Other research questions are:
How to keep advantages of current transportation systems?
What are the costs of this system?
Does the system lead to problems regarding safety?
What is the travel time of the systems?
Is the transportation system for floating cities fast enough? Does it lead to long travel times?
Does the transportation offer the desired amount of comfort?

How to improve disadvantages of the system?
Does the system decrease the walkability of the city?
Does it lead to problems regarding noise or other nuisance?
How much CO_2 is produced?

How to incorporate case specific characteristics?
Is the adaptability of the system great enough to withstand changes of the functions in the city?
Is the transportation system flexible enough to function when the size of the city changes?
Is the infrastructural system innovative?
Furthermore, space is more expensive in floating cities, and building on water is still more expensive than traditional building techniques (although this could change in the future). It would therefore be important to minimize the amount of infrastructure in the floating city and the weight of the infrastructure.

1.5. Scope

Theoretically, floating cities can be placed anywhere in the world. In this report, three designs are analysed. It is assumed that the cities will be able to cope with the Western lifestyle - similar to Dutch society, for example - and will also offer the same level of comfort.
Three designs by Blue21 will be analysed. These designs have considerably different design goals and are based on other design choices. The goal of the first design is to create a walkable city. The urban atmosphere is similar to Mediterranean cities such as Paris or Barcelona. The density is high and the functions are within walking distance. The idea of the second design is to create a flexible city. This design is created for the Seasteading Institute. The goal is to create a city that can grow over time on the water, that can be transported and from which parts can be connected and disconnected. The third design is called Cyclicity. The idea behind this design is to re-use of CO_2 and waste from the city. These designs will be further explained in Chapter 3: Case studies. One of these designs will be chosen and will function as a case study for comparing a number of transportation systems.
The focus of the report will be on analysing the transportation of persons and goods. The infrastructure needed for electricity or waste-water collection, for example, is not part of the scope of the report.

1.6. Research approach

Floating cities of a size of 25,000 inhabitants or more which facilitate the modern Western lifestyle and comfort do not yet exist Furthermore it is not known how these systems will function in such cities.
A method is developed to be able to get more insight into the transportation of persons in such cities by a literature search and analytical thinking. The method is based on the method research by design. This method generates insight and knowledge by studying the effects of a number of design interventions in an existing situation. This method can be defined as the *“development of knowledge by designing, studying the effects of this design, changing the design itself or its context, and studying the effects of the transformations”* (Jong and Voordt)
Because of the amount of uncertainties, it is not only necessary to create different design variants of the transportation systems, but also to change the context. Therefore both variants of the transportation systems and different designs of the floating city are created.
This project is an exploratory research project. The goal is to obtain insight into the situation and generate conclusions and recommendations for further research and future designs. A case study is chosen to test this method: the Seasteading city. More information about this can be found in *chapter 3, case studies.*
According to Roozenburg and Eeckels, every design project, regardless of its field, consists of phases of the basic design cycle. (Roozenburg and Eekels, 1995).

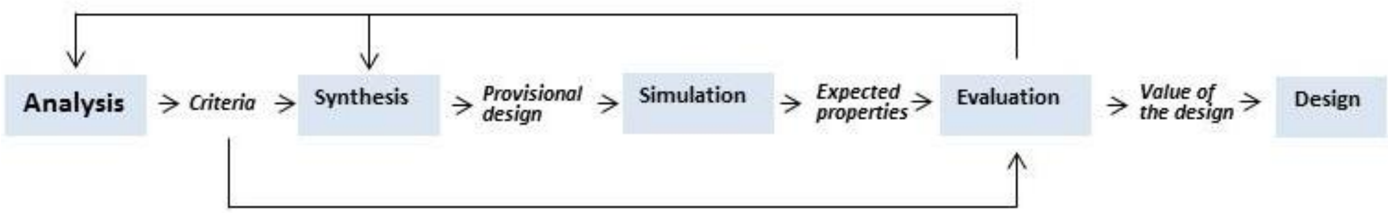


Figure 11, Basic design cycle (based on the work of Roozenburg and Eekels, 1995)

Based on these ideas, a research approach have been developed for this research that consists of five steps. The first step consists of the analysis of the situation and the creation of criteria for the designs, simulation and analysis. These criteria are based on the problem statement and the research questions. They consist of the following:

- The advantages of current transportation systems that should be taken into consideration, which are the following: comfort, costs, speed and safety.
- The disadvantages of the current system that should be taken into account, being: nuisance caused by transportation, a decrease in walkability and the output of emissions.
- Case specific characteristics that should be taken into account, which are the following: flexibility, scalability, innovation and required space.

Based on the analysis and the criteria, scenarios and transportation systems are designed (step 2a). The scenarios are designed by first analysing the vision of the client and by creating the program of requirements (the amount of houses, jobs and other functions that are needed). More information can be found in *chapter 3, scenarios*.
The transportation systems were designed by first analysing a number of transportation systems and selecting three significant different designs (step 2b). More information about this can be found in *chapter 4, transportation systems*.
There is a feedback loop between the evaluation and the scenario's. It was, however, not necessary to make big adjustments to the scenario. Adjustments to the transportation systems, on the other hand, were made.

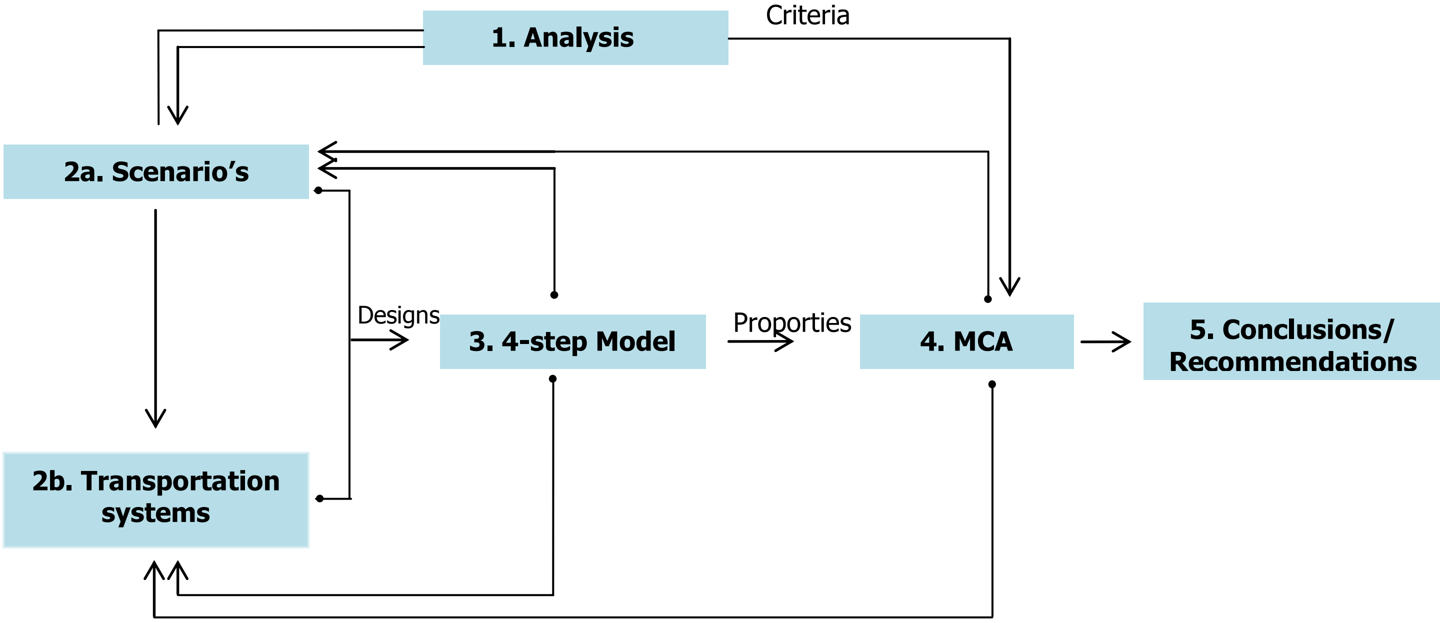


Figure 12, Design approach

The use of the four-step model is twofold (step 3). On the one hand, it creates input for the evaluation of the transportation system. On the other hand, it also predicts whether problems in the network of the system or problems regarding the capacity of the systems are likely to exist.
There are other wys of modelling transportation. A 4-step model is chosen because it suits the scale of the design well and uses the scenarios. The place where people live is determined and where they work. A choice model would create less insight into spatial configuration of the trip and fo an activity based model, more information is needed about the lifestyle of the future inhabitants.
Commonly used modelling software, is not used for the simulation. A tailor-made model is created instead. This makes it easier to tune the model towards the specific situation and criteria. The city will be developed in the future and the lifestyle could be completely different than the current lifestyle. Developing an own model would make it easier to cope with these differences and with the specific situation. Using common software also means that workarounds need to be made to be able to model the specific situation, which is also undesirable. More information about the 4-step model can be found in *chapter 5, the 4-step model*.
A multi-criteria analysis is used to evaluate the effects of the systems (step 4). It allows a certain amount of freedom for selecting criteria and it give clear inside in the decision making process. Furthermore the amount

of uncertainties makes it difficult to make a decision solely based on monetized values of the effects. More information about the multi-criteria analysis can be found in *chapter 6, the multi-criteria analysis*.
The report ends with conclusions and recommendations for further research.

2

Case studies

The methodology, as described in *chapter 1,6 research approach*, is applied to a case study. In this chapter three designs of the company Blue21 are described. One of these designs is used for the research. Blue 21 is specialized in creating designs for future floating cities.
As stated before, the designs are based on different design goals and principles. Design 1, the grid city, will be described first. The central goal of this design is a walkable city. Historic Mediterranean cities are sources of inspiration for the design. Design 2, the Seasteading project, is based on the idea of a flexible city that can grow over time. Design 3, the Cyclicity, is based on the idea of re-using nutrients from the city. By analysing these designs, a wide range of possibilities for floating cities is obtained.
All of the designs consist of modules. These modules are concrete constructions that are able to float on water. Parts of the basement are used for safety compartments. If there is damage at a specific place in the wall, one compartment can be filled with water while the others sill floats. In this way, the construction will be able to float even when it has sustained damage at a part of the construction.

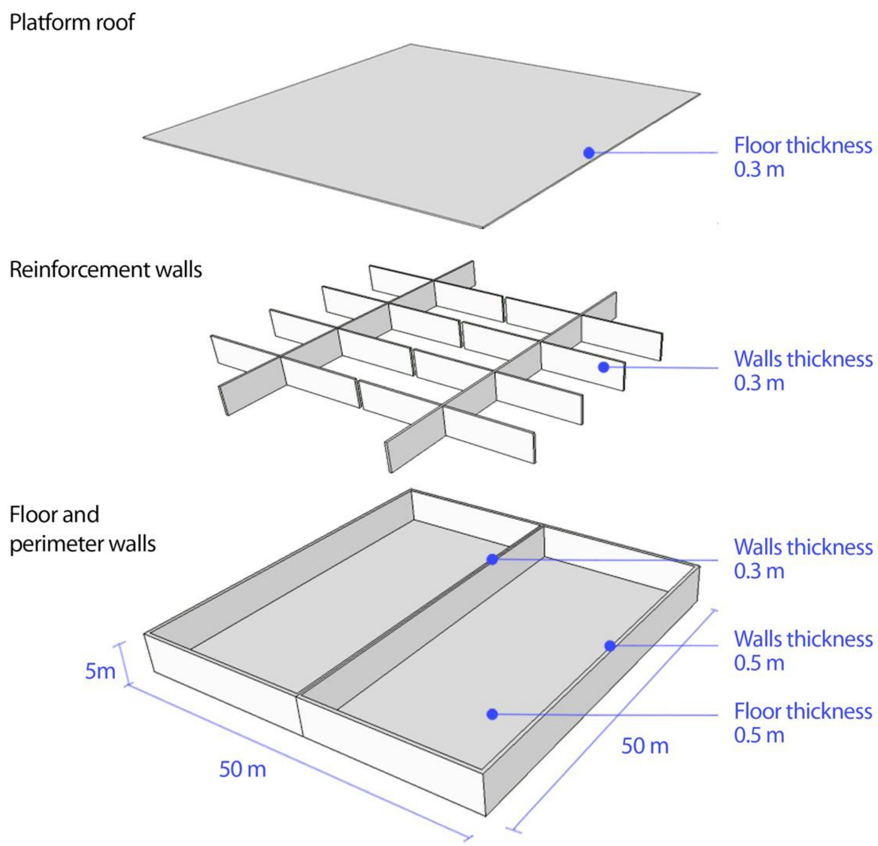


Figure 13, Modules (Blue21, 2013)

The area in these compartments cannot be used for functions as housing, parking, storage, etc. There is, however, a space in the middle of the module that can be used as such.

The size of the modules results from a compromise between the advantages of small size and the disadvantages of having more connections between the modules. Smaller modules mean less force in the structure. People furthermore get easier seasick when the modules are bigger.
On the other hand, when the modules are smaller, more connections between the modules are needed. These connections are costly and complicated in technical terms. Blue21 has chosen modules of 50 by 50 meters for the design of the grid city and the Seasteading city. More information about the modules can be found in the thesis *Seasteading Implementation Plan, Final concept report, 2013 (Blue21,2013*) and information about the feasibility of the construction of the modules can be found in the thesis *realising a floating city(Ko).*

2.1. Case study 1, Grid City

The main goal of this design is to create a city with a high walkability score. The main inspiration is a dense, mid-level, Mediteranean city centre. The city consists of a grid network with a lot of space for pedestrians; but there is also space for car traffic and water inside the city. All of the functions are in walking distance. The grid network will be built at once. The network will consist of 306 modules, each with 100 inhabitants. This means the total number of inhabitants is 30,600. The city is 1.054 km by 1.054 km (18 by 18 modules). The density will be around 275 inhabitants/Ha. This is higher than neighbourhoods such as Borneo Sporenburg, but lower than classical historical cities such as Paris or Barcelona. This design is meant for a floating city in a bay or near the mainland. The structure and form of the modules is probably weaker than designs with triangular shapes in it. The connection with the mainland will therefore be of importance for the design.

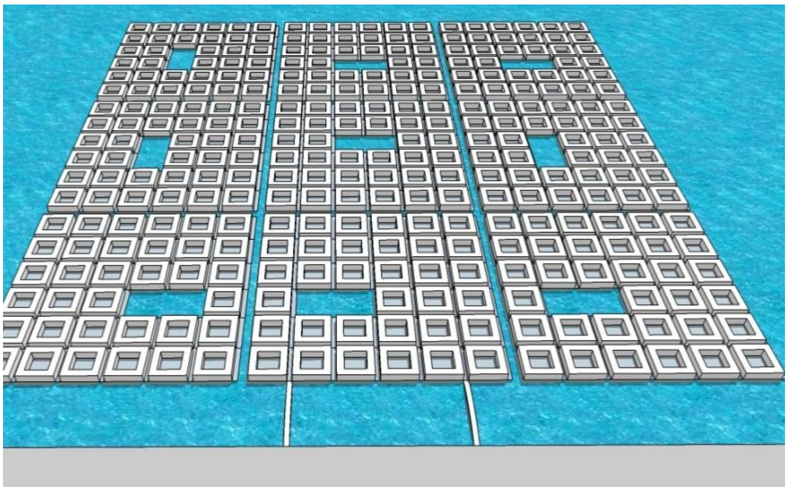


Figure 14. Grid City

The modules are connected to each other in such a way that they can move on the waves. A space of 0.5 meters is placed between the modules. A plane of seven meters is needed to connect the modules in such a way that normal disturbances caused by the water are not noticed. These planes will also be used as roads. As stated before, the central aspect of this design is a walkable city with a high density and with important functions in walking distance. Furthermore, the infrastructure in the city should be minimized, in space as well as in weight. The connection with the mainland will also be of importance. If the floating city is placed in a suburban setting, the car will probably be the most important mode of transportation. When the city is built next to a train station or other important public transportation hub, this will also be of importance.

2.2. Case study 2, Seasteading project

This design is commissioned by the Seasteading institute: an institute that experiments with new forms of government. One way to create a new government is to develop a floating city in the territorial waters. Many technical problems must be overcome to create floating urban structures, however, so it is probably impossible to create a floating city from scratch.
In addition, cities used to grow organically. Planning new cities was uncommon until the 20th century. Examples of big cities that are almost completely planned are Brasillia, Canberra, and Almere (in The Netherlands). Although these cities are planned, they change over time. (Watkin, 2000)
One way to make it possible for cities on the water to change and grow over time is by using a modular system. Floating platforms can be added to the system. In this way, they can grow or change. This system also offers the opportunity to use host cities as a place for cities to grow until they are big enough to withstand the forces of the ocean on their own.
The analogy of fish or other animals is used by Blue21. When fish are small, they live near the land. When they get bigger, they go to open waters; and when they are fully grown, they go to the ocean.

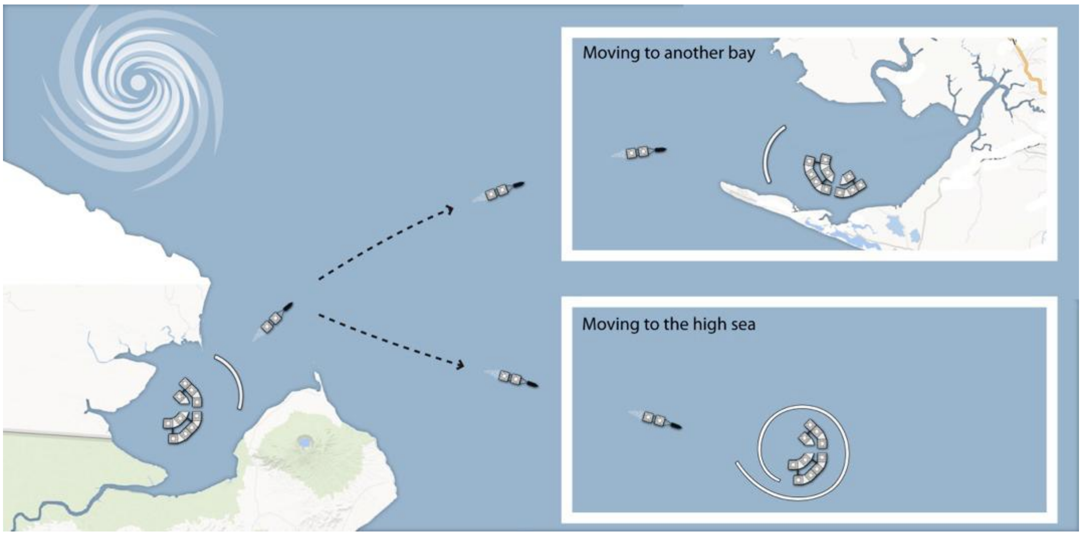


Figure 15, Transporting cities (Seasteading Implementation Plan, Final concept report, 2013)

The idea of this design is that it could grow from a village into a city. Pentagonal modules are also introduced to give the structure more strength. By creating structures with a triangular structure, high dimensional stability can be achieved.

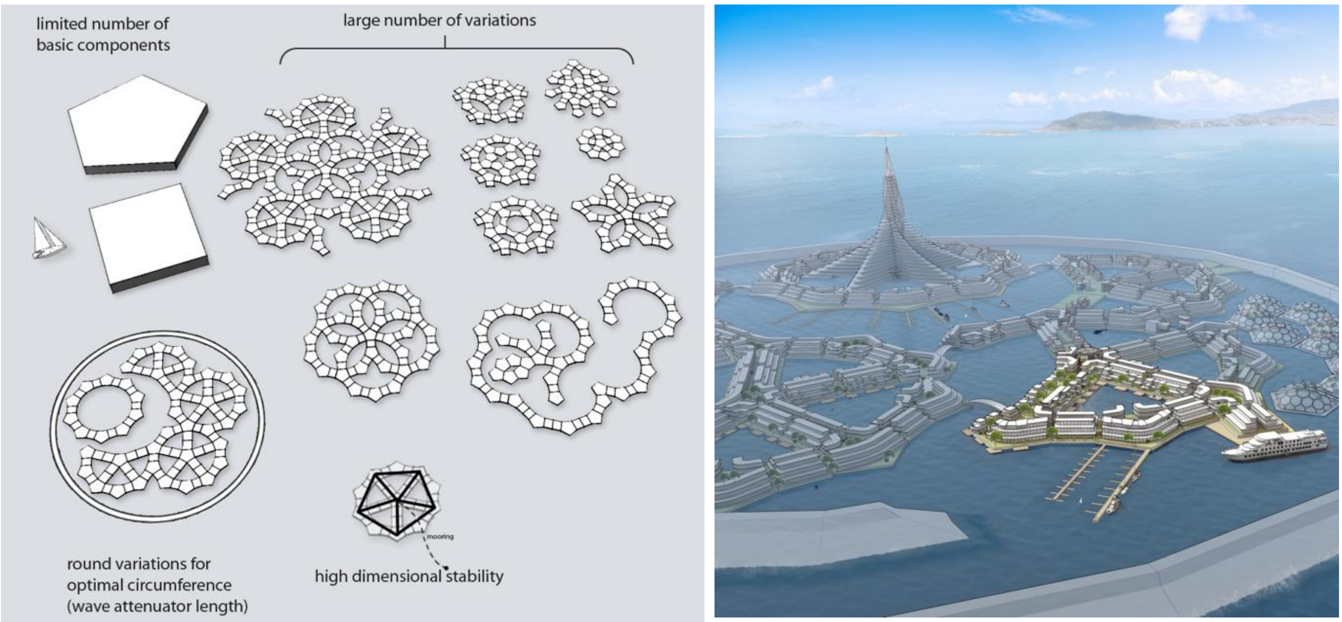


Figure 16, Variations of networks (Seasteading Implementation Plan, Final concept report, 2013)

In figure 11 a number of possible settlements are shown. As can be seen from the figure, a large variation is possible in network, cities and settlements. The structures consists of combinations of rectangular and pentagonal modules. The modules of this design have around 80 inhabitants. The connection with the main land is weak, but it is needed to create a harbour for the import of goods.
A design is depicted in figure 14. This design has 120 inh/Ha and a radius of 850 metres. The width and height of the area is 1.7 km. The total number of inhabitants is in between 20,000-25,000. The city is protected by a floating wave breaker. A number of products are possible, such as the floating breakwaters from Ecomarine, or FDN engineers.

2.3. Case study 3 Cyclicity

The underlying goal of the third design is to create a floating city that recycles nutrients and CO_2 from nearby cities. Near metropolitan areas, CO_2 is produced by the transport sector and the industry. In addition, there is an excess of nutrients because of (bio) waste and the sewage system. In metropolitan delta metropolises, there is an excess of water, CO_2 and nutrients. These are also the elements that plants need to grow. By using the nutrients and CO_2 from the city for agriculture, a system can be developed that could meet 44% of the world's food demand and that requires only 22 litres of fresh water for the production of fish and tomatoes in contrast to the 3,900 litres for chicken and 1,260 litres for tomatoes and 15,500 litres for beef required on land (Blue21, 2012). Although this subject is interesting, it is not within the scope of this report.

Figure 17, Impression, Cyclicity Project (Blue21, 2015)

2.4. Conclusions

Although the three designs are created by the same office (Blue21), each employs different design principles. The first design is a conventional system (a grid) that is widely used in different places over the world. When floating cities are created, it is not necessary that they have traditional designs for the infrastructural networks. The freedom the water offers for the design makes it possible to experiment with new types of networks.

The second design, on the other hand, is for a specific situation involving water. The main idea behind the design is that it could grow over time. Because of this, a city is created that consists of different modules that are connected. New modules could be attached to or older modules detached from this city. Furthermore the pentagonal form of the city comes from the desire to make the structure as strong as possible. The circle form is created because of the floating breakwater that surrounds the city. In other words, this design is specially created for a floating city.

The second design is also better from an academic perspective, because the network does not yet exist whereas grid networks or other networks have already been analysed and used in reality.

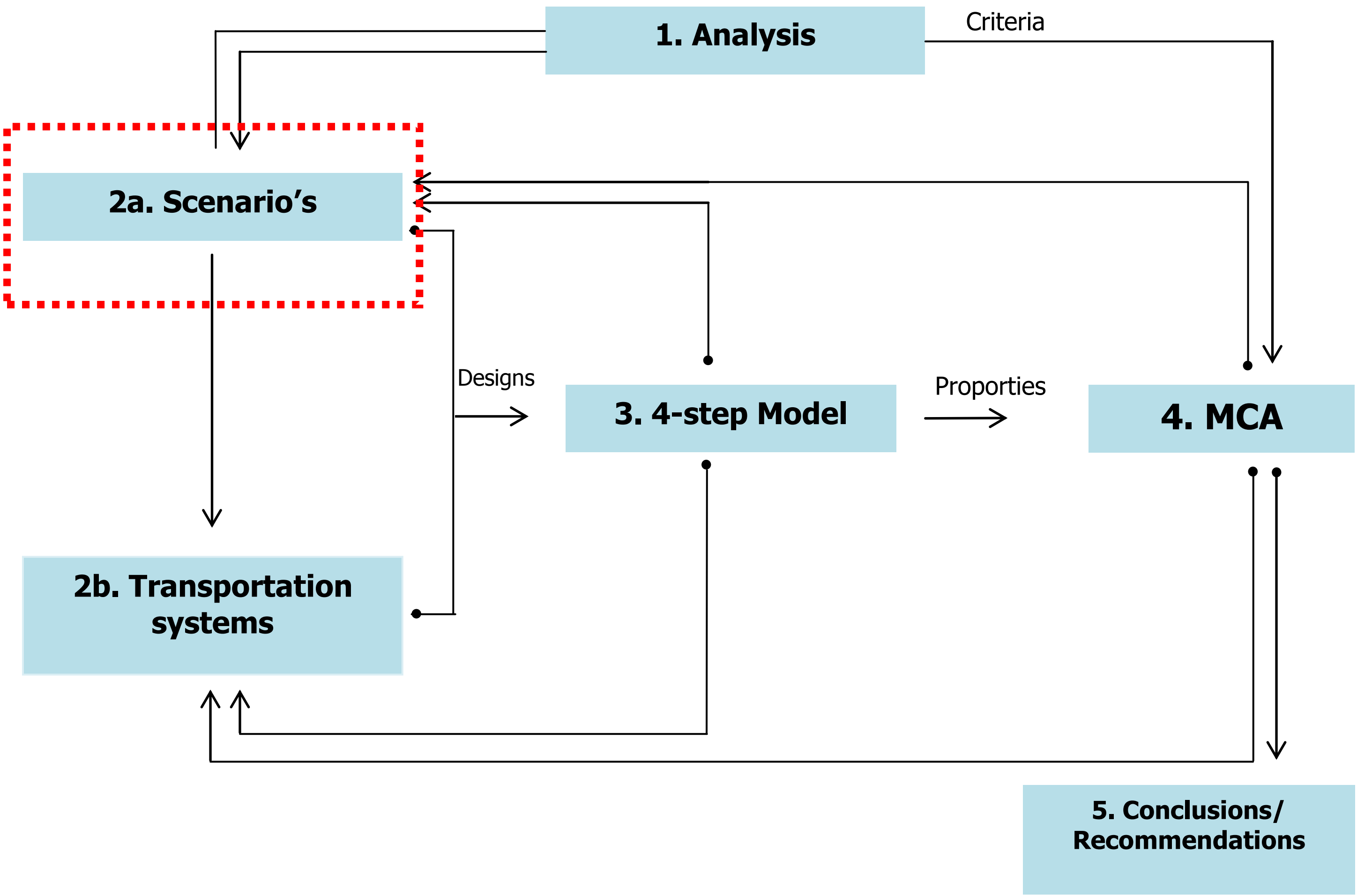
Although the third design was also created for a floating city, the lack of a clear idea for the infrastructural network of roads makes it hard to study. The design focusses mainly on the re-use of CO_2 and other pollutants from the city. Although the infrastructure used for this concept is an interesting research object, this is not the scope of the thesis. Besides, it is also possible to use a number of these concepts in the floating city.

The same is true for the design of the grid city. The basic idea behind this design is a walkable city. The grid city should become a walkable city, so reducing nuisance from automobiles is important.

The design is inspired by old inner cities. The city is designed to be a paradise for pedestrians. The idea for a dense, walkable city can, however, also be realised by the network of the Seasteading city. The main goal of the second design is to create a flexible city that could grow over time near a host city and transported towards the open ocean when big enough. This could be combined with a walkable city.

Furthermore, the second design is made for a client that wants to experiment with different government types and with inhabitants who have a clear and distinct lifestyle. Most inhabitants will have an entrepreneurial spirit and an active life. This gives tools for creating a vision and design.

Design 2, the Seasteading city, is chosen for analysis in this report because of its distinct and innovative infrastructure network. The basic idea behind the design also provides the most tools for the design. The ideas for the other designs can be combined with the second design. Walkability can, for example, be included as a criterion in the multi-criteria analysis, and ideas from the Cyclicity can be used in the design of the Seasteading city.


1. Analysis
Criteria
2a. Scenario's
Designs
3. 4-step Model
Proporties
4. MCA
2b. Transportation systems
5. Conclusions/ Recommendations

3

Scenarios

This chapter describes scenarios, which are based on the design of the Seasteading project. First, the vision is presented. Next, the spatial design and the program is shown, and scenarios for the four-step models are presented. The chapter ends with an overview of the different transportation systems developed for this city.

3.1. Vision Seasteading city

The project is initiated by the Seasteading community: an organisation founded by entrepreneurs from Silicon Valley (in the United States of America). The main motivation is to experiment with new types of government. The desire of the client is to make it possible to innovate more and to experiment with new technologies. The community is, however, hindered by laws and legislation. Some rules are, for example, made more than hundred years ago and are (according to the client) no longer relevant.
The motive of this project is to ensure that a certain kind of people will live in the floating city.
To describe the sort of people that will live in such a city, and to describe the perception of the world from this group, it is necessary to differentiate several groups of people. A number of ways of differentiating groups of people are possible.
For this report, the method of smart studies is chosen because of its simplicity.
This method uses a horizontal axis which describes whether an individual is focussed on the group or on itself, and a vertical axis which describes whether the group is open towards the world or focussed on itself. Four groups are differentiated by this method (OTB, 2011).
The group called “harmony” (yellow) consists of people who are open towards the world and have a cooperative attitude towards the society. They are also focussed more on the group than on themselves. The group is characterized by people who seek the ideal balance between work and family. The most important motto is that they are able to come to a solution together with the other people.
The group called “protection” (green) also consists of people who are oriented on their own group, but they do not have an open view towards the society. Instead, they are more focussed on their own group or their own group. This could be their neighbourhood, family, etc. The most important thing they search for is safety. The motto of this group is that you are stronger together than on your own.
The group called “control” (blue) consists of people with a strong individualistic character who want to have control and want to show what they have achieved. Power is seen as an important motif. This group is mainly focussed on it’s own and the people are focussed strongly on the individual. They look at the world with their own set of standards.
The group called “vitality” (red) consists of people who are also ego-oriented, but with a more open view towards society. They also have their own moral values and standards, but this results in a more progressive attitude towards society. The careers of individuals are not seen as the most important part of their world view, but the ability to develop themselves is the corner stone of their lifestyle

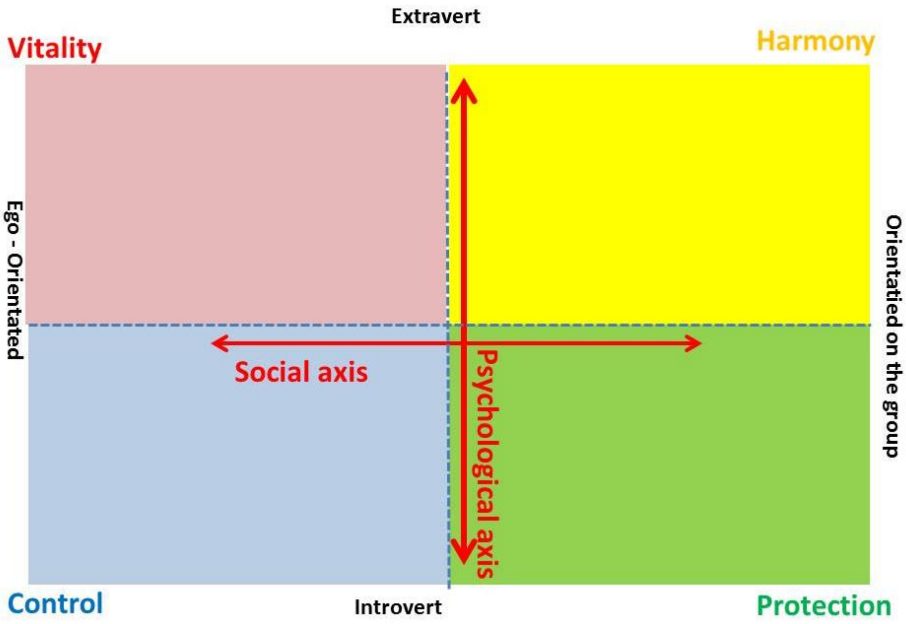


Figure 18, BSR model from smart studies (OTB, 2011)

The people of the Seasteading city incline most towards the ‘red’ group. This does not mean that the Seasteading city consists only of people from this group, but that the majority of the inhabitants belong to this group. This also means that they are open to more progressive ways of living. Jobs that are common for this group include work in the creative sector, although there will also be many people who work in the ICT sector.

Furthermore, the people want to be independent, so they also focus on being able to provide their own food. Besides this, it will also be necessary to develop other facilities such as a day-care and primary schools or even high schools and colleges so that people can develop themselves further. People will also be able to adapt to another lifestyle. This means that they are probably willing to change their mode of transportation easier than people from other groups.

Program

This chapter describes the vision of the Seasteading community. It may be assumed that a number of activities will appear in the Seasteading city. A number of activities will be necessary for the community to function; others can be expected to appear because of the type of people that live in the city. In Figure 19, an impression is shown of how a design of such a city could look. This design is also the basic concept of the scenarios of the Seasteading city.

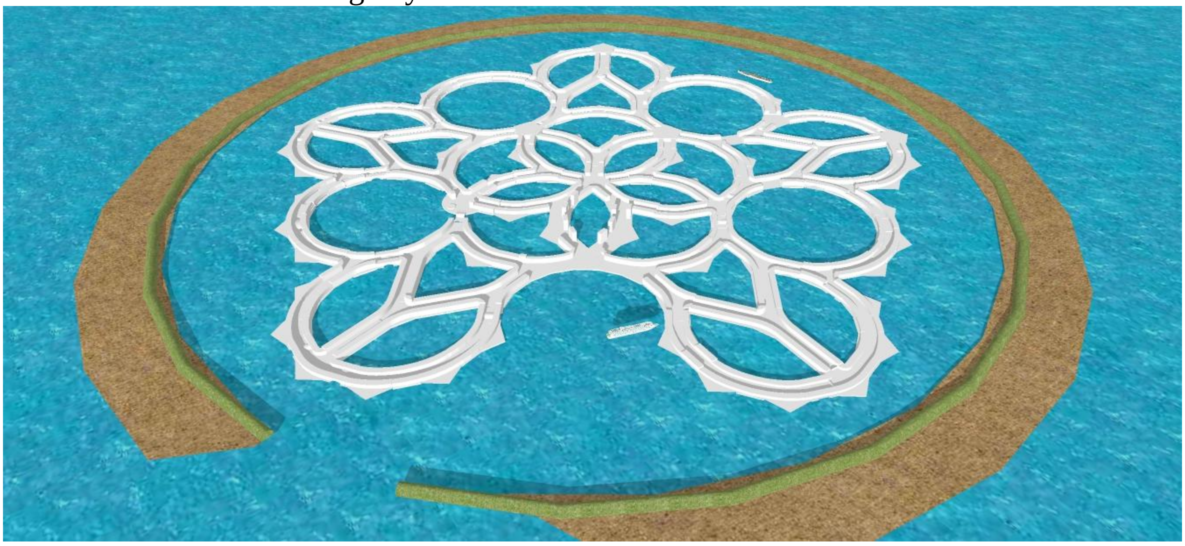


Figure 19, Impression, Seasteading Project

Food/energy production

Although it is possible to import all the products that are needed, it may be important to be independent from other countries for primary life needs or at least to have a backup system. It may also be assumed that, based on the specific case, the inhabitants will want to be independent as soon as possible.
One way to create energy is to produce algae. CO_2 and heat from the city can be used to grow algae. These algae can later be consumed or used as biofuel. Algae produces more oil than regular sources of oil such as palm oil and rape oil, and it also grows faster (omega project, 2015).
In addition, solar panels and wind mills can be used to create electricity. Drinking water is produced by osmosis from seawater. The water is pushed through a membrane that extracts salt from the water.
Besides algae or seaweed, fish may also be caught and farmed by the city. Nearby the city, fish farms are also exploited. These farms also make an important contribution to the food supply.

Harbour

It is also necessary to create a harbour in the city that makes it possible to reach other destinations such as fishing farms or nearby cities, for visitors or tourists to arrive at the city and to load and unload freight ships. It is possible to have different harbours in the city for tourists, inhabitants and freight, or to combine the harbour for tourists and inhabitants, for example.

Figure 20, Impression harbour Cheung Chao

These activities can be combined with restaurants and shops. The harbour will attract enough inhabitants for the restaurants and shops to be successful, and it will also add atmosphere to the area to attract such facilities.
Figure 20 is an impression of a harbour at Cheung Chao. This harbour consists of boats and other functions, such as restaurants, shops and harbours.

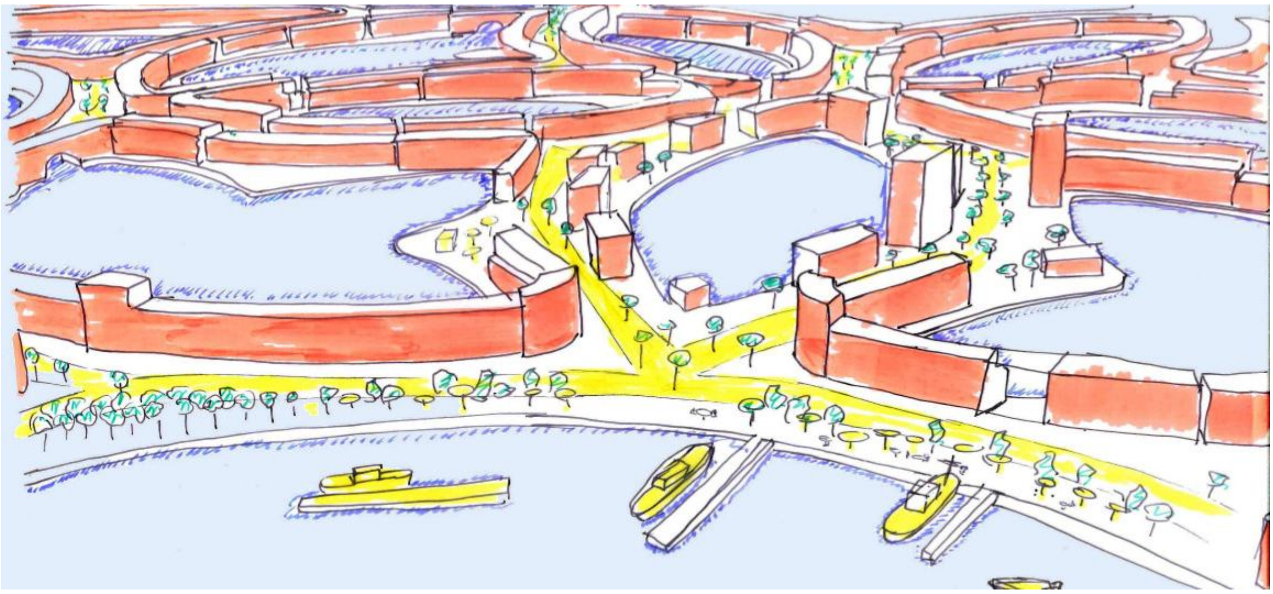


Figure 21, Impression harbour, Seasteading city

Figure 21, Impression harbour, Seasteading city gives an impression of how this could work in the Seasteading community. Boats can moor at mooring places near the quay. There is also space for terraces and people to sit down and look at the boats. The infrastructure network is placed in the middle of the road. This can be either a road for cars, a lane for automated vehicles or space for pedestrians and cyclists. Roads near the harbour can also have a special atmosphere because of their locations. On this picture, different roads are shown. It is possible to design various roads: boulevards with terraced houses, streets that open towards the water or streets with parks in which buildings are placed.

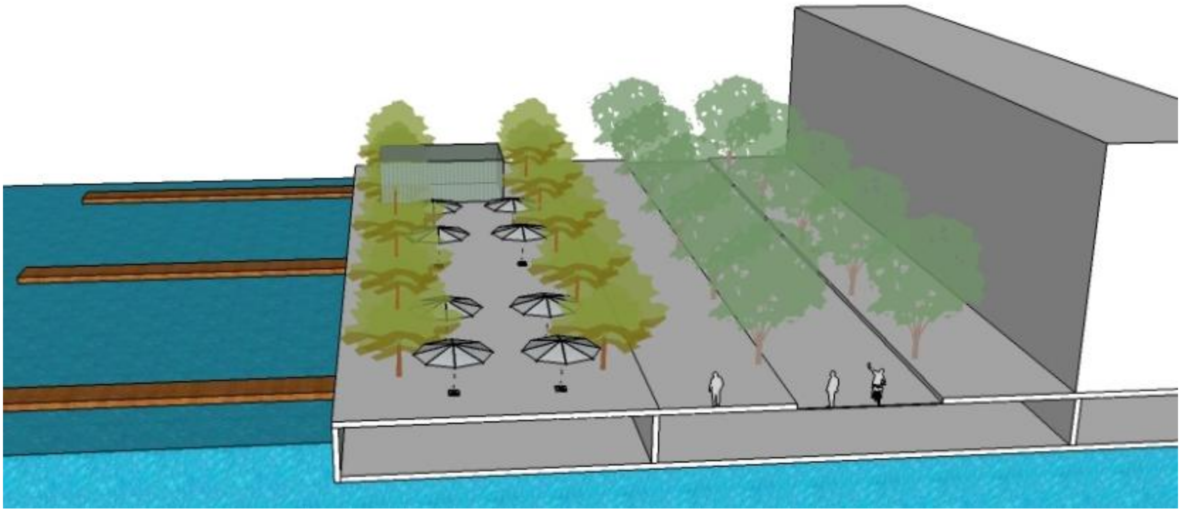


Figure 22, Section harbour

Figure 22, Section harbour shows a section of a street near the harbour. On the right side is a place for shops and restaurants. A road for traffic (slow mode) is placed in the middle. On the left side are terraces and mooring places for boats and ships.

Dwellings

Figure 24 shows an impression of a module that focusses on housing and offers opportunities to develop other functions such as shopping and restaurants on the first floor. The modules consist of rectangular building blocks that measure 50 by 50 meters and of pentagonal modules with a radius of around 63 meters and with sides that are 50 metres long.

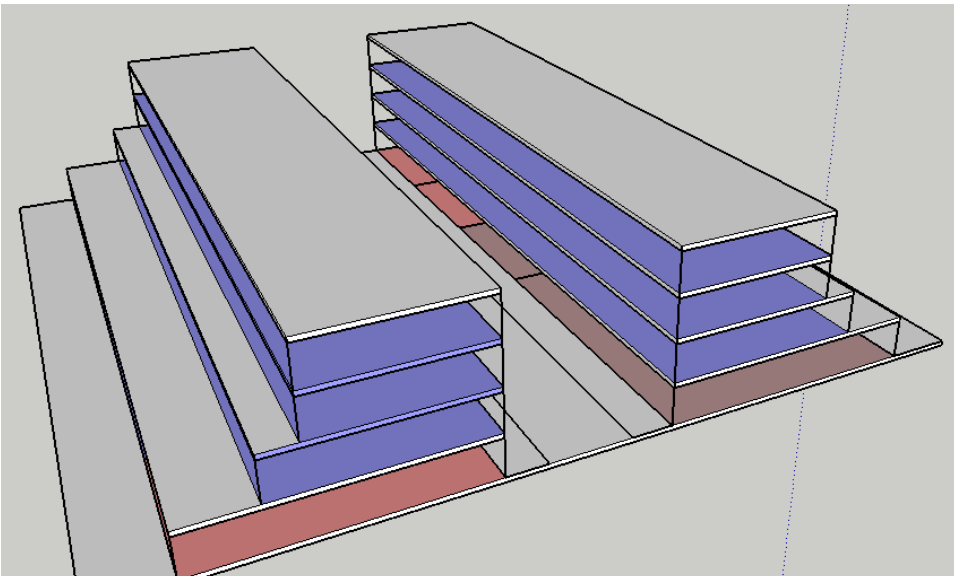


Figure 23, Schematic design of a module focused on housing, shops and restaurants

The modules have free space at the outside (5 metres), and the houses have a depth of 10 metres. The street is approximately 13 metres wide, with a sidewalk of 3.5 metres on each side.
In case the module consists of dwellings combined with other functions, the number of inhabitants is around 140. When the whole module is used for housing, the number of inhabitants is around 180.

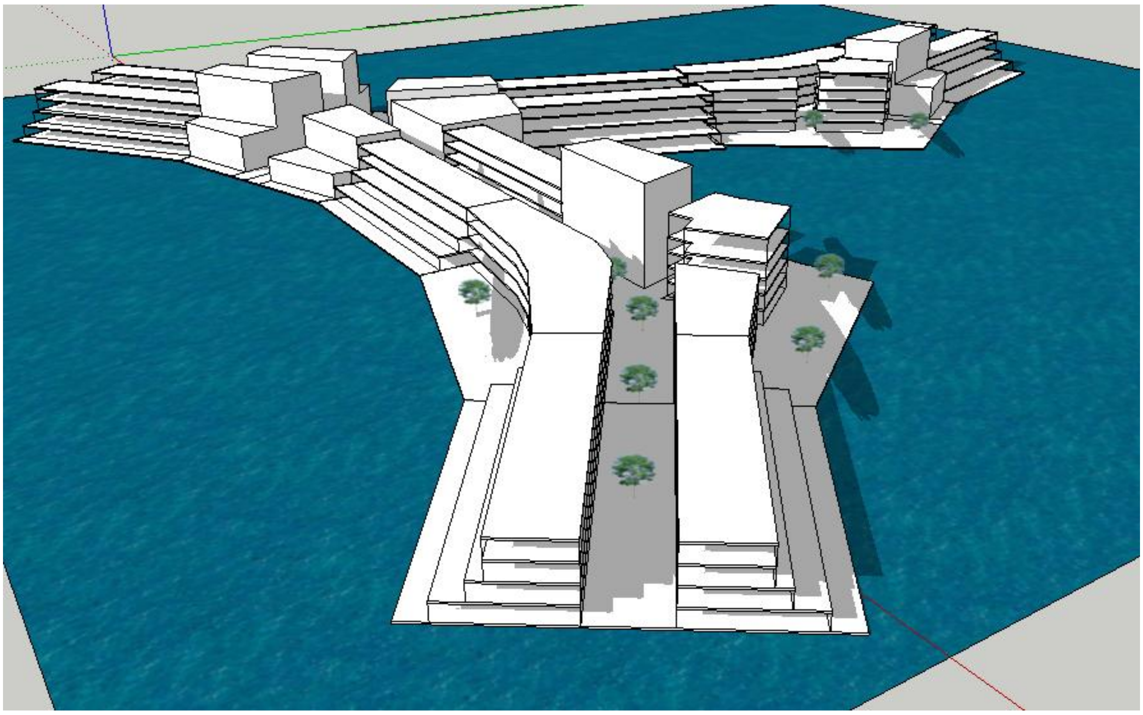


Figure 24, Impression of a region of the Seasteading city

It is possible that special functions will develop at crossings. These are places where many people drive, and the buildings are also visible from several directions. Functions that could develop at these places include shops, supermarkets, restaurants or schools, and daycares.

Jobs (ICT and creative)

In Figure 25, types of jobs in the Netherlands the percentage of the different types of jobs in the Netherlands is given (source: CBS).
In the Seasteading city, few people working in industry, transportation and real estate, because these working fields are rather small. The government sector is also small in the Seasteading city, because the client wants to experiment with new types of governments and because the ideology is also to create a smaller government sector. There will be jobs in the field of education, as well as in day-care, elementary schools and higher education.

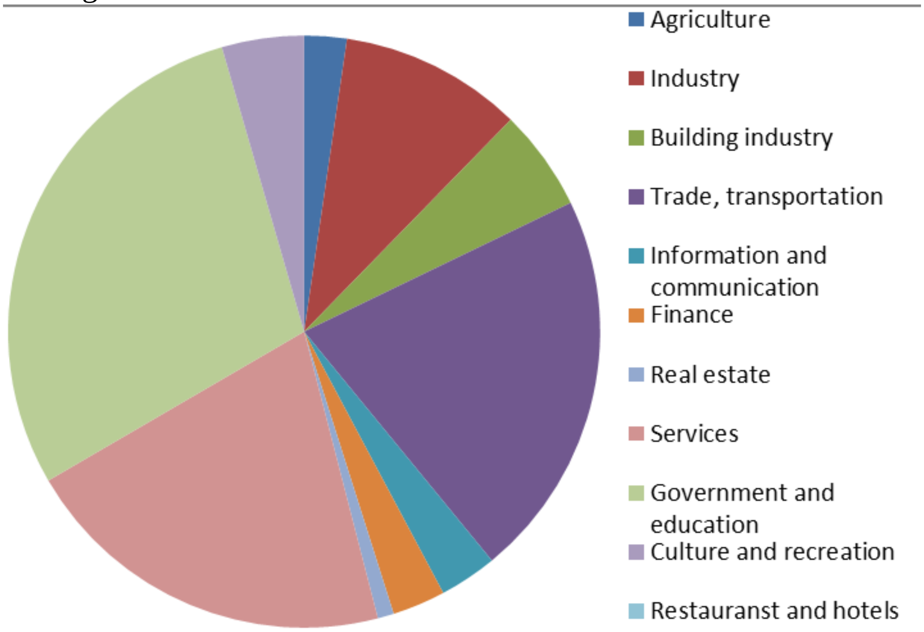


Figure 25, types of jobs in the Netherlands

Tourists

A hotel can be placed towards the water to use it as an extension of its interior. Hotels can also serve as mini icons that the inhabitants may use to navigate around the city.
A hotel can be of different sizes. In this report, a standardized module is used in which a hotel can serve around 300 tourists and provide jobs for the inhabitants

Other functions
Other functions, such as schools and day-care centres, can be placed in the Seasteading city in a similar way. Furthermore, a number of other facilities such as day-care centres and high schools will be placed in the Seasteading city. The educational facilities will be like those of other cities of comparable size in The Netherlands. Other facilities that are placed in the Seasteading city include family doctors and a health-care central. These are not taken into account in the current scenarios, because their effect is insignificant.

3.2. Scenarios of the Seasteading city

Two designs are created for this report, a concentrated scenario and a dispersed scenario. At first the concentrated scenario will be described. After this, the dispersed scenario will be described. As stated before, it is necessary to create a number of scenarios because of the uncertainties. In addition to this, it is the ideology of the Seasteading community is to create a libertine community in which everyone can start a business anywhere in the city if they want to. Comparing a concentrated scenario with a dispersed scenario could also generate insight about the subject of town-planning and the effects of this planning on transportation.
The scenarios describe a situation in which a number of cruise ships arrive at the Seasteading city. Around 1,500 tourists will arrive at ring 8. The number of travellers that can sleep at a hotel in the hotel cluster is modelled at 2,700. A total 750 tourists will also leave the Seasteading community.
Furthermore a number of inhabitants will travel from their home towards shops. Around 8% of the inhabitants travel from homes to shops.

3.2.1 Scenario 1

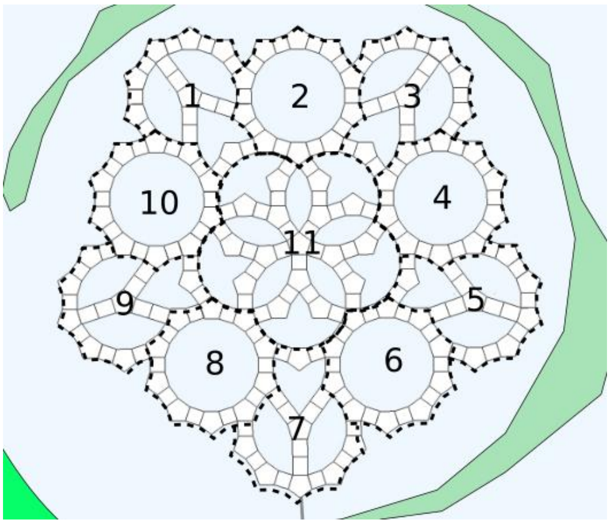
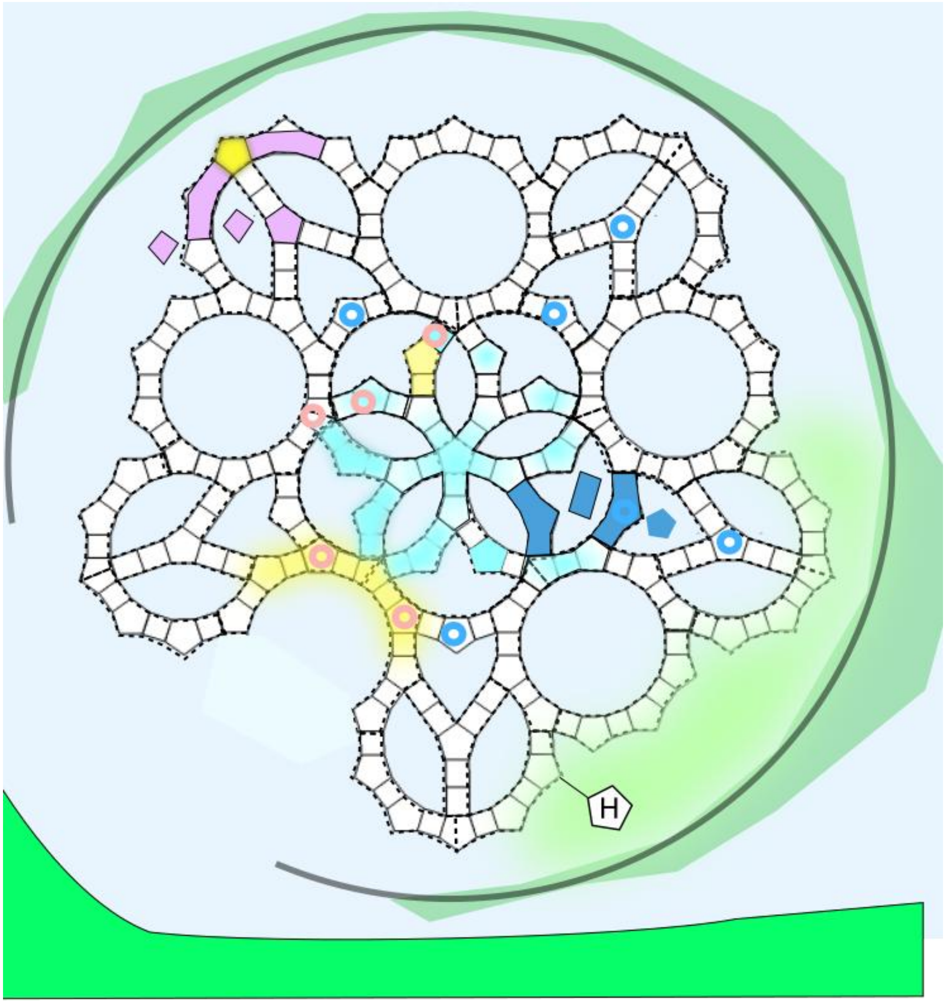


Figure 26, Division of the city

The Seasteading city is organised in different regions, these are numbered clockwise from one to ten, starting from the upper left ring. The middle ring is given the number eleven. The regions consist of modules that focus on specific functions such as housing, offices etc. Clusters will be developed to take advantage of the positive effect of clustering.
Ring one consists of a cluster that focusses on tourism. The ring consists of a number of hotels and one module with dwellings, shops and restaurants. The first, second and third rings consist mainly of dwellings with day-care centres and supermarkets. The facilities in these rings are based mainly on the daily system.
Ring five consists of dwellings and an educational hub. Ring six consists of dwellings and a number of business offices that are focussed on ICT and the creative sector. The ICT and the creative sector are placed near educational facilities to facilitate interaction between education and the work field.
Ring seven focusses mainly on dwellings, but there is also a nearby helicopter pad. The sixth, seventh and eighth rings are placed where algae are produced for energy and food. Ring ten is a housing area, and ring eleven is an ICT sector.
Most of businesses are placed in ring 11 because of the ICT sector. Other rings with a large number of jobs include ring 5 and 6, because of the educational hub (5) and the ICT facilities. There will also be people working in aquaculture who are placed outside the city and inside the city in rings five to seven. Places outside the city can be reached via the harbour (region 8).



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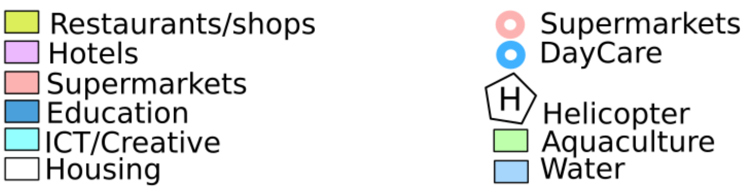


Figure 27, Seasteading city (scenario 1)

3.2.2 Scenario 2

As stated above, the second scenario is a dispersed scenario. It is based on an ideology in which everything can be created everywhere in the city by the inhabitants themselves. All functions are divided over the city like a scrambled egg. This can, for example, be compared to older inner cities in which working, living and recreation were combined.
There is, however, still a central place in the form of a harbor, at which ships can moor. Creating small harbors at the waterside all over the city could be more expensive, because scale factors cannot be used. Instead of developing one crane to handle a number of ships, more cranes would be needed to handle the same number of ships.

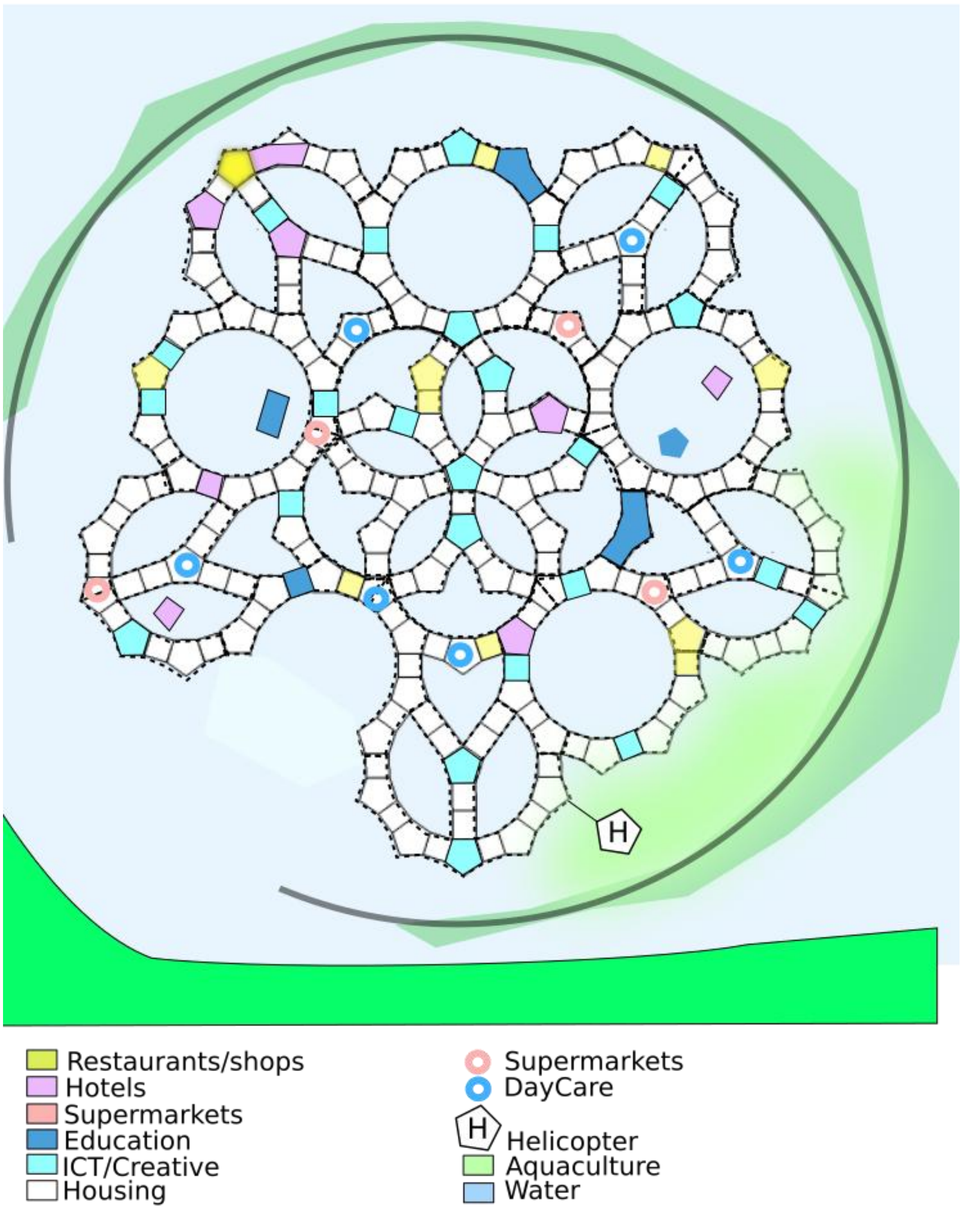
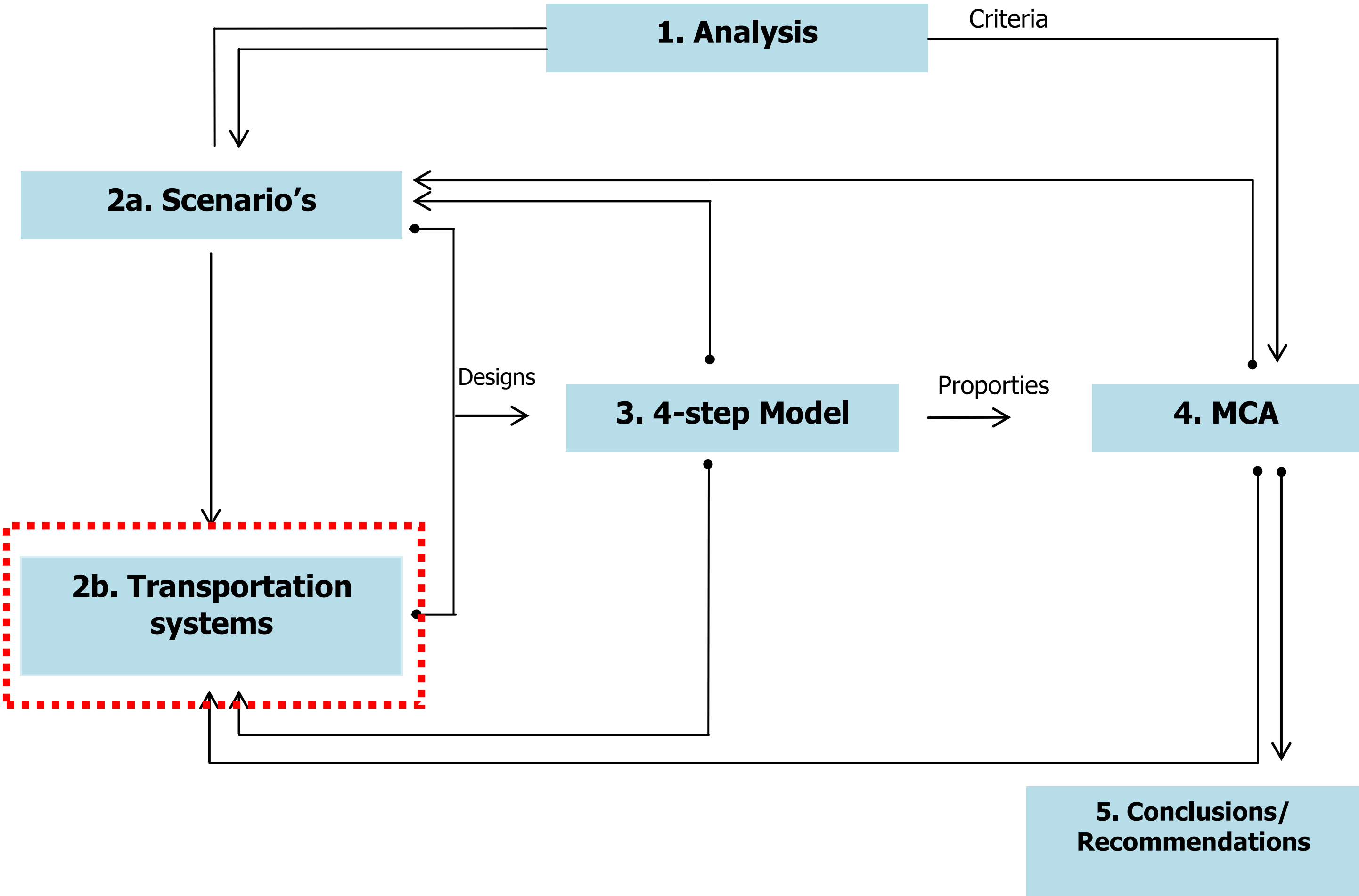


Figure 28, Seasteading city (scenario 2)


1. Analysis
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4

Transportation systems

This chapter describes the different transportation systems that will be evaluated. Normally, transportation systems are created in an existing environment, and if there is already a certain kind of infrastructure, this is most often used. This diminishes the possibilities for creating a completely new system. But because floating cities are created from scratch, it is possible to create a new system. In this chapter three significantly different transportation systems are designed.

4.1 Personal, collective and water transportation

The different transportation systems are divided into personal transportation, collective transportation and a system based on water transportation. Transportation systems can be divided in a number of ways. For this report, a division based on personal versus collective transportation is chosen. *Personal transportation* is defined as a transportation system in which everyone has an individual transportation unit. Examples include cars, e-bikes, motorized bicycles, etc. This category is further divided into slow transportation (e.g., bike or pedestrian) and fast transportation, (e.g., car).

Collective transportation consists of transportation systems in which the infrastructure of the transportation system and the vehicles are operated by a company or government institution. The system is financed by the society. In floating cities, it seems likely that the system would be financed collectively by the inhabitants. This is a consequence of the wish of the inhabitants to create an independent city. It is unlikely that a government would invest in such a system. Collective transportation can be further divided into mass or personal. Mass transportation consists of transportation systems like trains, busses, metro's, trams etc. while personal transportation consist of smaller units that are operated in a collective way. An example of this is a taxi or an Ultra RPT.

It is furthermore necessary to evaluate transport that is based on water, because this could become an important way of transportation in a floating city.

Table 4, Division of transportation modes

Personal	Slow	Land	Car, bicycle
		Water	Swimming/peddling
	Fast	Land	Car with driver
		Water	Personal boat
Collective	Mass	Land	Bus, train, tram etc.
		Water	Ferries, ships etc.
	personal	Land	Public transportation with small vehicles, taxi's
		Water	Ferries for small groups of people, gondola's etc.

The main reason why this division is chosen is that these systems differ significantly from each other. Collective transportation transports groups of people with vehicles that are operated by a third entity. People do not own the vehicles themselves. These vehicles are often operated on dedicated infrastructure such as a

railway, but this is not necessary. Personal transportation on the other hand consists of people who use their own vehicles (e.g., cars) on infrastructure (often roads) that are also used by other people.
Beside the difference in infrastructure, vehicles and operations, the financing of the systems also differs. In systems that are focussed on personal transportation, people buy their own cars and only the infrastructure is paid communally. Collective systems are operated by companies or other third parties, and people pay for example for a ticket to get from one place to another. The infrastructure is also often built collectively.
It is likely that people who live together in a small community will also divide the costs of the transportation collectively. It is unlikely that governments will invest in the city, because of the desire of the inhabitants to become independent.
Designing and evaluating all the combinations of transportation modes in combination with a scenario could lead a lot of output and the amount of information could make it difficult to draw clear conclusions. Furthermore the research would be unfocussed. Besides this, this is also not that time efficient. It is better to select a number of combinations of transportation systems, which are relevant for this case. When three different combinations are evaluated, clear conclusions can be drawn. For this report three combinations are chosen.
One transportation system, is focussed on personal transportation and consists of roads on which cars or other types of motorized transport -such as motor cycles, scooters or e-bikes- can take place. This transportation system also consists of a basic transportation system with slow modes.
Transportation system 2 focusses on collective transportation. A base transportation network in which people can walk and cycle everywhere is also included. Although it is theoretically possible to use all kinds of transportation modes, a number of requirements have to be met. First of all, the transportation systems have to fit the city scale and heavy infrastructure is also more expensive in a floating city. It is also desirable to minimize the amount of infrastructure in the floating city. The critical mass is also not high enough for mass transportation systems, so mass transportation is not included in this research. The transport is based on personal collective transportation or collective transportation with small vehicles. Examples of transportation modes that would suit the system include automated vehicles or bus transportation. Because the case study is set for the future and for a Western society, it is more likely that a system with automated vehicles will be used than a regular bus system.
The third transportation system is based on water transport and incudes both a mode for personal and collective transportation. It contains also a network for the basic transportation such as walking and cycling. Slow personal water transportation, such as peddle boats, is not seen as relevant for this report. Faster personal water transportation (small boats) is taken into account. This is seen as a transportation mode that could become important for floating cities. Mass transportation systems such as ferries are not relevant for this city, because the scale is not big enough for such a system. Small collective water transportation, similar to the ULTRA RPT system on the other hand, could potentially function well in this kind of cities. It is however noteworthy that a system as such does not yet exist in an urban environment.

Table 5, Combination of transportation systems

			Transportation system 1 (Personal)	Transportation system 2 (Collective)	Transportation system 3 (Water)
Personal Transportation	**Slow mode**	**Land**	X	X	X
		Water			
	Fast mode	**Land**	X		
		Water			X
Collective Transportation	**personal**	**Land**		X	
		Water			X
	Mass	**Land**			
		Water			

4.2. Transportation system

Based on the division, as described in the previous chapter, thee transportation systems are designed. At first the basic transportation system is described, the transportation system 1 (personal), transportation systems 2 (collective) and transportation system 3 (water) are described in turn.

4.2.1 Basic transportation system (slow modes)

Slow modes have several advantages over faster modes. Slow modes cause almost no nuisances. Furthermore, the costs of the vehicles are relatively low in comparison with motorized transportation. It is, however, not sufficient for long distances.
A fine grained and dense robust network is used for the slow modes. When a road in the network cannot be used, people can still use other routes to get to their destination and the system can still function. In the appendix, the travel time for the basic modes is given. These times are based on a walking speed of 4.3 km/h. The highest average travel time from one ring to another is 24 minutes. The longest time from one *module* to another *module* is found to be around 30 to 45 minutes**.**

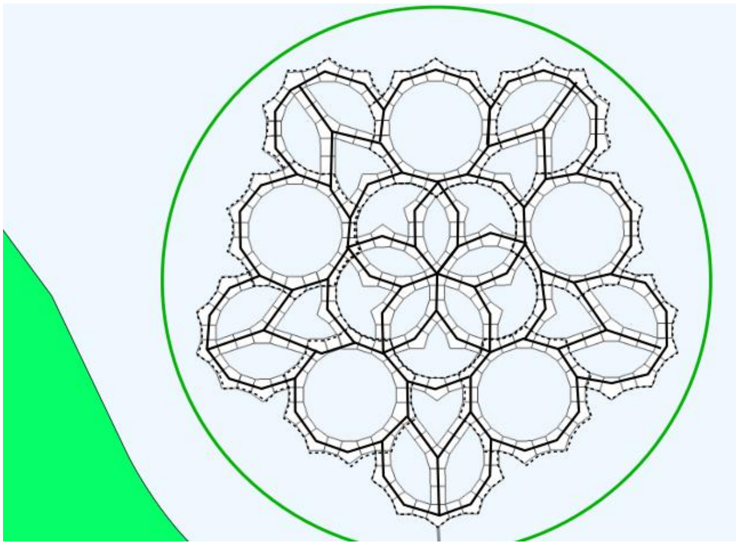
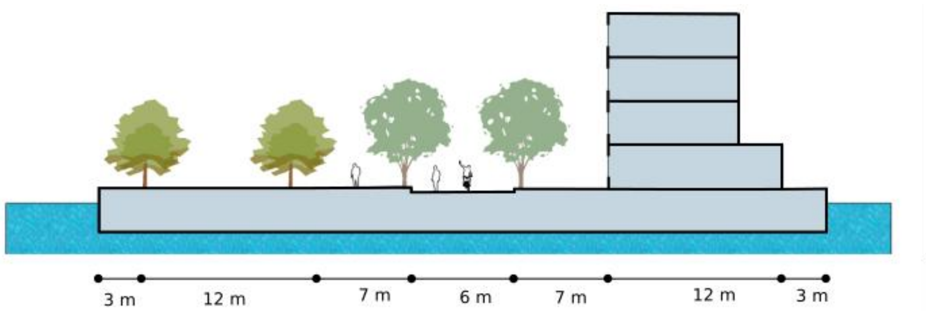


Figure 29, Basic transportation network

The bicycle has the potential to become an important mode in the future Seasteading city. In *Appendix B, Travel times* the travel times for bicycle trips can be found. In Figure 32 a section of the basic network is shown. There is a lot of space for the cyclists (6m) and the pedestrians (14m). At some places a relation with the water and the public space can be created, at other places boulevards are made.



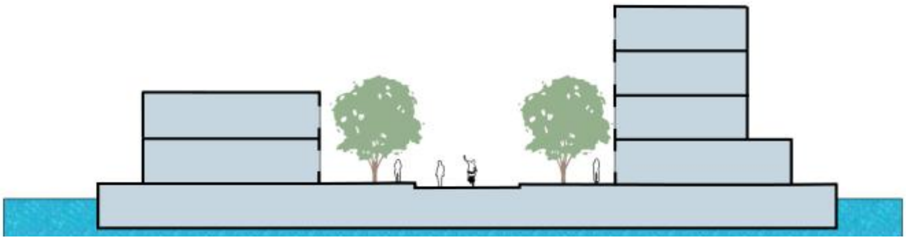
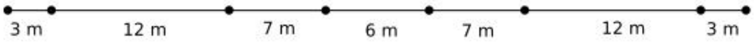


Figure 30, Basic transportation, section



4.2.2 Transportation system 1, personal transportation system

Because of the scale of the floating city, it is possible that car transportation will not be as important as it is at the moment in most places in the world. In addition, car transportation will not be used that much when there is no strong relation with nearby places for which car transportation is necessary. It is also possible that the characteristics of personal, transportation will change, because of new technology.

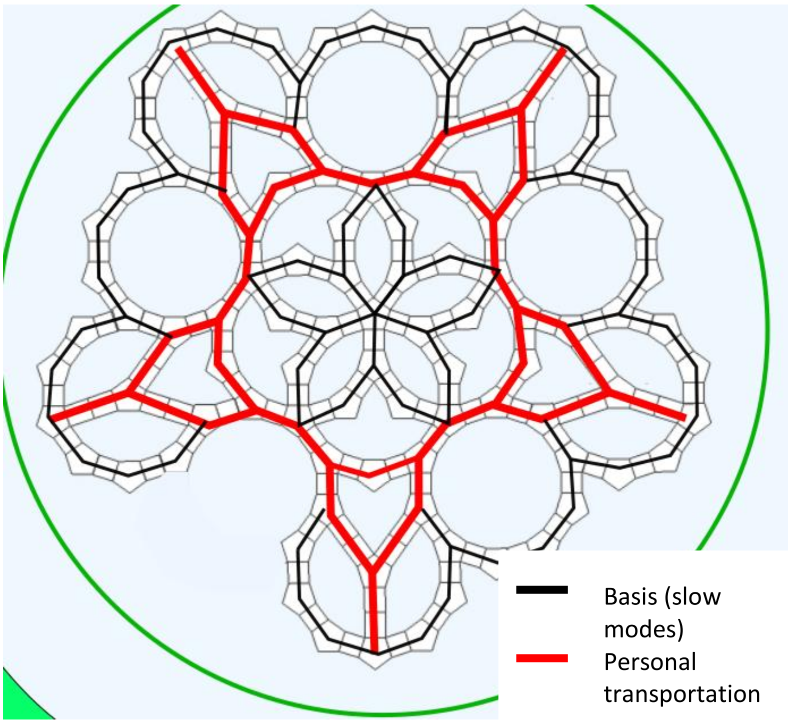


Figure 31, Networks of transportation system1 (personal)

A dense network is created in which all the roads are used for slow modes such as walking and cycling (black). There is, however, also a network that is assigned to faster modes such as cars, motorized bikes or e-bikes (red).
The speed of the car is estimated to be around 30 km/h. The time used to get to the faster transportation (for example, to get the car out of the garage) is estimated at one minute. The parking time is estimated at two minutes. The travel time depends mainly on the time needed to get to the car, park the car, etc. The travel times can be found in the appendix.

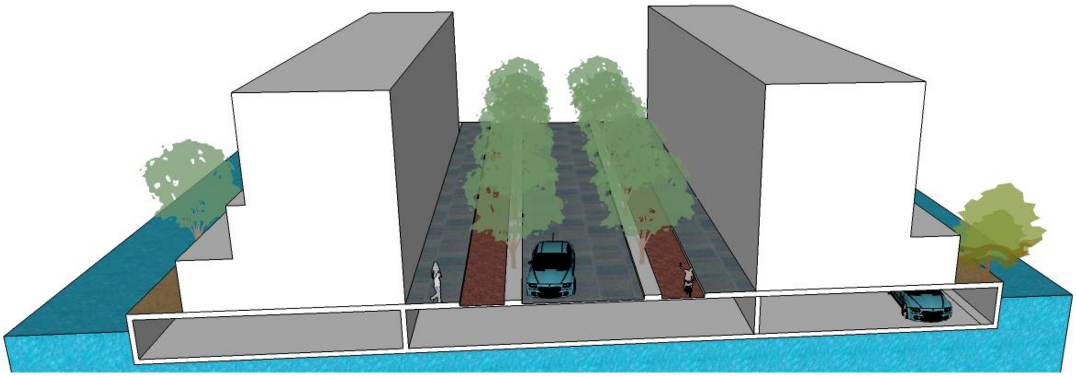


Figure 32, Section transportation system, personal

The section for the car lanes consists of a place for pedestrians (7m in total), bicycles (7m) and cars (6m). A bicycle path with a width of 3.5m would be able to cope with intensities higher than 4,500 cyclists per minute (Allen, 1998).
Furthermore, there is also space for trees and greenery between the car lanes and the sidewalks. If there are no cars on the roads, it is possible to create a section of 6m for the bicycle and 14 m for pedestrians. There are also other ways to use the space. It could, for example, be possible to also have two bicycle lanes and to use the middle of the road for greenery or to combine everything into a mixed-use area.

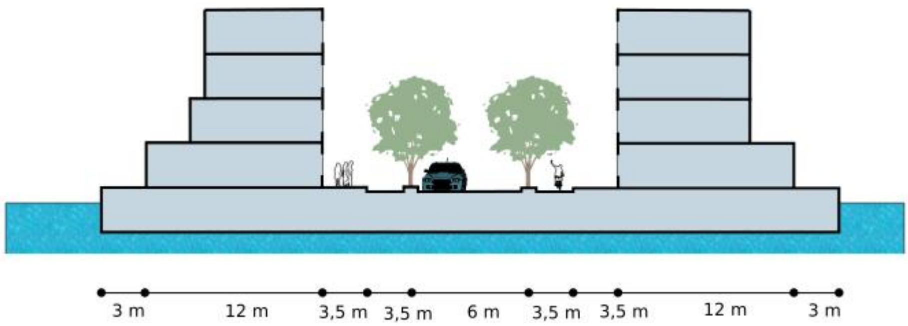


Figure 33, Section transportation system 1 (personal)

4.2.3 Transportation system 2, Collective

This collective transportation system is designed for an Ultra RPT system. Although the focus of this transportation system is on determining whether public transportation is feasible in the Seasteading city, there is also place for slow modes such as cyclists or pedestrians. The basic transportation system is used for slow modes.
Ultra RPT is an automated system in which vehicles are guided by a computer. The first public system was opened in 2011 in Heathrow and consisted of 21 vehicles and a track of 3,4 km (Lowson, M. V., et al. 2003) It is possible to operate vehicle with four seats and with ten seats on these networks. The transportation system is an on demand system. When people want to travel, they can push a button and a vehicle will arrive as soon as possible.
Two networks are developed for this transportation system, because on the one hand the implementation of the network is expensive, but on the other hand it will have a positive effect on the amount of travellers. Furthermore the network will probably have to expand when the city grows further.

Vehicles for 10 persons are operated on this network. The waiting time at the stops is at average 1 minute. The speed of the vehicles is 30 km/h. The travel times of these systems can be found in the appendix. The inner ring of the city is used for this transportation system.
Network 2 is a network that is operated throughout the city, similar to the network used in transportation system 1 (personal). Vehicles for 4 people are operated on this system.

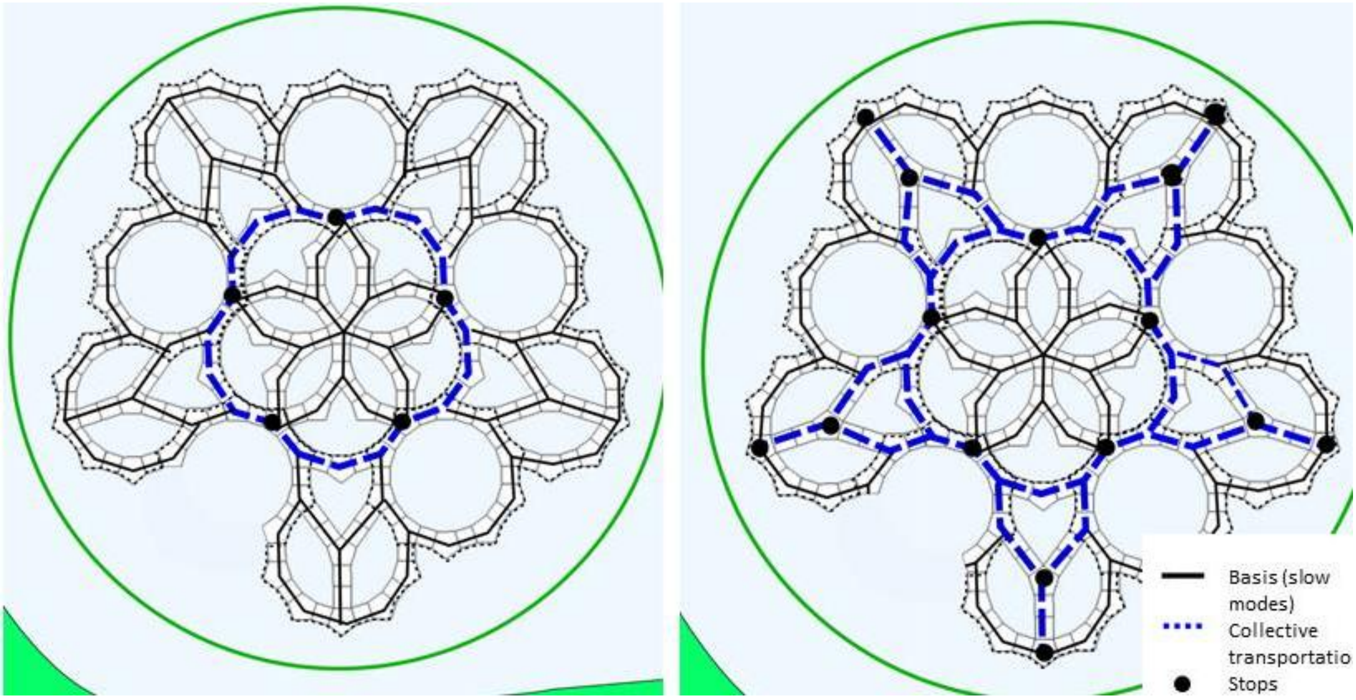


Figure 34, Networks transportation system 2 (collective), network 1 (left) and network 2 (right)

The Ultra-rapid transportation system requires less space in a city, so more space can be used for pedestrians, cyclists etc. The Ultra RPT creates a different urban atmosphere than the use of car transportation.

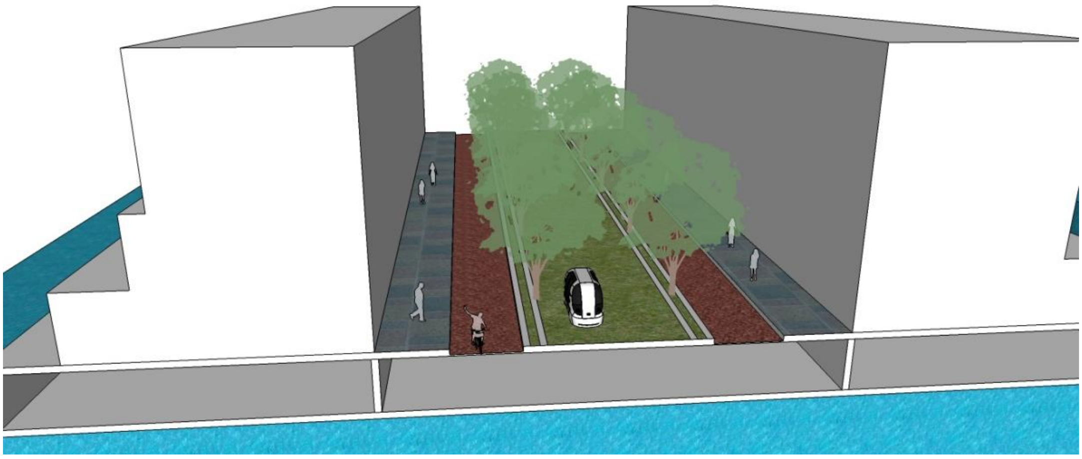


Figure 35, Transportation system 2 (collective)

The lanes of the ultra-rapid transport system need less space than the lanes for cars in the transportation system for personal transportation. In Figure 36, Section transportation system 2 (collective) a typical section of this system can be seen. The space for pedestrians is 3,5m, for cyclists 4m and for the Ultra RPT 5m.

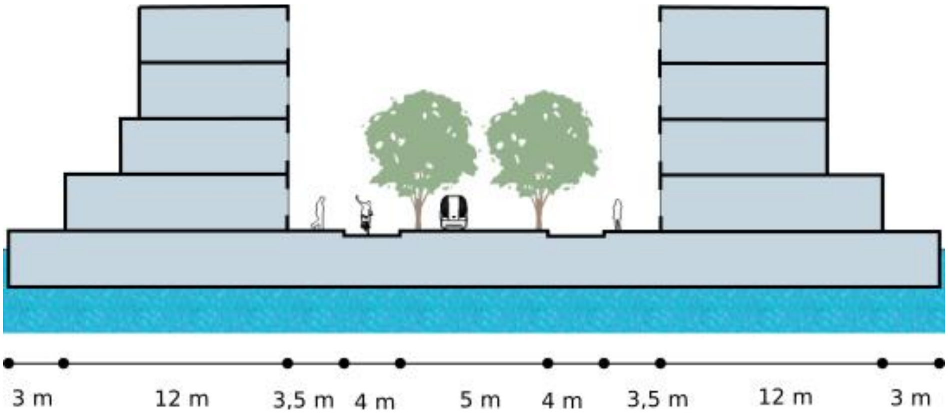


Figure 36, Section transportation system 2 (collective)

4.2.4 Transportation system 3 (water)

This transportation system focusses on transportation on water. Most of the modules in the Seasteading city are connected to each other, so at some places space is made available to create bridges. This way, a network is created which makes it possible to travel to several destinations in the city. From rings 2, 4, 6, 8 and 10, it is possible to travel towards modules in the Seasteading city and to the inner ring (11). This transportation system includes the basic transportation system, a system for personal transportation and a system for collective transportation.

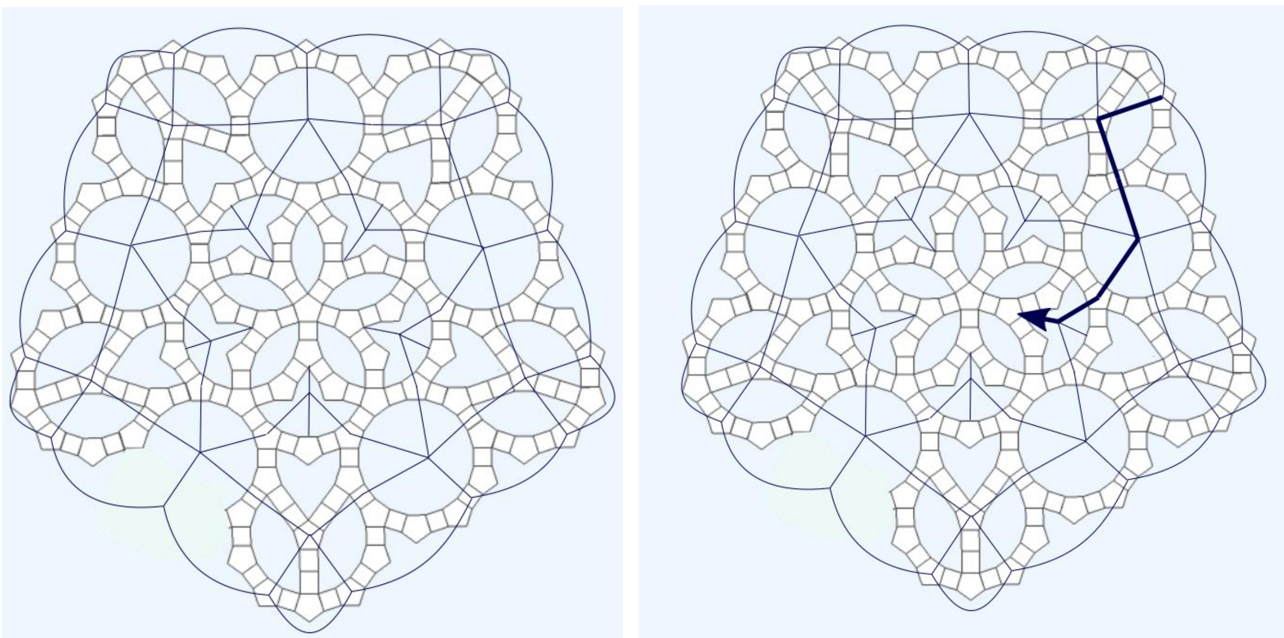


Figure 37, Transportation on water, network

It is unlikely that huge ships will be used for transportation inside the city. They could, however, be used for the transportation between the floating city and nearby land, however. For this system to function it is necessary to create harbours, these harbours can be combined with other functions. In figure 40, an impression of a square near the water can be seen. The city is closed by terraced buildings and opens up towards the water near the crossing.

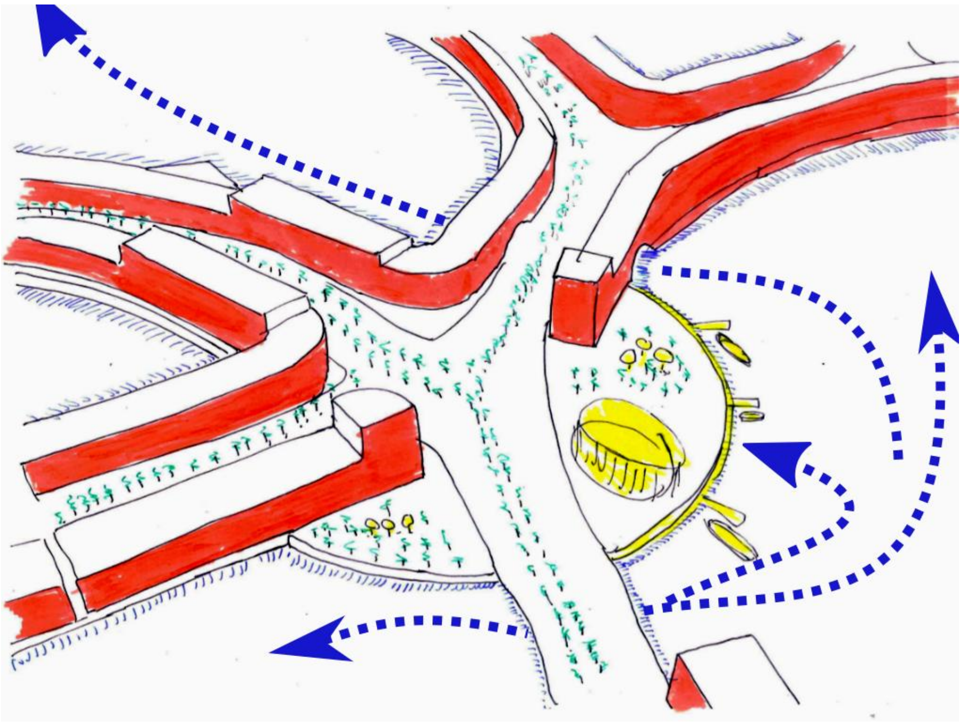


Figure 38, Water transportation (square)

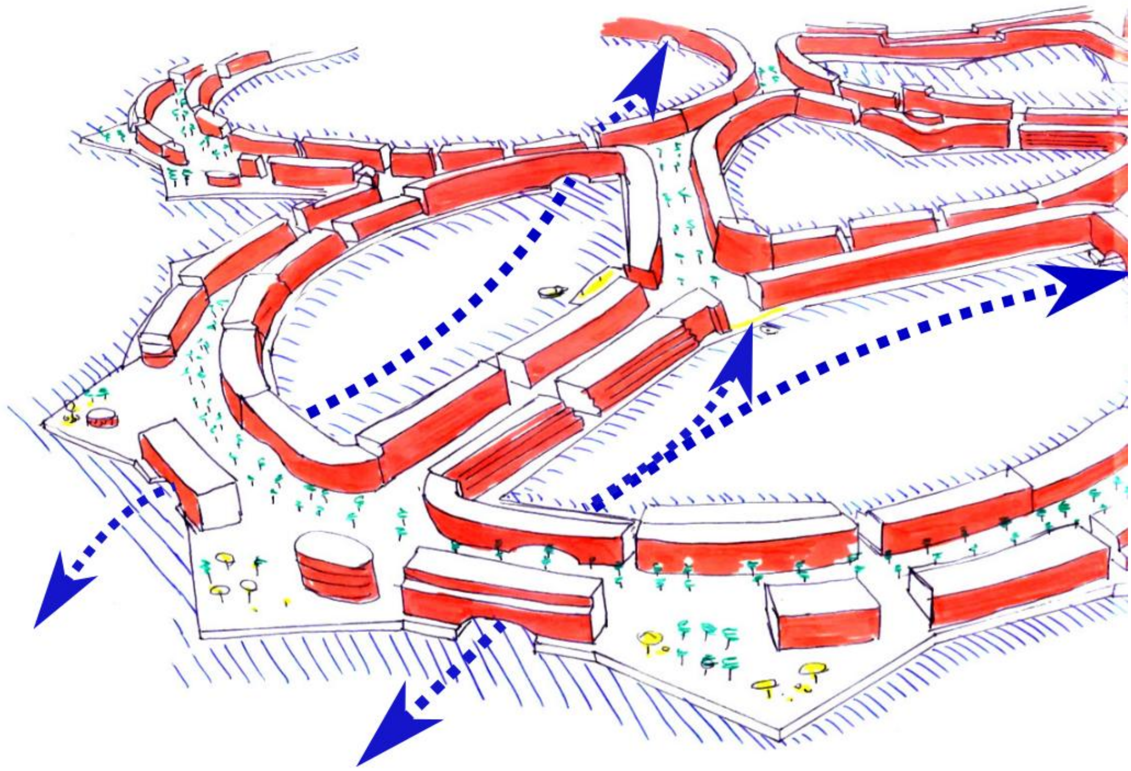


Figure 39, Seasteading city, impression

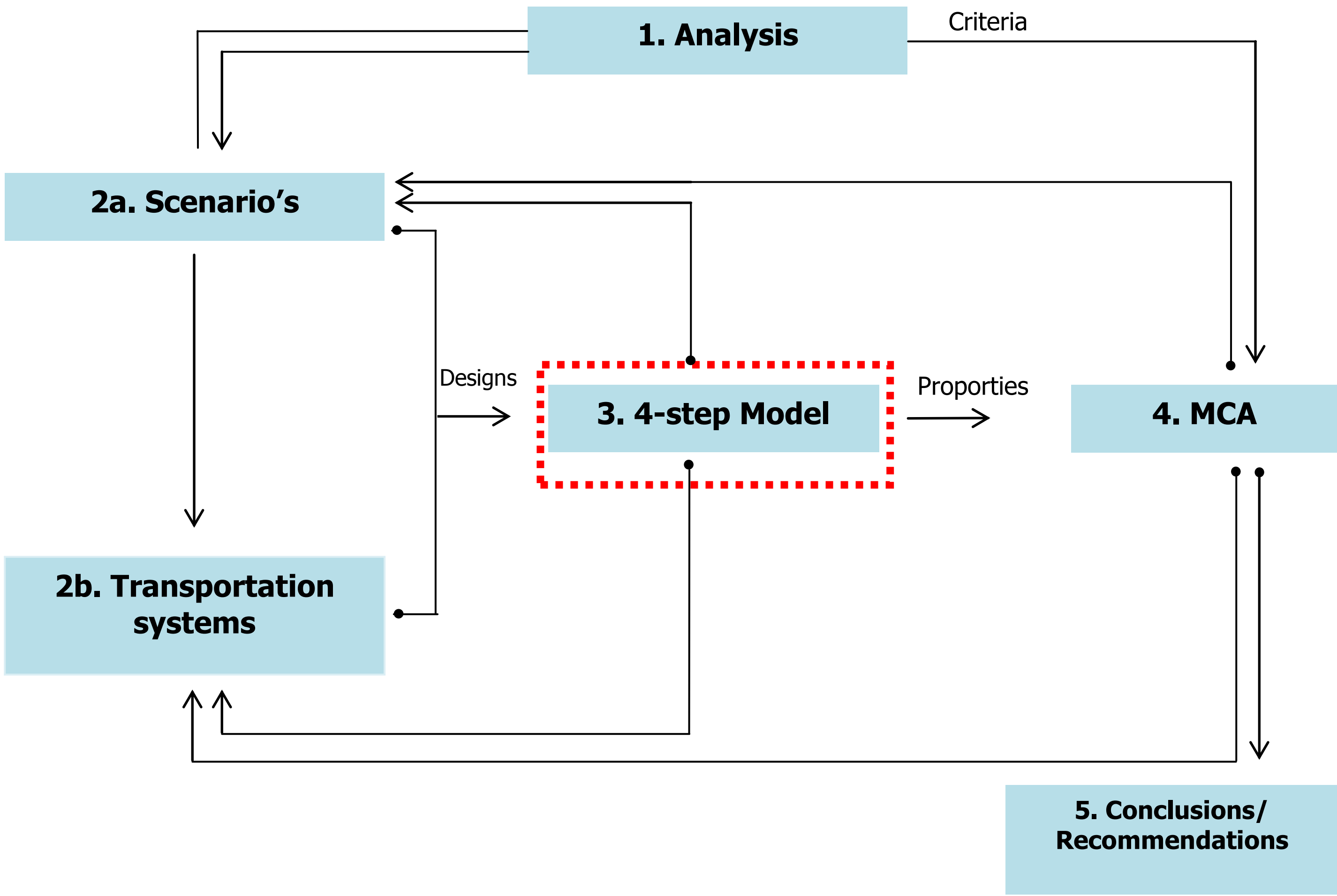
Personal and collective transportation is used in this transportation system. When people use their own boat, they first have to walk to the mooring place; around 2 minutes are needed to get the boat started. The travel time is around 12km/h. When people use the collective system, an additional 5 minutes is needed as waiting time. The travel times can be found in *Appendix B, Travel times.*

4.3 Conclusion

A number of different transportation systems needs to be created. The personal transportation system consists of cars, motors, scooters etc. The basic system (slow modes) is also used in combination with this transportation system, so two networks and two transportation modes are modelled with this system.
Transportation system 2 (collective) consists of an Ultra RPT network. The scale of the city is too small for mass collective transport. The futuristic situation of the floating city, furthermore, makes it more likely that a system of automated vehicles will be used, instead of a system with taxis or busses. Two networks are developed for this system. One that operates in the inner ring of the city and one that uses a network that covers the whole city. This transportation network models two different networks and because the base mode is also included, two different transportation modes.
Transportation system 3 (Water) consists of collective and personal water transportation modes. The basic system (slow modes) is also included, so a total of three modes are tested. A network in between the modules of the city is created for transportation system 3 (Water).
The transportation systems, as can be seen in Table 6, Overview of the amount of modes and networks per transportation system

Table 6, Overview of the amount of modes and networks per transportation system

	Amount of transportation modes:	Amount of networks:
Transportation system 1 (Personal)	2	2
Transportation system 2 (Collective)	2	3
Transportation system 3 (Water)	3	2


1. Analysis
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5

The four-step model

This chapter describes results from the four-step model. These results are the basis for the multi-criteria analysis. At first the methodology is explained, than the results are described and a few calculations regarding the capacity are made. At the end of the chapter a number of conclusions are drawn

5.1 Methodology

In figure 41the overall approach of the model is shown. At first two scenarios are created together with three transportation systems. These will be simulated by a four step model, used to calculate the network loads of the model. The four-step model consists of four sub models: trip generation, trip distribution, mode choice and assignment. The results of this model will also be used for the multi-criteria analysis. More information about this can be found in chapter 6, multi-criteria analysis.

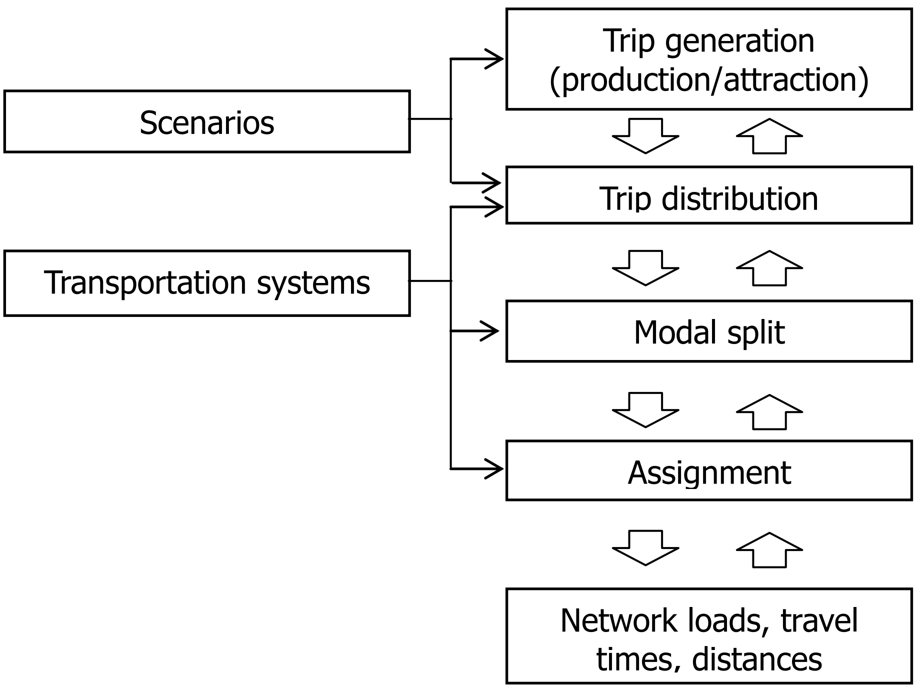


Figure 40, Overview of the research approach, the four step model

At first the spatial program (zonal data) of the two scenarios are used to calculate the frequency of trips between the zones. People want to perform activities and these activities are spread out over the Seasteading city. The number of people that want to travel due to the activities is calculated during the trip generation.

The trip generation will be modelled by creating a matrix for the production and the attraction potential of the zones. The attraction and production is based on the zonal data, derived from the amount of facilities or activities of the Seasteading city for example work, shop etc. and the amount of inhabitants of certain zones.

The scenario's consists of a peak hour (8:00-9:00) of a working day in the Seasteading City. A number of people commute from home to their work. Although the Seasteading city is modelled in a future situation and it could theoretically be possible that everyone will work from home, it is probable that it will still be necessary for people to meet each other during their work process, even if it's technically possible to work at home. Some of the inhabitants also come from nearby cities and travel to their job inside the city. This is modelled by the production of the guest workers in ring 8 and the attraction of ring 8. There are also students and children in the Seasteading city. The students will need to get to school around this time and some of the children are brought to day-cares. The amount of people that want to go to work, is on the one hand inspired by the current situation, but on the other hand also adjusted so it would fit the specific case study better.

Current situation

The share of inhabitants with a job in the Netherlands is around 51 % of the total population and according to the OVIN 58.8% of the job related trips in the Netherlands are in between 7:00-9:00 in the morning (CBS, 2015). The share of trips from students in the morning between 7:00-9:00 is around 70.9 % according to the research in the Netherlands (OVIN/MON). Around 10% of the Dutch population studies and the households consist of 2,3 people on average.

Seasteading city

In the Seasteading city it is necessary that more people work, so it is assumed 60% of the people have a job. Most people will work in the creative sector and the ICT. Although it is technically possible for people to work at home in the future, it is probably still necessary to travel to their job. It would for example still be necessary to discuss with colleagues or business partners.
Because the distances in the Seasteading community are smaller, it is more likely that people depart from their home at the same moment in the Seasteading community than in the Netherlands. Therefore the share of trips for the peak hour (8:00-9:00) will be around 65% in the Seasteading community. The production for the number of people that want to go to work is calculated by multiplying the number of inhabitants by 0.4.
In the Seasteading city 30% of the inhabitants study and around 70% of the students leaves during the morning peak, the production for this category is estimated by multiplying the households with 0.2.
Some of this people also need to bring their child to a day-care. It is assumed that they will go to their jobs after dropping of their children during the peak hour. The share of people that bring their children to a day-care is estimated at 4%. Table 7, Zonal data, scenario 1 shows the production and attraction potential of the different rings for scenario 1 (concentrated).

Table 7, Zonal data, scenario 1 (concentrated)

Production potential:					Attraction potential:				
region:	Inhabitants	Children	Tourists	Workers	Jobs	shops	Touristic attraction	education	Daycare
1	980	25	2,700	0	292	110	1,400	0	1
2	1,760	40	0	0	0	0	30	0	0
3	1,880	47	0	0	2	10	40	0	1
4	1,600	40	0	0	4	20	30	0	2
5	1,640	41	0	0	224	20	40	450	2
6	1,600	40	0	0	0	0	30	0	0
7	1,760	40	0	100	0	0	40	0	0
8	1,080	29	1,500	1,000	280	1,400	1,660	0	0
9	1,760	40	0	0	0	0	40	0	0
10	1,760	40	0	0	0	0	30	0	0
11	3,140	79	0	0	3,566	300	90	300	0
Total	19,000	460	1,100	1,100	4,368	1,860	3,430	750	6

Table 8 shows the production and attraction potential of the different rings for scenario 2 (wide-spread). A difference is that there is a clear relation between ring 1 and 8 because of the amount of tourists that want to travel from and to these rings in scenario 1 (concentrated), furthermore there are a lot of jobs in ring 11. The production and attraction is more spread out over the city in scenario 2 (wide-spread).

Table 8 Zonal data, scenario 2 (wide-spread)

Production potential:					Attraction potential:				
region:	Inhabitants	Children	Tourists	Workers	Jobs	shops	Touristic attraction	education	Daycare
1	1,300	32,5	1,200	2,700	296	110	650	0	1
2	1,500	37,5	0	0	676	100	40	100	0
3	1,760	44	0	0	196	210	60	0	1
4	1,620	40,5	300	0	224	100	190	50	0
5	1,560	39	0	0	380	10	40	150	1
6	1,600	40	300	0	572	400	220	0	0
7	1,620	40,5	0	0	430	110	50	200	1
8	1,740	28,5	1,500	1,500	22	110	1,530	0	1
9	1,560	39	300	0	276	210	210	100	1
10	1,620	40,5	300	0	592	300	210	100	0
11	3,120	78	300	0	706	200	230	50	0
Total	19,000	460	1,100	4,200	4,368	1,860	3,430	750	6

Distribution will be calculated by a singly constrained gravity model in which the production is known and the attraction potential is used. The production is based on the data of the inhabitants, the amount of tourists and people that come to the city only to work. The basic formula of a singly constrained model is:

$$T_{ij} = \alpha_i P_i X_j F_{ij}$$

T_{ij}= the number of trips from zones *i* to zone *j*
α_i= = a balancing factor
P_i= The production potential of zone j
X_j= attraction potential of zone *i*

F_{ij}= accessibility of j from i

The attraction for commuters for the peak hours is for example calculated on the number of jobs in a certain area divided by the total number of jobs times the inhabitants of an area.

$$X_{ij} = \frac{\frac{A(jobs)_j}{d_{ij}^r}}{\sum \frac{A(jobs)_j}{d_{ij}^r}} \times A(Inhabitants)_i$$

$A(jobs)_j$= the number jobs in j
d_{ij}= A distance factor between zone i and zone j
r =distance factor=0
$A(inhabitants)_i$ = The amount of inhabitants in zones i.

The production potential of a zone consists of:

- Workers, (40% of the people)
- (Guest)workers, that arrives in the harbour
- Tourists,
- Students (20% of the people)
- Shoppers (4% of the people)
- Children (4% of the people)

The attraction potential of a zone consists of:

- the number of jobs /$\sum jobs$
- the number of shops/$\sum shops$
- Touristic attraction/$\sum touristic\ attraction$
- Educational facilities/$\sum educational\ facilities$
- Day-care/$\sum daycares$

After the trip distribution, a mode choice model will be performed. This model is based on a model from Maanen and Verroen. Although the model is developed in 1992, it is useful for the report, because of the way the division used. The modes are divided in slow modes, public transport and faster transportation (in this case car). A logistic relation is assumed between the choice models.

As can be seen in Table 10, the variables consist of a constant for a certain transportation mode, a variable based on the concurrency between the slow or public transport versus the use of a car, a variable based on the distance and the time of the mode divided by the time by car.

Table 9, constants mode choice (Maanen, Verroen, & Heerema)

Variable	Slow mode	Public transportation
Constant	3.753	2.681
Concurrency	-2.512	-2.372
Distance	-0.11	-0.002
Travel time Collective transport/Car transportation	0.084	-2.269
Travel time Slow modes/ Car transportation	-1.109	0.477

It can be expected that the constant for slow transportation for the Seasteading city will be slightly higher than what has been found in this research, because of the type of population that will live in the Seasteading city.
The concurrency variable is defined by Maanen and Verroen as a function that divides the number of cars within a household by the amount of driving licenses in the households. (Maanen, Verroen, & Heerema). This factor is used as a constant in the model, because there is no information about who in the city will have a driving license or a car in the future.

The variable for the distance will probably be similar for the future situation. Furthermore it is assumed that the variable for the ratio of the travel times of the slow modes divided by the travel time of the car is similar in the Seasteading city as in the research of Maanen and Verroen.
The variable regarding the travel time for public transportation on the other hand is changed to -1.2, because it can be assumed that public transport will become more popular in the future Seasteading city, because the type of transport (small guided vehicles) offers more comfort, frequency and reliability than the public transport from the research of Maanen Verroen. The constants used in the model are presented in Table 23, Transportation system 3, characteristics basic system.

Table 10, Mode choice Seasteading city poject

Variable	Slow mode	Public transportation
Constant:	3.8	2.7
Concurrency:	-2.5	-2.3
Distance:	-0.05	-0.002
Travel time Collective transport/Car transportation:	0.08	-1.2
Travel time Slow modes/ Car transportation:	-1.1	0.5

An all or nothing assignment is used for the fifth step, the route assignment. The number of travellers is assigned to a certain route from one zone by assigning all the travellers to the shortest route between the regions. The shortest route between two zones is used, because problems with congestion are not taken into account.

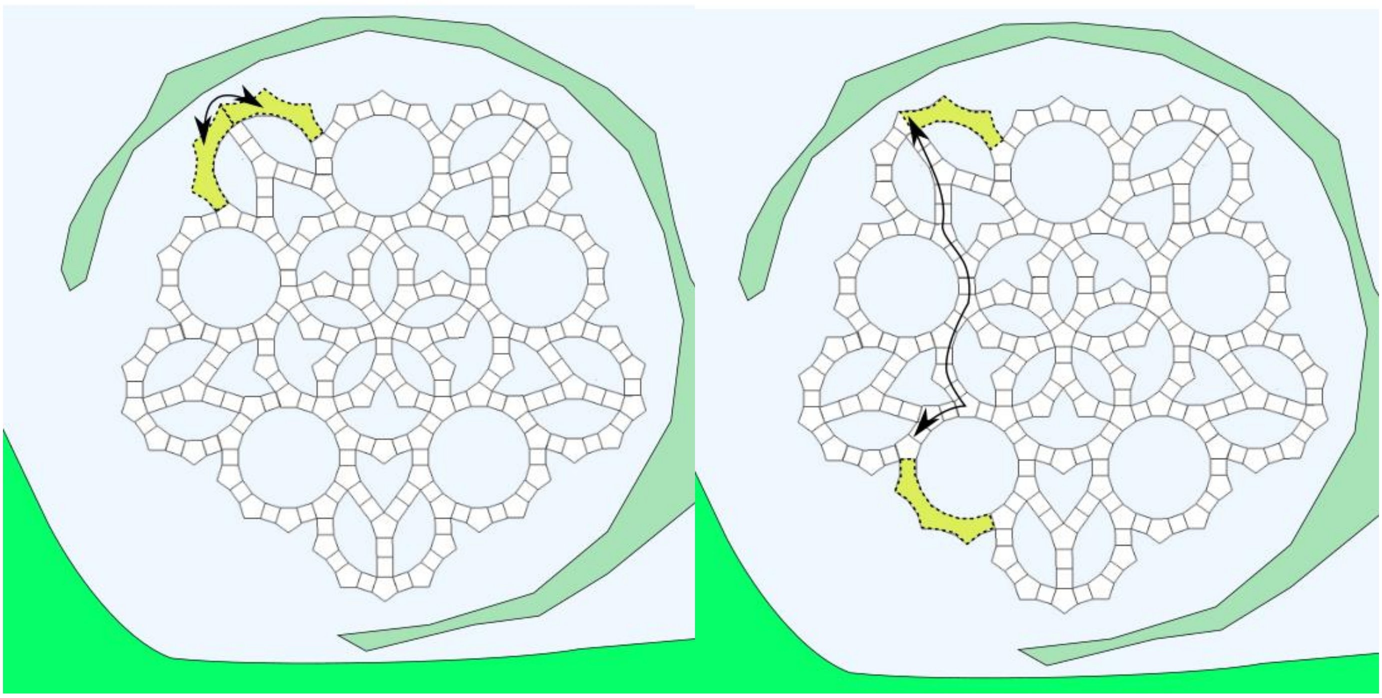


Figure 41, All or nothing assignment

The network in Figure 42, links of the transport systems is used to perform the all or nothing assignment for the land-based transportation systems. The water transportation uses the network of

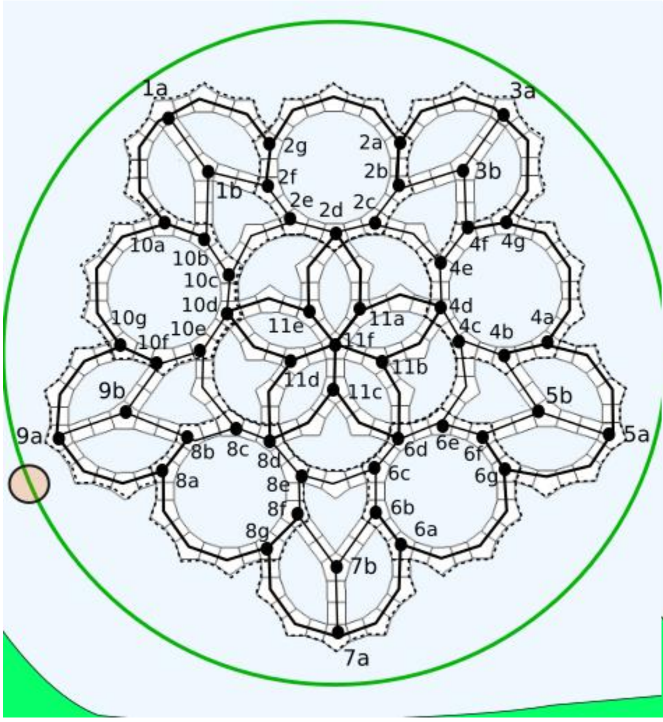


Figure 42, links of the transport systems (land-based)

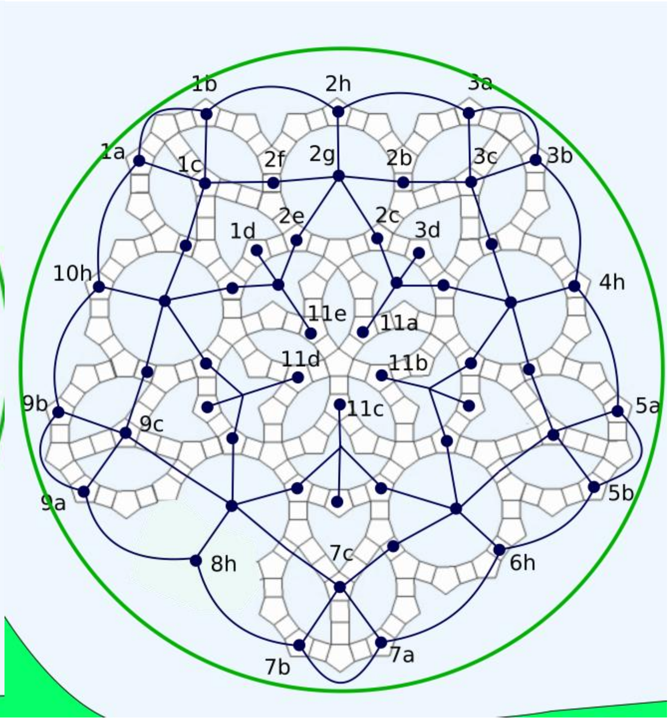
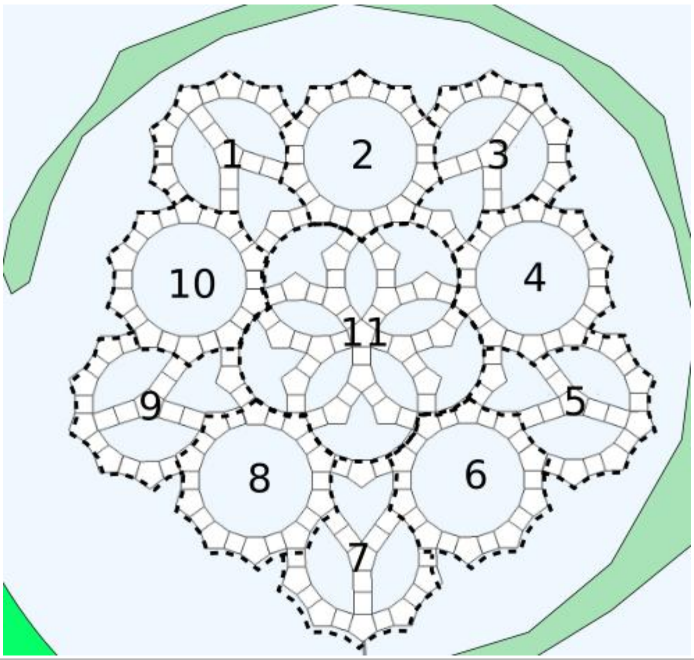


Figure 43, links of the transport systems (water-based)

5.2. Zones

The regions of the Seasteading city are subdivided in different zones. These zones are used in the model. Although the size of the rings is one hand arbitrary, it is an important decision. Bigger zones leave out to much detail, while smaller regions make it impossible to create a clear model. The majority of the regions consist of six to eight modules, while some regions has three modules and one consist of only one module (11.6). The regions furthermore make use of the symmetry in the design of the Seasteading city. In figure 29 the zones, the regions and the relation between the two are shown.



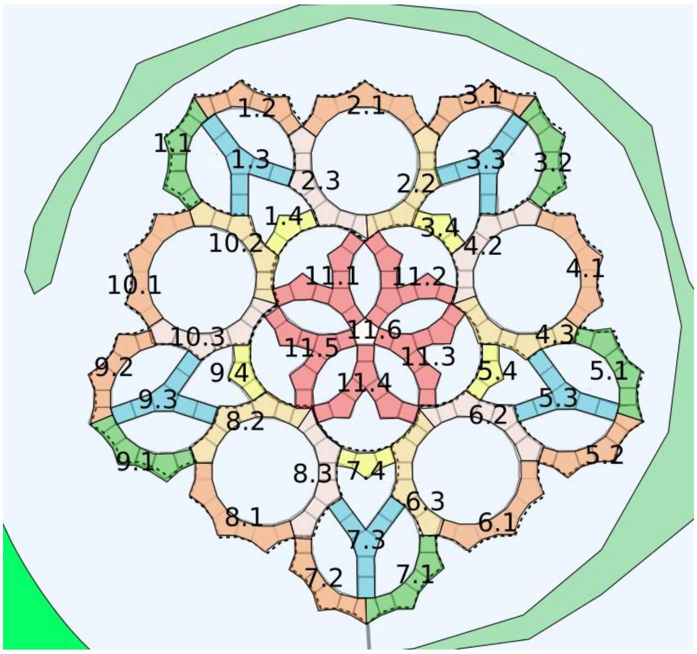


Figure 44, zones Seasteading City

In the report the tables with the program, production and attraction etc. consist of the different rings (ring 1-11), in the appendix however excerpts of tables are included that consists of the zones. More information about how the model works can be found in *Appendix C, Model*.

5.3. Results of the four-step model

In this chapter the results of the four-step analysis are presented. At first, the result of the trip distribution is presented. After this, transportation system 1 (personal) and the results of transportation system 2 (collective) and transportation system 3 (water) are described. The focus of the chapter lies on the network loads and on the testing whether or not the transportation system can cope with the expected traffic intensity. The two previously described scenarios are used to test the capacity of the transportation system. The first scenario (concentrated) focusses on a layout which is clustered and mono-functional; the second scenario (wide-spread) consists of a city in which the functions are spread out over the city.

5.3.1 Trip Distribution

In Table 11, an origin and destination matrix is shown for scenario 1 (concentrated). The rows represent the origin of the trips and the columns the destination. From region 1 to region are for example 1.703.
As can be seen in Table 11, there is strong relation between ring 1 and 8. The region where most people arrive at is region 1 (touristic zones), region 8 (harbour) and region 11 (ICT cluster). People travel furthermore to ring 5 and 6 because of the education centres (ring 5) and the jobs (ring 6). The other region does not have a lot of attraction, because they focus mainly on housing.

Table 11, Origin and destination matrix, scenario 1 (concentrated)

	1	2	3	4	5	6	7	8	9	10	11	Total:
1	1,170	24	41	43	269	24	31	1,703	31	24	839	4,199
2	110	0	16	31	387	0	0	646	0	0	1,251	2,442
3	105	0	15	30	370	0	0	617	0	0	1,194	2,331
4	110	0	16	31	387	0	0	646	0	0	1,251	2,442
5	95	0	13	27	335	0	0	558	0	0	1,081	2,109
6	110	0	16	31	387	0	0	646	0	0	1,251	2,442
7	85	0	11	23	286	0	0	475	0	0	996	1,876
8	707	13	25	27	215	13	17	1,038	17	13	1,415	3,501
9	80	0	11	23	282	0	0	470	0	0	910	1,776
10	110	0	16	31	387	0	0	646	0	0	1,251	2,442
11	131	0	19	37	461	0	0	769	0	0	1,488	2,905
Total:	2,814	37	198	334	.	37	49	8,215	49	37	12,929	

Scenario 2 (wide-spread) models a situation in which the functions are dispersed over the city, instead of concentrated into regions. As can be seen in Table 12, the production is the highest for ring 11. A small amount of production comes from the other zones. The reason is that region 11 is in this scenario a region with a lot of inhabitants.

Table 12, Origin and destination matrix, scenario 2 (wide-spread)

	1	2	3	4	5	6	7	8	9	10	11	Total:
1	318	223	130	162	171	305	238	581	244	324	298	2,995
2	119	273	142	125	206	298	289	59	224	329	285	2,350
3	112	258	134	118	194	282	273	56	212	310	270	2,220
4	181	289	154	148	219	332	307	196	253	362	319	2,761
5	103	236	123	109	178	258	250	51	194	285	247	2,035
6	180	287	153	147	217	329	305	196	251	360	317	2,742
7	97	225	113	101	166	241	230	46	177	264	235	1,895
8	400	302	136	189	199	362	248	700	251	376	399	3,561
9	148	214	115	113	162	249	227	180	191	272	240	2,113
10	181	289	154	148	219	332	307	196	253	362	319	2,761
11	203	339	180	171	256	386	360	207	293	422	371	3,186
Total:	2,041	2,936	1,536	1,531	2,187	3,374	3,036	2,468	2,543	3,666	3,299	

5.3.2 Transport system 1, personal transportation

This system focusses on personal transportation systems. Car transportation will probably still be important in the future, although, the popularity will probably be lower because of the scale of the city. Slow modes are also integrated in this system and are modelled by the basic transportation system. First the results of the basic transportation system will be described and after this the results of the personal transportation system.

Basic transportation system

A connection between ring 1 and ring 8 for scenario 1(concentrated) can be seen in Figure 45. Furthermore, there are trips near ring 2, ring 4 and ring 6. In scenario 2 (wide-spread) the trips are more dispersed over the network.

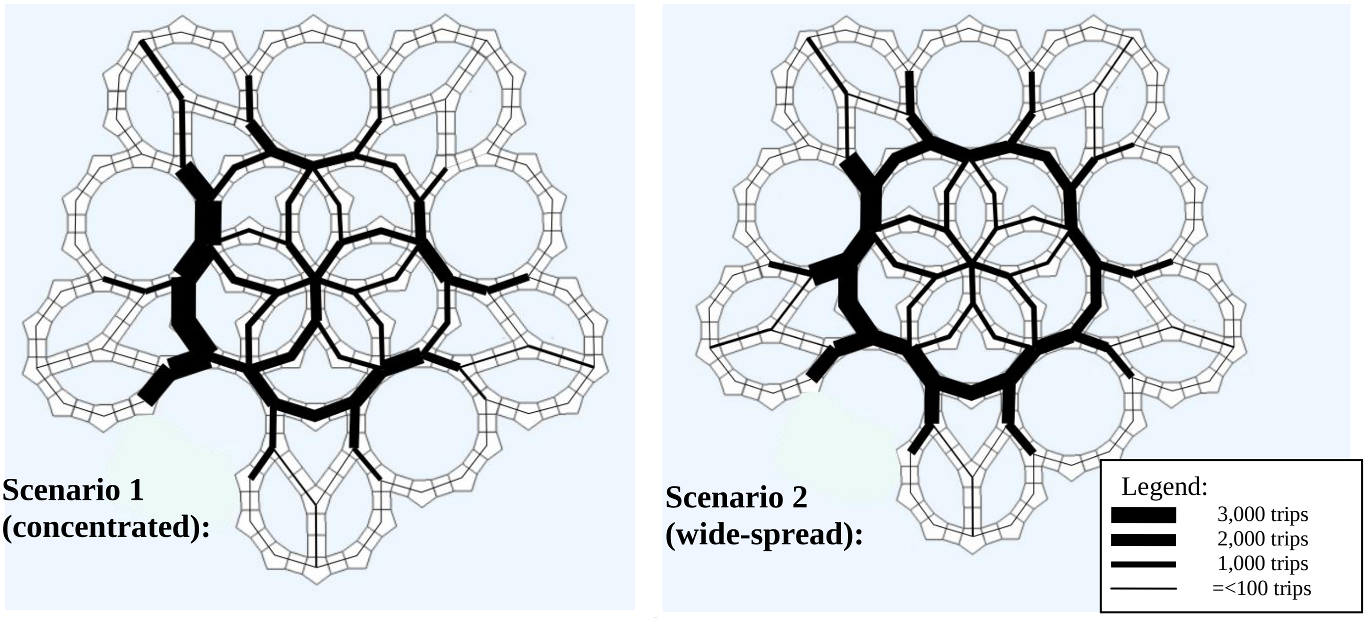


Figure 45, Transportation system 1 (personal), amount of trips (basic transportation system)

In scenario 1 (concentrated), 80% of the travellers use slow mode transportation, such as bicycles and walking. The total distance covered is 15,600 km in scenario 1 (concentrated) and 17,000 km in scenario 2 (wide-spread). The average distance in scenario 1 (concentrated) is 100 meter lower than in scenario 2 (wide-spread). As a result, the average travel time is also lower. The travel time is 13 minutes in scenario 1(concentrated) and 14 minutes in scenario 2 (widespread).

Table 13, Transportation system 1, characteristics basic system

	Scenario 1(concentrated):	Scenario 2 (wide-spread):
Modal share:	76%	76%
Total distance (km):	15,600	17,000
Average distance (m):	900	1,000
Total travel time (hrs):	3,700	4,000
Average travel time (min):	13	14

The relation between ring 1 and 8 in scenario 1 (concentrated) can also be seen in table 14. There are four links with trips in between 1,500 and 2,000 trips. Scenario 2 (wide-spread)., on the other hand, has more links with traffic loads between 500 -1000 trips and 1,000- 1,500. In short, the trips are better divided over the network in scenario 2 (wide-spread) than in scenario 1 (concentrated), but the trips are also longer.

Table 14, Amount of links with a certain amount of trips.

	Scenario 1(concentrated):	Scenario 2 (wide-spread):
>2000 trips	0	0
1500-2000 trips	4	0
1000-1500 trips	5	8
500-1000 trips	38	42
<500 trips	113	110

Personal transportation system

In figure 48, a clear connection between region 1 and 8 in scenario 1 (concentrated) is also visible. The number of trips is also more levelled in scenario 2 (wide-spread).. In scenario 1(concentrated) a small number of links are quite high in comparison with scenario 2 (wide-spread), but the network in scenario 2 (wide-spread) has more links with more than 100 trips.

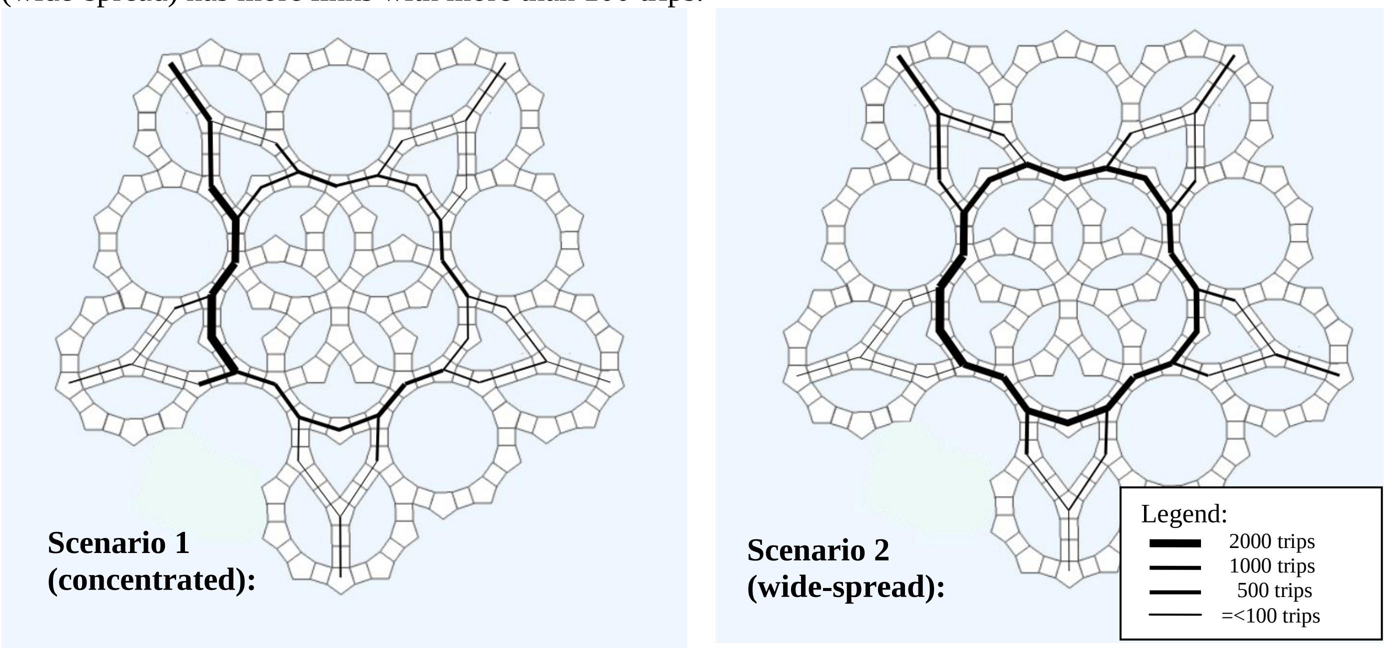


Figure 46, Transportation system 1 (personal), amount of trips

The modal share for the personal transportation system is 24% for both scenarios. The amount of trips people make is more or less the same. The average distance, however, is higher in scenario 2 (wide-spread). The placement of the ICT and creative centre in the middle of the city in scenario 1 (concentrated) caused a lot of (relatively) small trips between the home and the jobs of inhabitants. In scenario 2 (wide-spread), these jobs are distributed over the city.

Table 15, Transportation system 1 (personal) characteristics

	Scenario 1(concentrated):	Scenario 2 (wide-spread):
Modal share:	24%	24%
Total distance (km):	4,000	5,200
Average distance (m):	755	1,000
Total travel time (hrs):	290	325
In vehicle time (min):	3.2	3.7
Average travel time (min):	11,5	11,9

The number of trips is significantly lower than in the basic transportation system. Only three links have more than 500 trips in scenario 1 (concentrated). Scenario 2 (wide-spread) induces more links with loads between 100 and 400 trips and has less roads with less than 100 trips than scenario 1 (concentrated). The absent of roads with loads more than 500, in addition, indicates a better division of the traffic over the network.

Table 16, Transportation system 1 (personal) , amount of links with a certain amount of trips.

	Scenario 1 (concentrated)	Scenario 2 (wide-spread):
>500 trips	3	0
400-500 trips	5	9
300-400 trips	4	13
200-300 trips	13	17
100-200 trips	21	24
<100 trips	117	97

The relation between ring 1 and ring 8 is also visible in Table 17. Only two rings have a requirement of more than 1500 parking places. The amount of parking is also more equally divided in scenario 2 (wide-spread).

Table 17, number of rings that requires a certain amount of parking places

	Scenario 1 (concentrated):	Scenario 2 (wide-spread):
>1500 parking places	2	0
1000-1500 parking places	0	0
500-1000 parking places	2	6
<500 parking places	7	5

5.3.3 Transport system 2, collective transport

This system focusses on the collective transportation system. The design of this variant consists of an -Ultra RPT on demand- system. At first the results of the basic systems will be described and after this the results of both networks of the collective transportation system will be presented.

Basic transportation system

Figure 47, shows the same relationship between zones as was presented in transportation system 1 (personal). The transportation is also more spread out over the city in scenario 2 (wide-spread). The share of people using the basic transportation system (slow modes), however, is higher than in transportation system 1 (personal).

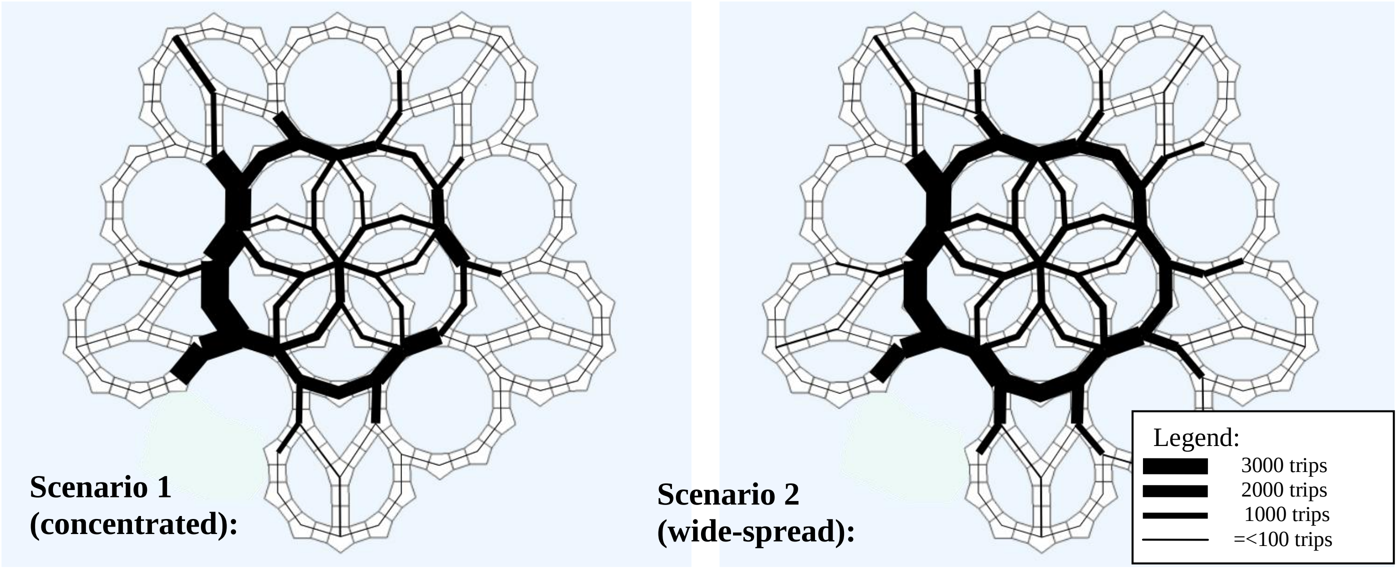


Figure 47 Transportation system 2 (collective), amount of trips (basic transportation system)

The amount of people that choose to either walk or cycle is around 90% in both scenarios. The total distance people travel by the basic transportation mode is also higher than in the previous transportation system. Especially scenario 2 (wide-spread) invokes a long total distance. The average travel time is also larger.

Table 18, Transportation system 2, characteristics basic system

	Scenario 1 (concentrated):	**Scenario 2 (wide-spread):**
Modal share:	89%	90%
Total distance (km):	18,500	20,000
Average distance (m):	930	1,000
Total travel time (hrs):	4,300	4,800
Average travel time (min):	13	14

Six links have travel loads of over 1,500 trips in scenario1. Only two links have this amount in scenario 2 (wide-spread). More roads, however, with more than 500 trips exist in scenario 2 (wide-spread). The trips are also better divided over the total network in scenario 2 (wide-spread) in this basic transportation system. Scenario 1 (concentrated). furthermore, has more links with less than 500 trips.

Table 19, Transportation system 2, amount of links with a certain amount of trips.

	Scenario 1 (concentrated):	**Scenario 2 (wide-spread):**
>2000 trips	2	0
1500-2000 trips	4	2
1000-1500 trips	13	19
500-1000 trips	50	56
<500 trips	108	103

Collective transportation network 1

As can be seen in Figure 48, the amount of travellers of the collective transportation system is significantly lower than the amount of users at the personal transportation network.

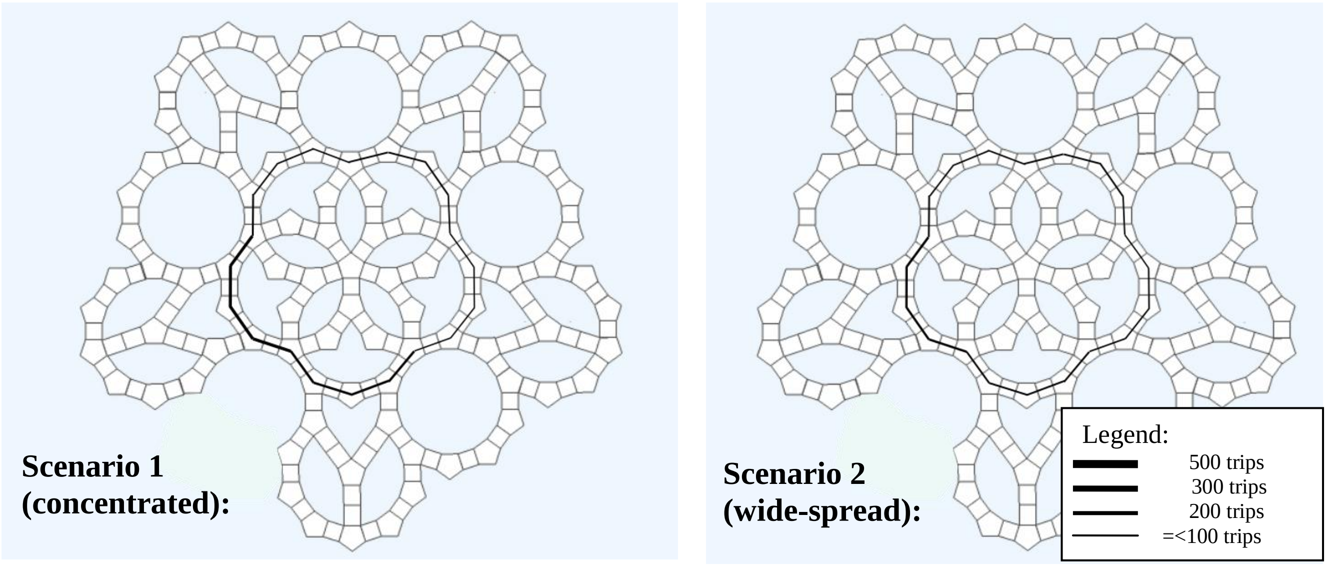


Figure 48, Transportation system 2 (collective), amount of trips (network 1)

The modal share is lower than in transportation system 1 (personal). The modal share is lower in the scenario 2 (wide-spread) than in scenario 1 (concentrated). The total distance of the trips is also low in comparison with the previous transportation modes. Fewer people make trips and the trips are also shorter (740m and 750m)

Table 20, Transportation system 2, characteristics network 1

	Scenario 1 (concentrated):	Scenario 2 (wide-spread):
Modal share:	11%	10%
Total distance (km):	1,800	1,800
Average distance (m):	740	750
Total travel time (hrs):	140	140
In vehicle time (min):	3.4	3.8
Average travel time (min):	12.8	13.7

The total amount of trips is low. Only 15 links have traffic loads of more than 100 trips in scenario 1 (concentrated). and only 11 lines have more than 100 trips in scenario 2 (wide-spread).

Table 21, Transportation system 2, Travel loads

	Scenario 1 (concentrated):	Scenario 2 (wide-spread):
>200 trips	3	0
100-200 trips	12	11
<100 trips	145	149

Collective transportation, network 2

In Figure 49, the results for the second network of transportation system 2 (collective) are shown. The amount of people that are using collective transportation has increased in comparison to network 1 of the collective transportation system.

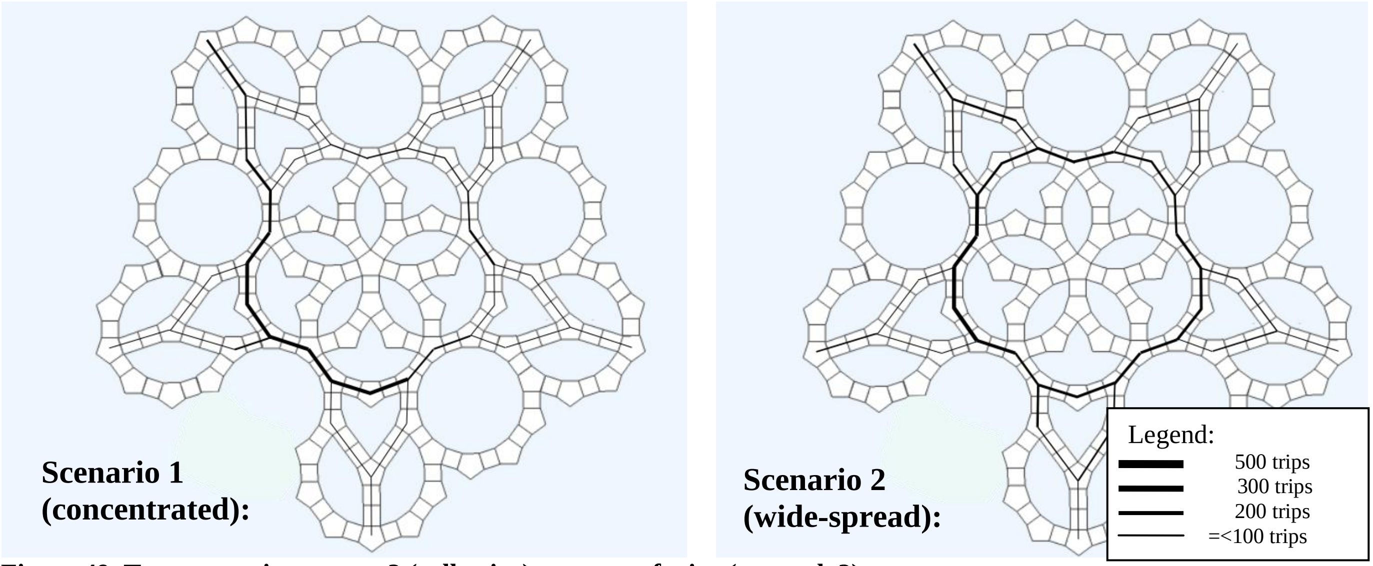


Figure 49, Transportation system 2 (collective), amount of trips (network 2)

More people will choose to travel with this transportation mode. The total distance is also higher in Scenario 2 (wide-spread). The trip distances interestingly increase significantly from 765 to 937 and the average and total travel time are also higher. In scenario 1 (concentrated)., the average travel time is 4,5 minutes and in scenario 2 (wide-spread), 6 minutes.

Table 22, Transportation system 2, characteristics network 2

	Scenario 1 (concentrated):	Scenario 2 (wide-spread):
Modal share:	16%	14%
Total distance (km):	2,800	3,000
Average distance (m):	765	937
Total travel time (hrs):	280	330
In vehicle time (min):	4.5	6
Average travel time (min):	11.8	12.2

	Scenario 1 (concentrated):	Scenario 2 (wide-spread):
>200 trips	4	6
100-200 trips	17	37
<100 trips	143	123

5.4.3 Transport system 3, (water)

This system consists of both personal and collective water transportation, in combination with the basic transportation system. At first the results of the basic systems will be described and after this the results of the water transportation system for both the personal as the collective transportation.

Basic transportation system

The amount of people choosing to either walk or cycle is similar to transportation system 1 (personal). There is no difference between the scenarios regarding the modal share. The relationship between region 1 and 8, as mentioned in the previous chapters, is also visible in Figure 50.

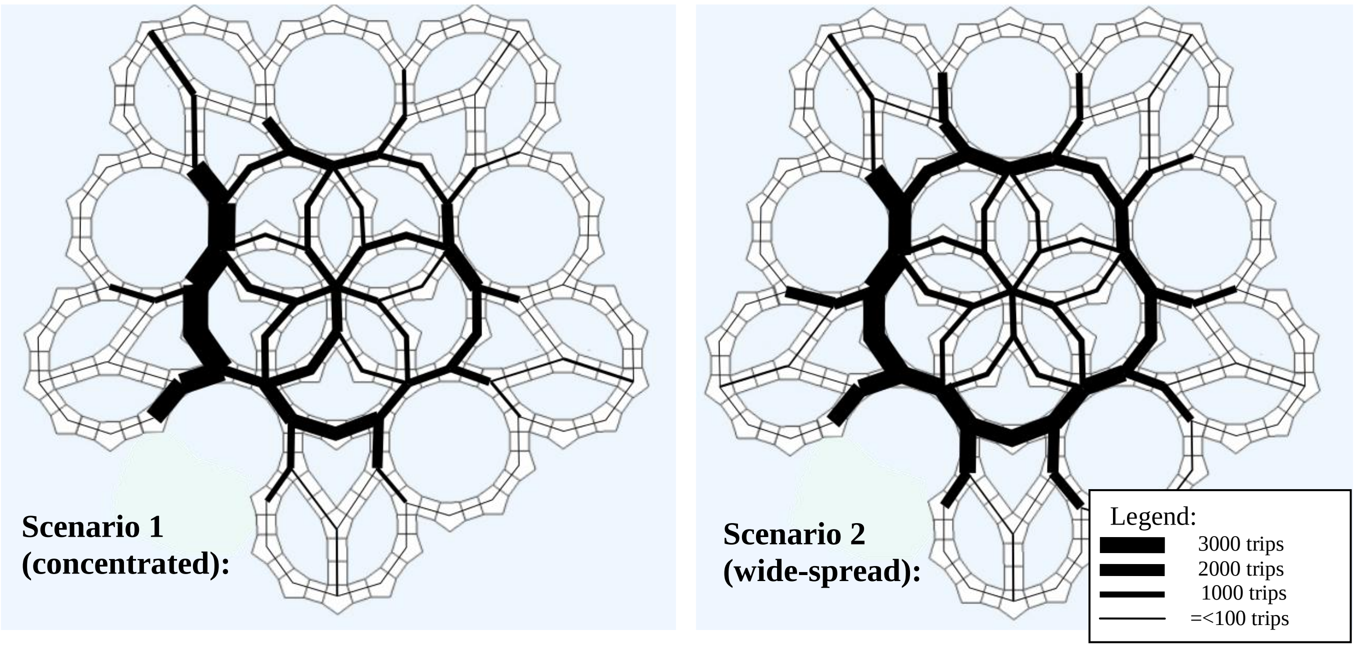


Figure 50, Transportation system 3 (water), amount of trips (basic transportation system)

The choice for a certain transportation mode is similar in both scenarios (75%). The average and total distance travelled, however, is higher in scenario 2 (wide-spread). This also results in higher travel times and. The average travel time is one minute higher and the total travel time 350 hours.

Table 23, Transportation system 3, characteristics basic system

	Scenario 1(concentrated):	Scenario 2 (wide-spread):
Modal share:	75%	75%
Total distance (km):	17,000	18,000
Average distance (m):	915	1,000
Total travel time (hrs):	4,050	4,400
Average travel time (min):	13	14

The high amounts of travellers lead to one link with more than 2,000 trips and 3 links with 1,500-2,000 trips. The amount of trips is more levelled in scenario 2 (wide-spread).

Table 24, Amount of regions that need a certain amount of parking places

	Scenario 1 (concentrated):	Scenario 2 (wide-spread):
>2000 trips	1	0
1500-2000 trips	3	0
1000-1500 trips	12	10
500-1000 trips	46	52
<500 trips	112	107

Water transportation system

As can be seen in Figure 51, Transportation system 3 (water), amount of trips, the water system gives a slightly different image than the other figures. Although there is still a connection between ring 1 and ring 8, the trips are more dispersed over the city in both scenario 1 (concentrated). and scenario 2 (wide-spread).

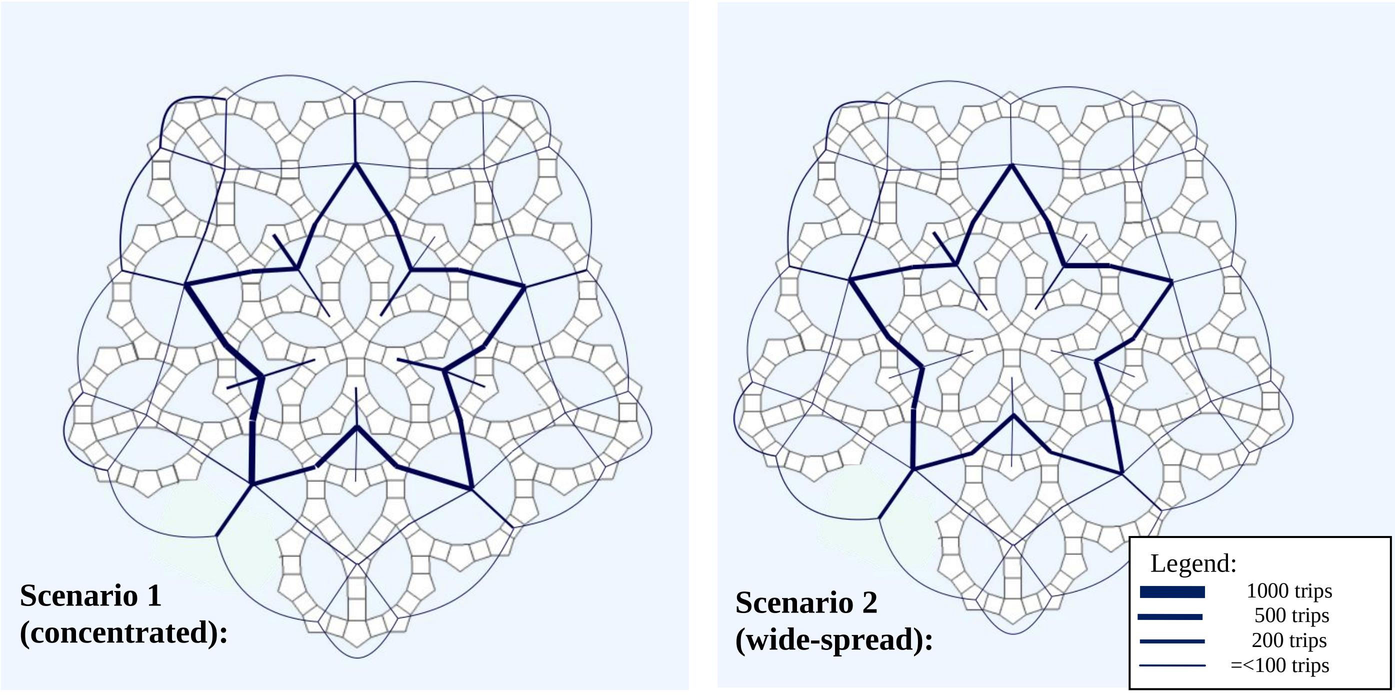


Figure 51, Transportation system 3 (water), amount of trips

The modal share of the water transportation is around 21%. This is in between transportation system 1 (personal) and transportation system 2 (collective). The total distance is also higher in scenario 2 (wide-spread) and the travel time is almost the same.

Table 25, Transportation system 3, characteristics personal water transportation

	Scenario 1 (concentrated):	Scenario 2 (wide-spread):
Modal share:	21%	21%
Total distance (km):	4,500	5,250
Average distance (m):	1,200	1,500
Total travel time (hrs):	1,000	1,100
In vehicle time (min):	7,2	8
Average travel time (min):	11,8	12,6

The trips are divided over the network in both scenarios. Scenario 1 (concentrated). has three links with 500-1,000 trips and scenario 2 (wide-spread) has only one link with less than 500 trips.

Table 26, Transportation system 3 intensity links personal water transportation

	Scenario 1 (concentrated):	Scenario 2 (wide-spread):
>500 trips	8	1
400-500 trips	20	14
300-400 trips	15	26
200-300 trips	15	2
100-200 trips	20	30
<100 trips	89	87

The amount of regions that need more than 500 mooring places is three for both scenarios. In scenario 1 (concentrated). there are furthermore two regions that need more than 1,000 mooring places.

Table 27, Transportation system 3 required amount of mooring places

	Scenario 1 (concentrated):	Scenario 2 (wide-spread):
>1500 mooring places	0	0
1000-1500 mooring places	2	0
500-1000 mooring places	1	3
<500 mooring places	8	8

In Table 17 the characteristics of collective water transportation are shown. The modal share is 4%. The total distance is 6,200km in scenario 1 (concentrated). and 6,900km in scenario 2 (wide-spread). The average distance is 1,300 meters in scenario 1 (concentrated). and 1,400 meters in scenario2 (wide-spread). The average travel time respectively 17 and 18 minutes.

Table 28, characteristics water transportation (collective)

	Scenario 1 (concentrated):	Scenario 2 (wide-spread):
Modal share:	4 %	4 %
Total distance (km):	6,200	6,900
Average distance (m):	1,300	1,400
Total travel time (hrs):	1,400	1,400
Average travel time (min):	9	10

There aren't any roads with trips higher than 500, although eight roads have more than 100 travellers. This amount of travellers could make it difficult to create a cost effective timetable, although a system similar to transportation system 2 (collective) could be developed.

5.5. Evaluation of the capacity of the systems

It is possible to distinguish problems with congestion through modelling. It is, however, difficult to do in this case, because the behaviour of the drivers, pedestrians and cyclists have a huge impact on the performance of the network. It is not known how the behaviour of these people would be in the future. Modelling these streams for example at crossings is therefore not in the scope of the report.

It is however possible to calculate if it is likely that the amount of trips on a certain links or the requirement for a certain amount of parking space would lead to capacity problems.

Basic transportation mode.

The link with most trips in the basic transportation system has around 2,300 pedestrians. The pedestrian area -at the place of the link- has an effective width of 2,5 meters, a length of 50 meters and a total surface area of 125 square meters. This means that when people walk 52 meters/minute (3.2 km /h), the dwell time is around 1 minute; A total of 2,300 people will walk this area in an hour, so 38,3 people will walk through the area every minute. The total area available space for these people will than become 3 square meters.

The bicycle paths are, however, also a bit over-dimensioned. It is possible to decrease the size of the bicycle paths to 2 meters and still offer the desired capacity.(ALLEN et al.). When the width of the bicycle paths is decreased to 2 meters, the effective width of the pedestrian area becomes 3,5 meters.

There are four links with more than 1,500 travellers of slow mode transportation in combination with transportation system 1 (personal), six in combination with transportation system 2 (collective) and four in combination with transportation system 3 (water). Capacity problems at these links are not that likely, because there is enough space for pedestrians. Problems at crossings are however possible.

Furthermore, space for the parking of bicycles needs to be reserved. The highest number of parking places for the bicycle is in the harbour ring. A total of 1,300 people are arriving at the area. If everybody uses a bicycle, around 2,000 m^2 is needed for bicycle parking. The space on a whole module is 2,500 m^2 (50m x 50m).

Transportation system 1 (personal)

The calculation of the capacity of the roads (dedicated for fast transportation) also depends on the behaviour of the vehicles. The key question here is what the distance between the cars is at which the drivers feel safe. The maximum number of vehicles on one lane is 800 per hour. This means that if 800 cars need to travel on the road in 1 hour (3,600 seconds), the head time should be 4.5 seconds. This is (at a speed of 30 km (8 1/3 meter/sec)) 37.5 m. It is therefore unlikely that the current intensity would lead to capacity problems such as congestion, also because a number of people will use scooters, motor bikes, E-bikes etc. Problems at intersections, on the other hand, cannot be excluded.

Problems with parking places are furthermore possible. When all users of the personal transportation will use a car, the number of parking places would become 1,300 *25= 17,450 m^2. Although this is unlikely, especially if there is little space in the city, parking facilities will have to be taken into account.

Transportation system 2 (collective)

The vehicles operated on network 1 can transport ten persons per vehicle. The average travel time is around 4 minutes. This means around 150 people can be transported by one vehicle in one hour. The total number of passengers for this system is on average around 2,500. This means that at least 17 vehicles are needed to transport the travellers. It is, however, likely that more vehicles are needed due to inefficiencies.
The ultra-rapid transit system on network 2 on the contrary can transport four persons per vehicle. The average travel time of an ultra-transit vehicle is around 5 minutes. The number of people a vehicle can transport is around four. The total average number of passengers for this system is 2,500. The average travel time is around 4 minutes. This means around 60 people can be transported by one vehicle in one hour. This means that at least 42 vehicles are needed to transport the travellers. This transportation system does not require parking places, although warehouses for the storage of the vehicles will need to be built.

Transportation system 3 (water)

There is one link in transportation system 3 (water) at the route between region 8 and region 1, where more than 700 ships sail. It is unlikely that capacity problem will arise at the water between the modules, because, a lot of space is available at these places. Problems at bridges could, however, be possible. When bridges are around 10 metres wide and for example two ships can pass in both directions, it means that around 11 ships will pass the bridge per minute. It is, however, likely that more ships can sail through the bottlenecks at the bridges, because the ships probably won't be that wide. The possibility of congestion near the bridges is however something that needs to be taken into account if the water transportation will become an important mode of transportation in the design of a floating city.

Furthermore, it is possible that problems arise at the mooring places of the ships. Most ships arrive and leave at module 8.1. The attraction is 396, and the production is 432. This means that at least 432 places are needed. When 5.6 m^2 of space is needed to moor a ship, and 6.4 m^2 is required for manoeuvring. (Neufert, 2012), a total of 5,184m^2 is necessary. This is a bit more than the surface of two modules.

5.6. Conclusions

It can be concluded, that in scenario 1 (concentrated), more roads with high travel loads and more regions with a high requirement for parking exist than in scenario 2 (wide-spread).

Table 29, overview characteristics transportation systems

	Transportation system 1 (personal)		Transportation system 2 (network 1)		Transportation system 2 (network 2)		Transportation system 3 (water, personal)		Transportation system 3 (water, collective)	
	Sc. 1	Sc. 2	Sc. 1	Sc. 2	Sc. 1	Sc. 2	Sc. 1	Sc. 2	Sc. 1	Sc. 2
Mode share (basic)	76%	76%	89%	90%	84%	86%	75%	75%	75%	75%

Mode share of the specific transportation systems	24%	24%	11%	10%	16%	14%	19%	19%	5 %	5%
Distance (average, meters)	900	1,000	740	750	765	937	1,200	1,500	1,200	1,500
In vehicle time (minutes)	3.2	3.7	3.4	3.4	4.5	6	7.2	8	9	10
Travel time (average) (minutes)	11.5	11.9	12.8	13.7	11.8	12.2	11.8	12.6	-	-

The modal share for the basic transportation is furthermore high in all transportation systems. The amount of travellers is lowest for the collective transportation system. Almost all links in the transportation systems have less than 500 trips. Some links in the basic transportation system, on the contrary, could become crowded.

Table 30, Intensity links of the basic transportation system

	Transportation system 1 (personal)		Transportation system 2 (network 1)		Transportation system 2 (network 2)		Transportation system 3 (water, personal)		Transportation system 3 (water, collective)	
>2000 trips	0	0	2	0	2	0	1	0	1	0
1500-2000 trips	4	0	4	2	4	2	3	0	3	0
1000-1500 trips	7	8	13	19	13	19	12	10	12	10
500-1000 trips	45	49	50	56	50	56	46	52	46	52
<500 trips	113	110	108	103	108	103	112	107	112	107

Table 31, Intensity links of the transportation systems

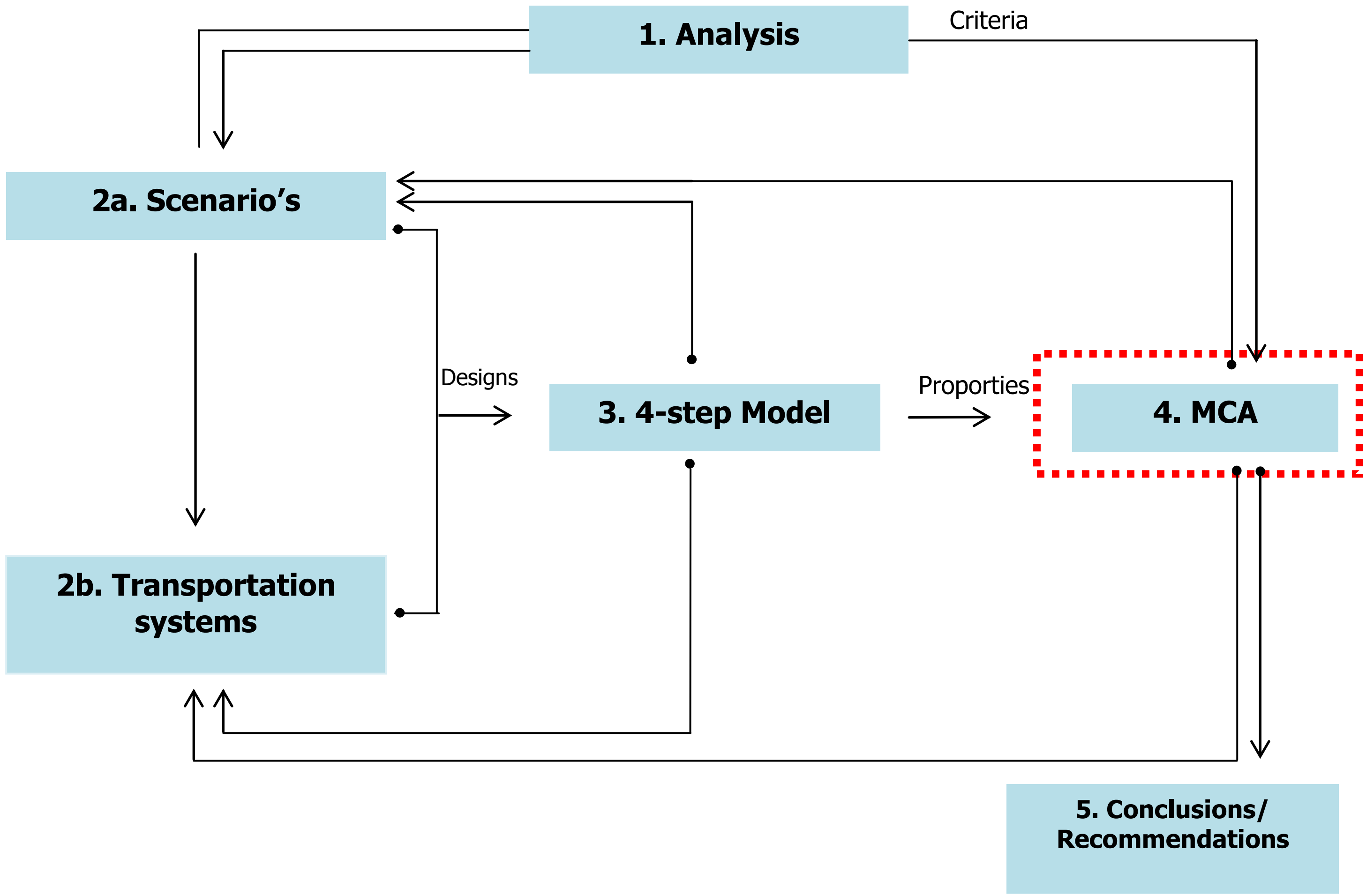
	Transportation system 1 (personal)		Transportation system 2 (network 1)		Transportation system 2 (network 2)		Transportation system 3 (water, personal)		Transportation system 3 (water, collective)	
>500 trips	3	0	0	0	0	0	3	0	0	0
<500 trips	157	160	160	160	160	160	157	160	160	160

The amount of regions that have more than 1,000 parking places is higher in scenario 1 (concentrated). Than in scenario 2 (wide-spread), for all the transportation systems. Both the trips and parking/mooring places are more divided in this scenario.

Table 32, Requirement of the parking and mooring places of the transportation systems

	Transportation system 1 (personal)		Transportation system 2 (network 1)		Transportation system 2 (network 2)		Transportation system 3 (water, personal)		Transportation system 3 (water, collective)	
>1500 parking/mooring places	2	0	2	0	2	0	1	0	0	0
1000-1500 parking/mooring	0	0	4	2	4	2	3	0	2	0
500-1000 parking/mooring	2	6	13	19	13	19	12	10	1	3
<500 parking/mooring places	7	5	50	56	50	56	46	52	8	8

It is unlikely that capacity problems such as congestion will arise in transportation system 1 (personal) and transportation system 2 (collective), based on the number of trips on the links. Traffic delays could however arise at crossings and capacity problem could also exist in transportation system 3 (water) at the bottlenecks near the bridges. Furthermore, the amount of parking and mooring places needs to be taken into account when the city is designed.


1. Analysis
Criteria
2a. Scenario's
Designs
3. 4-step Model
Proporties
4. MCA
2b. Transportation systems
5. Conclusions/ Recommendations

6

Multi-criteria analysis

This chapter describes the results of the multi-criteria analysis. At first, the methodology itself is explained, as is the reason for using this particular method. After this, the different criteria are described, and scores are calculated. These scores are based mainly on a combination of the results from previous chapters and calculations with rules of thumbs, standard values or values derived from comparable situations.
The three transportation systems are compared with each other and transportation system 2 (collective) is evaluated in combination with the two different networks, so in total four transportation systems are compared. Transportation system 3 (water) has two different modes, but this does not lead to different scores on the criteria. The chapter ends with a small conclusion, in which the preference of the people from Blue21 is used together with what the author thinks the preference of future inhabitants will be.

6.1 Methodology

The analytical hierarchical process (AHP) is used in this report. It was developed by Saaty in 1977. It is one of the most used models. It allows users to assess the weights of the criteria given in an intuitive way. If quantitative ratings are impossible, it is still possible to recognize which criteria are more important. (Saaty, 2008)
At first, the main goal is stated and sub goals are connected to his. The sub goals can also be seen as ways to achieve the main goal. The multi-criteria analysis is based on the problem statement and the main goal is to develop a feasible transportation system. The sub-goals are the following: to keep the positive elements of current transportation systems, to improve the negative aspects and to use the elements that are related to the current case study and to floating cities in general.
The first criterion is cost. Other elements that can be seen as positive are safety, speed and comfort.
The second set of criteria considers ways to decrease the nuisance and problems of current transportation systems. Noise and emissions should be decreased, and walkability should be improved.
Furthermore, it is important to use the advantages of water transportation. Possible elements are flexibility (the amount of which the transportation system can cope with changes in the city) scalability (the amount of which the systems can cope with a growing city) and innovativeness (this analyses how much the system adds an innovative character of the city).
The final grade of the criteria depends both on a score and a weight. The score reflects the effect of the design variant on a certain criterion and the weight reflects the importance of such criterion. The score can be based on a pairwise comparison between designs. Costs of two designs can for example be compared with each other. A design could for example be twice or three times as expensive. If it is not possible to make such comparisons, a score can be given by a professional.
The scores need to be prioritized, either because the set of scores has inconsistencies or because they are based on different calculations and have different scales and units. This problem is solved in this report by first calculating the scores relative from each other. The comparison of the different criteria is placed in a table and this table is normalized. The average difference of the scores is used as priority vector and thus as final score. An example of this process can be seen in *chapter 6,2, costs*.

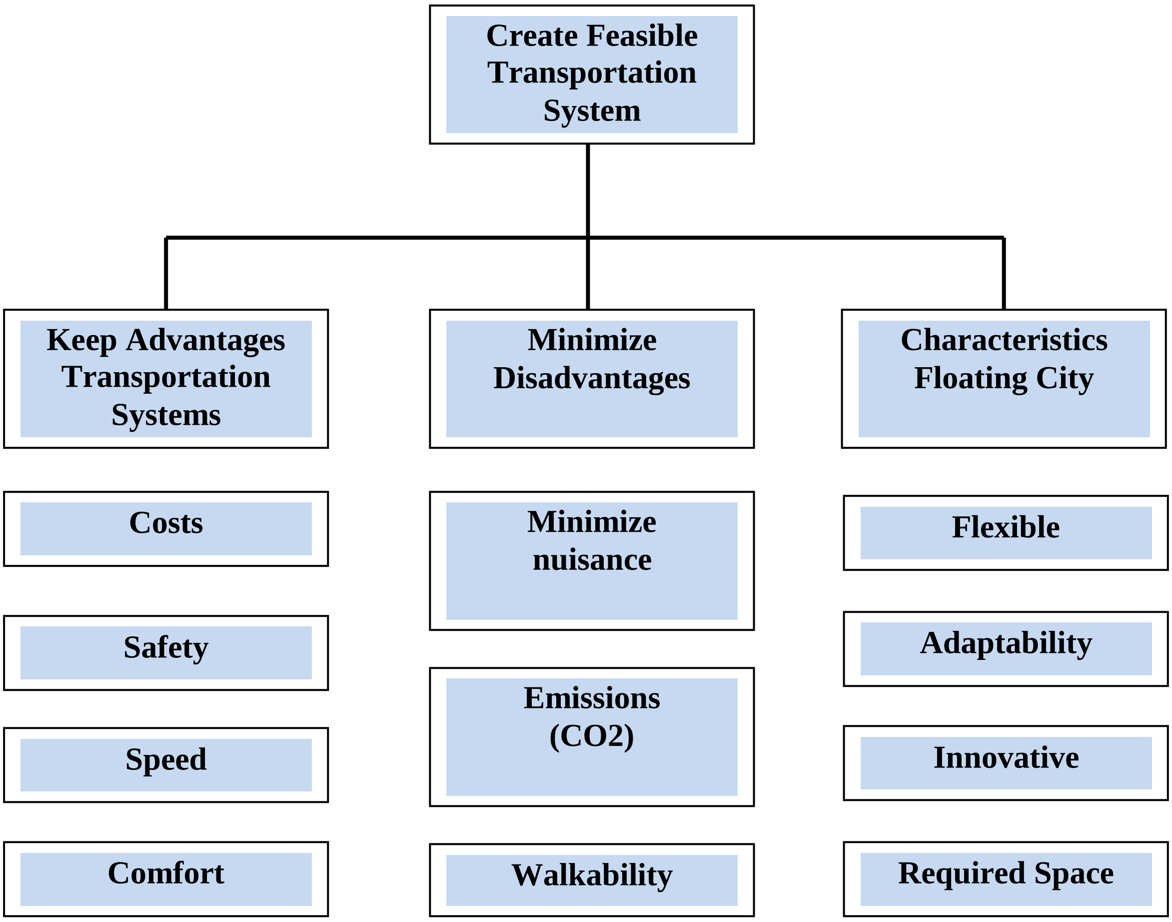


Figure 52, Multi-Criteria Analysis

Grades are developed by pairwise comparison. One criterion is for example twice as important as another one. The grades are also prioritized. The need for prioritizing comes from the fact that people tend to give inconsistent weights for the different criteria

Prioritizing help to reflect a better judgement of the height of a score, but sometimes this is not sufficient. If the costs for the systems are for example close to each other and a small relative difference in costs results in a huge difference in absolute outcome, the weight of the criterion should be adjusted. When for example the costs consist of several millions, a small change in percentages, could lead to a high difference in absolute costs. When on the other hand a criterion has a small influence on the results, this should be reflected in the weights assigned to the criteria.

Two sets of weights are used. At first, the results of a workshop held at the client's office (the office of Blue21) are presented. After this, the weights - as stated by the author - are given. The weights from the workshop held at Blue21are based on grading them on a scale from zero to ten. The reason for this grading is that it is easy and therefore suitable for a workshop. Furthermore, the weighting between zero and ten also diminishes the possibility of affecting the outcome of the workshop.

6.2 Costs

This criterion describes the costs of the systems. The transportation systems are evaluated and the results are presented with a small conclusion. The costs are calculated over the course of twenty years. An interest rate of 5.5% is used, because people tend to find future costs less important. The yearly costs are therefore decreased with 5.5%.

Transportation system 1 (personal)

The costs of the transportation systems consist of implementation costs, maintenance costs of the infrastructure and the costs for the user. The cost of the infrastructure can be calculated by multiplying the

total area of the roads by 90 €/m^2 (Houben & Molenaar, 2014). This would mean that a road will cost €315/metre. This is similar to the findings of the report *Road infrastructure cost and revenue in Europe.* (Doll & Essen, van, 2008)
The amount of parking places is calculated for a situation in which 25% of the people will travel by car. It is difficult to estimate the costs of a parking garage, so the costs of a parking garage from another project is used. The total surface of the parking spaces is calculated by 303 €/m^2 (Tilburg, 2015). This would mean that the implementation costs of the system is estimated at €18.8 million euro's.
The maintenance and depreciation costs of the cars are calculated by multiplying the number of cars by 500 and 80 euros per year, respectively (Consumerreports, 2015). The fuel cost is calculated by multiplying the total number of kilometres by 0.08 euro.
The different kind of costs is combined into one score. It is the plan of the community to leave the place in the future and it is therefore unlikely that a government will be willing to pay for the costs of implementing or maintaining the system. As a consequence, the inhabitants will have to pay for these costs themselves. The total costs for the community is taken into account, although it is possible that for a specific group of inhabitant a transportation system is less expensive. How the costs of the systems are divided over the inhabitants, is not in the scope of this report.

Table 33, Multi-criteria analysis, costs: transportation system 1 (personal)

	Costs:	Unit:	Implementation	Year 1	year 20	Total costs
Infrastructure (costs)	€315	5,700 km	€1.8 million			€1.8 million
Maintenance costs		5 %		€440,000	€150,000	€1.1 million
Parking places	303	33,025 m^2	€10 million			€10 million
Maintenance parking places	€500,000	5 %		€500,000	€170,000	€6.5 million
Depreciation costs car	€ 500	1321#		€107,000	€37,000	€34 million
Maintenance costs Car	€ 80	1321#		€105,000	€36,000	€22 million
Fuel costs	€ 0.08	1.2 million km		€95,000	€32,500	€1.1 million
Total						€58 million

Transportation system 2 (collective), network 1

The initial infrastructure is calculated in the same way as the first transportation system. The cost of this system is 6,500 €/km (ultraglobalprt, 2015), so the initial costs for the infrastructure are much higher. The cost for parking space is, on the other hand, lower. The same number is used to calculate the costs of parking spaces for the vehicles. The maintenance of the infrastructure and the parking spaces are also 5% of the initial costs per year. The operational costs are 1.2 €/km (ultraglobalprt, 2015). The total costs are also combined into one score. How the inhabitants pay for the system is not taken into account.
When network 2 is used, the implementation costs of the network will increase.

Table 34, Multi-criteria analysis, costs: Transportation system 2 (collective)

	Costs:	Unit:	Implementation	Year 1	year 20	Total costs
Infrastructure (costs)	€6,500	2,800 km	€18 million			€198 million
Maintenance costs		5 %		€900,000	€320,000	€12 million
Storage facilities	€303	1,000 m^2	€303,000			€300,000
Maintenance Warehouse		5 %				€2 million
Operational costs	€1,2	273,000 km				€4 million
Total						€37 million

Transportation system 2 (collective), network 2

The costs of network 2 are made up in the same way as network 1. The total amount of costs is higher than the costs of network 1, because the network is bigger and more wide-spread. The total costs are €70 million, the cost of the infrastructure is €62 million.

	Costs:	Unit:	Implementation	Year 1	year 20	Total costs
Infrastructure (costs)	€6,500	5,700 km	€18 million			€62 million
Maintenance costs		5 %		€900,000	€320,000	€12 million
Storage facilities	€303	1,000 m^2	€303,000			€300,000
Maintenance Warehouse		5 %				€2 million
Operational costs	€1,2	273,000 km				€4 million
Total						€70 million

Transportation system 3 (water)

The cost for this transport system is calculated in the same way as for the other systems. The costs for infrastructure are of course different, because the infrastructure itself is not used by the vehicles. Bridges are however needed for this system to function. The cost of infrastructure is calculated by multiplying the costs of bridges by the number of bridges. The cost of a bridge is assumed to be a million euros. The maintenance cost for these bridges is also calculated by using 5 % of the total initial costs per year. The cost of the harbours is calculated by multiplying the total length of the mooring places by €475. Estimating the costs of a harbour is difficult, so costs of another project are used. (Muiden, 2015).
The cost of a boat is around €16,000 (stanford, 2015). With a lifetime of ten years, the depreciation costs are €1,600 per year. The fuel costs are calculated by multiplying the total distance travelled (km) by 0.89 €/km. The costs are also combined into one score.

Table 35, Multi-criteria analysis, costs:Transportation system 3 (water)

	Costs:	Unit:	Implementation:	Year 1:	year 20:	Total costs:
Infrastructure (bridges)	€100,000	35	€3,500,000			€3,5 million
Maintenance costs		5 %		€1,750,000	€600,000	€2,3 million
Costs harbors	€475	510	€240,000			€240,000
Maintenance harbors		5%		€12,000	€4,200	€157,000
Depreciation costs ship	€1,600	5,000		€8 million	€3 million	€112 million
		0				0
Fuel costs	€0,90	€ 1,6 million km		€1.4 million	€500,000	€ 18 million
						€137 million

The differences between the scenarios are not that high and are mainly due to either the amount of vehicles that are needed or because of the difference in the total distance that the vehicles in the systems cover. Therefore, the average of the scenarios is used and this number is normalized. System 1 scores best on this criterion. System 2 is expensive to build, but the operational costs are low. The last system scores generally low on this criterion, mainly due to the high fuel costs and the depreciation costs for the ships.

In Table 36, the costs of the systems are presented relative to one other. Transport system 1 is for example 0.64 times cheaper than system 2, and 0.5 the price of system 3.

Table 36, Multi-criteria analysis, costs pairwise comparison

	Transport system 1	Transport system 2 Network 1	Transport system 2 Network 2	Transport system 3
Transport system 1 (Personal)	1	1.6	0.8	0.42
Transport system 2 (Collective)	0.64	1	0.53	0.27
Network 1	1.2	1.9	1	0.51
Network 2	2.4	3.7	0.51	1
Transport system 3 (Water)	1	1.6	0.83	0.42
Total:	2.8	4.5	2.4	1.2

The numbers in the column total are set to one. The rest of the table is also divided by the numbers the total column of Table 36 The result of these calculations are shown in Table 37 The average of the numbers in the columns for system 1,2 and 3 are used in the calculation of the multi Criteria analysis.

Table 37, Multi-criteria analysis, costs normalized

	Transport system 1	Transport system 2 Network 1	Transport system 2 Network 2	Transport system 3	Average
Transport system 1	0.19	0.19	0.29	0.19	0.21
Transport system 2					
Network 1	0.12	0.12	0.12	0.19	0.14
Network 2	0.23	0.22	0.35	0.23	0.26
Transport system 3	0.46	0.46	0.18	0.46	0.39
Total:	1	1	1	1	1

The average of the numbers will be used as a priority vector. This vector is either positive for weights that should be high and negative for weights that should be low (such as the costs). The weights are than calculated with this priority vector. In the other chapters of the report this calculation is not shown, but the priority vectors are given.

Table 38, Multi-criteria analysis, priority vector of the cost criteria

	Costs:	Priority vector:
Transport system 1 (Personal)	€ 58 million	-0.21
Transport system 2 (Collective)		
Network 1	€ 37 million	-0.14
Network 2	€ 70 million	-0.26
Transport system 3 (Water)	€ 137 million	-0.39

6.3 Safety

This chapter describes the safety criterion of the multi-criteria analysis. Safety can be measured in different ways. The number of accidents can be measured, the number of things that could go wrong or the number of people that are critically injured because of a certain transportation mode or accidents with fatal consequences. The last way of measuring safety is chosen, because not all of the small accidents are registered. The same goes for the number of people that are injured. Especially if the injuries are small, it is not registered.

It is arguable that cars are the most dangerous machines made by men, followed by guns. The number of accidents that ends in death is 4.55 per kilometre. This is higher than rail or buss transport. It is possible that the number of accidents is less because the system operates in an urban environment. Fatal traffic accidents are less common in public environments of cities than on highways, because of the reduced speed. In America the amount of fatal injuries is estimated at 3.75 accidents per billion kilometres. Because the speed of the system is lower than that of the speed in American and because technological improvements could decrease the number, 1 fatal accident per a billion mile is used in the MCA.

Rapid personal-transit systems make it possible to create systems that are safer than regular traffic. Accidents are still possible, however. The number of casualties is around 0.24 per mile. (Savage, 2012)
It is difficult to estimate the safety consequences of water transportation. One reason is that little data on water transportation exists. Besides, a system with personal boats in an urban environment, in which short distances are travelled by boats as a way of commuting, is not rare in current times. Venice, on the other hand, is more oriented to tourism, and water transportation is more focused on transporting groups through the city. According to research, 704 accidents have occurred. Because more people will use the boat themselves, and because there will be more boats, the same score is given to this system as system 1. The final score consists of the score for the first system with a reduction because of the expected decrease in accidents with passengers.

Table 39, Multi-criteria Analysis, safety

	Accidents per billion km's	Normalized score	Priority vector
Transport system 1 (Personal)	1	0.44	-0.5
Transportation system 2 (Collective)			
network 1	0.24	0.06	-0.06
network 2	0.24	0.06	-0.06
Transport system 3 (Water)	--	0.44	-0.47

6.4 Travel time

At first, the travel time of transportation system 1 (personal) is given. After this, the time of the other two is considered. In general, one can say that there is a difference in travel time between the scenarios, because people take different routes in the second scenario. In the first scenario, people can travel to the centre of the city for work-related purposes and shopping. In the second scenario, this is not possible because the functions are dispersed over the whole city.
The scores for this scenario are given for the two different modes: a slow mode and a faster mode. The average speed of the travellers is then used for the final decision making and a normalized priority vector is created.

Table 40, Multi-criteria analysis, travel times

	Travel time (minutes)			
	Basic transportation		**Transportation system**	
	Scenario 1	Scenario 2	Scenario 1	Scenario 2
Transportation system 1 (Personal)	13	14	3.3	3.7
Transportation system 2 (Collective)				
network 1	13	14	3.4	3.8
network 2	13	14	4.6	6.3
Transportation system 3 (Water)				
Personal	13	14	7.2	8
Collective	-	-	9	10

In Table 41, Multi Criteria travel times, average and normalized the travel time of the scenarios are normalized. Transportation system 1 has a travel time of 13 minutes in scenario 1 and 14 minutes in scenario 2. The fast transportation systems have a travel time of 3.4 minutes and 3.7 minutes. Transportation system 2 is slower than system 1, because the fast transportation option (the personal rapid transportation) has a lower patronage than system 1. The travel time will decrease slightly when transportation network 2 is used.

System 3 is slightly faster than the previous system, but also a bit slower than system 1. The transportation system, on the other hand, is slower than in transportation system 1. The differences of the travel times are small; this is also reflected in the priority vector.

Table 41, Multi Criteria travel times, average and normalized

	Travel time, Average (minutes)			
	Scenario 1	Scenario 2	**Total**	**Pr. Vector**
Transportation system 1 (Personal)	11,5	11,9	11	-0,23
Transportation system 2 (Collective)				
network 1	12,8	13,7	13	-0,27
network 2	11,8	12,2	12	-0,25
Transportation system 3 (Water)				
Average	11,8	12,6	12	-0,25

6.5. Comfort

Comfort can be measured in a number of ways. One could research the protection against bad weather or wind, or one can look at the quality of the interior of a vehicle, the amount of transfers, and the amount passengers have to walk. It is likely that a huge number of other ways to research exists. The preference for a certain mode is already taken into account by the calculating of the mode choice. Furthermore, it is likely to create vehicles for public transportation that is equally comfortable as the vehicles used in the system for personal transportation.

For transportation system 1 only the number of people using the slow mode transportation is taken into account, the access and egress trips are neglected although there is a distance between the places where cars are parked and where the roads are, most of this distance will be covered by car. The distance between houses and parking places are neglected because of the low distance.

The number of people using slow modes is also higher in transportation system 2 (collective) and transportation system 3 (water), mainly due to the egress and access time. Transportation system 3 (water) scores a slightly bit better.

Table 42, Comfort, distances slow transportation, access and egress

	Distance slow transportation			Distance, access			Distance, egress		
	Sc1	Sc2	Av	Sc1	Sc2	Av.	Sc1	Sc2	Av.
Transport system 1	921	1,004	963	(203)	(207)	(211)	(342)	(237)	(290)
Transport system 2									
network 1	934	1,019	976	284	263	276	294	240	267
network 2	930	1,010	975	262	264	263	262	243	253
Transport system 3	916	999	957	212	225	214	220	219	220

Table 43, shows the total average distance people have to walk when these transportation systems are used. The priority vector is also given. The distances from and to stops is highest for transport system 2, network1, followed by network 2. The distances from and to stops in transportation system 3 (water) is slightly lower than in the transportation system 2 (collective). Transportation system 1 (personal) offers most comfort, mainly because of the fact the vehicles (whether cars, motor cycles etc.) are parked near houses, jobs or other facilities.

Table 43, Multi Criteria comfort, average and normalized

	Sc1	Sc2	Av.	Pr. Vector
Transport system 1	921	1,004	963	-0,18
Transport system 2				
network 1	1,512	1,522	1,519	-0,29
network 2	1,454	1,517	1,490	-0,27
Transport system 3	1,348	1,443	1,391	-0,26

6.6. Walkability

This criterion focusses on creating a more dynamic city in which car transportation is no longer the most important mode. This is done by creating dense, multi-functional cities with good walking facilities. *"Walking continues to enjoy a renaissance as a serious mode of urban transportation"* (Institute of Transportation Engineers. ,2010). Neighborhoods that facilitates walking well, and where people can reach different facilities without using their car, have healthier inhabitants and the housing prices are also higher, as long as inhabitants have alternatives for walking. (Joe Cortright. 2009.) Gary Pivo, 2011)

Newer generations are furthermore less depended on car transportation and walkable cities attract more people from the creative class. A high score for walkability suits the red group of people (active) well. (R Florida, 2012)

Walkability is therefore not only a trend that is part of the focus on a healthier lifestyle; it can also be seen as a continuation of the ideas of Jane Jacobs (*The Death and Life of Great American Cities*) to create vibrant communities.

According to research, the following elements should be taken into account when designing for walkability: a walk score (which evaluates the number of functions in walking distance), the transit score (the number of transit stops), the bike score (which reflects the quality of the infrastructure used for cycling), the length of the block and the crime score. (Nozzi, D. (2006). Measuring Walkable Urbanity.)

One reason is the number of functions that are within walking distance. Because most important functions are within walking distance, a score of 1,000 is given. The transit score reflects the number of transit options in or nearby the city. Because system 1 has the fewest stops, a score of 25 is given. Transportation system 2 (collective) scores an 85, because most of the stops are in walking distance. There is, however, little large-scale public transport such metros or fast transportation to other cities, although these other cities can be reached by boat or helicopter. The bike score describes the quality of the bicycle infrastructure. A score of 100 is given to all the systems, because the quality of the bicycle areas should be good. Another important element is the length of the blocks and the crime score. The length of the blocks matter, because it is easier to reach other places if the blocks are not too long, because fewer detours will be necessary. A low crime score is also important because people are more likely to walk if they feel safe. A score of 100 is given to these elements. (walkscore, 2015)

Table 44, Multi-criteria analysis, Walkability

Label	**Walk score**	**Transit score**	**Bike score**	**Length blocks**	**Crime score**	**Average**	**Pr. vector**
Transport system 1 (Personal)	100	25	100	100	100	85	-0,23
Transport system 2 (Collective)							
network 1	100	85	100	100	100	97	-0,26
network 2	100	85	100	100	100	97	-0,26
Transport system 3 (Water)	100	65	100	100	100	93	-0,25

6.7. Nuisance

This criterion analyses the nuisances caused by the system. These could, for example, be noise, fumes from exhaust or other elements that disturb people. Because of difficulties involved in predicting how future systems will behave in an urban environment, it is difficult to make a prediction of the nuisance that will be created. The producer of the ULTRA RPT system states that the system does not create any nuisances; but it is likely that elements that have not yet been taken into account could lead to nuisances. Besides, it is also possible that cars in the future create a lot less nuisance than they do now because of technologic improvements. The nuisance of transportation system 2 (collective) will be similar to that of transportation system 1 (personal) if network 2 is used.
Because of this, the total built area that is exposed to the system (within a distance of 20 metres) is taken into account. Differences between the transportation systems are not taken into account. Transportation system 1 (personal) and the second network of transportation system 2 (collective), collect and distribute scores lowest on these criteria (-0,42). The amount of built area exposed to the infrastructure is the highest. Transportation system 2 (collective) in combination with network1, has a score of 0.16,
Transport system 3 (water) scores best on this criterion. The reason is that most of the transportation is on water, and it can be assumed that it is not close to the housing areas. The built area near the bridges is also taken into account. The score of this system is adjusted, because noise can reach further over water than over land, so it's possible that the effect of noise is underrated.

Table 45, Multi-criteria analysis, Nuisance

Label	Built area (m2)	Score	Priority Vector
Transport system 1 (Personal):	278520	0,42	-0,42
Transport system 2 (Collective):			
Network 1	108060	0,16	-0,16
Network 2	278520	0,42	-0,42
Transport system 3 (Water):	700	0,..1	-0,..1

6.8. Emissions (CO2)

This criterion describes the amount of CO_2 that is emitted by the presented transportation systems under the given scenarios. As can be seen from Figure 53, the output of CO_2 has decreased significantly between 1994 and 2003. ACEA stands for the European producers, JAMA the Japanese and Kama the Korian. The ACEA is the biggest manufacturer of cars for the European market. to the target for the European Union, is that the amount of CO_2 in 2014 130 grams is. The target for 2021 is 93 grams. It is therefore not unlikely that the output will decrease further and an output of 80 grams CO_2 is used in the calculation of the total output. (Europe environment agency, 2014)

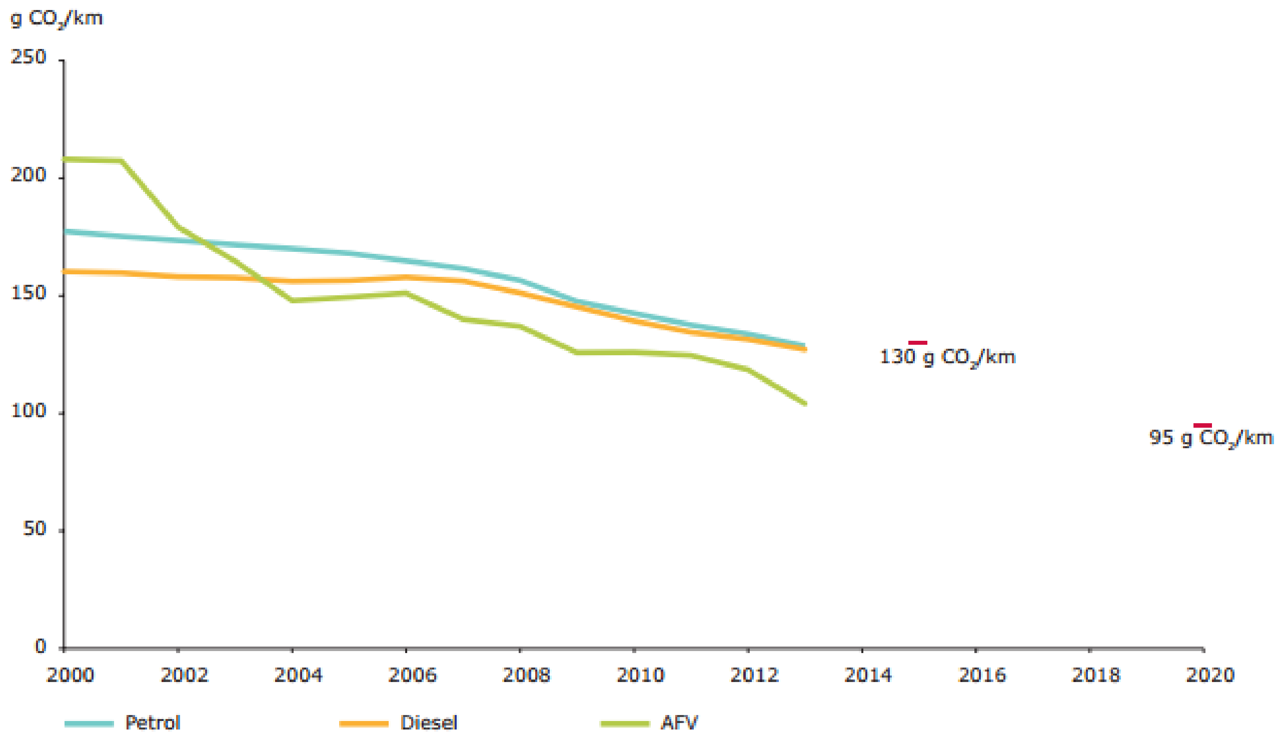


Figure 53, CO_2 output per kilometre

An ULTRA personal rapid transit system works on electricity. There are no emissions other than the CO_2 that might be emitted by the production of the electricity. When the energy is produced by solar energy there is no CO_2 output at all.
It is difficult to estimate the output for boats, because it is very much dependent on the speed the boat sails. When a small boat sails at an efficient speed, an output of 320 grams of CO_2 per kilometre can be realised. At higher speeds the output will increase. In Table 46, the average output per day can be seen. These numbers are normalized and a priority vector is created.

Table 46, Multi-criteria analysis, emissions

Total distance	Output	Sc 1 (CO2/day)	Sc2 (CO2/day)	Average (CO2/day)	Normalized Sc 1	Sc2	Av.	Pr Vector
System 1	80	320000	416000	85760	0,3	0,2	0,3	-0,3
System 2	0	0	0	0	0	0	0	0
System 3	320	1024000	1440000	175680	0,7	0,8	0,7	-0,7

6.9. Flexibility

This chapter describes the flexibility of the system. The term *flexibility* is used to describe the extent to which the transport systems can cope with changes in the layout of the city. At first, transportation system 1 (personal) is described; after this, transportation system 2 (collective) and transportation system 3 (water) are considered. Transportation system 2 (collective) is discussed in combination with both networks. The chapter ends with a small conclusion and a report of the final score for the transportation systems. The figures in this chapter show the amount of trips on the links, including the production and attraction of these rings, in contrary to the figures in chapter5, in which the through traffic is visualised. By visualising both the production and attraction, insight is generated to which regions are busy.

Transportation system 1 (personal)

As can be seen from Figure 54, scenario 1 includes a clear axis between rings 1 and 8. This axis is also apparent in scenario 2. There is, however, more production and attraction at other places in the city, such as in rings 4, 6 and 10. It is unlikely that the number of travellers will lead to congestion problems. The change in attraction and production could, however, lead to problems regarding parking spaces. When many parking spaces are built in region 8 and the functions move to ring 8, new parking spaces must be built or people will need to walk distances so big that it is not beneficial to drive the car anymore.

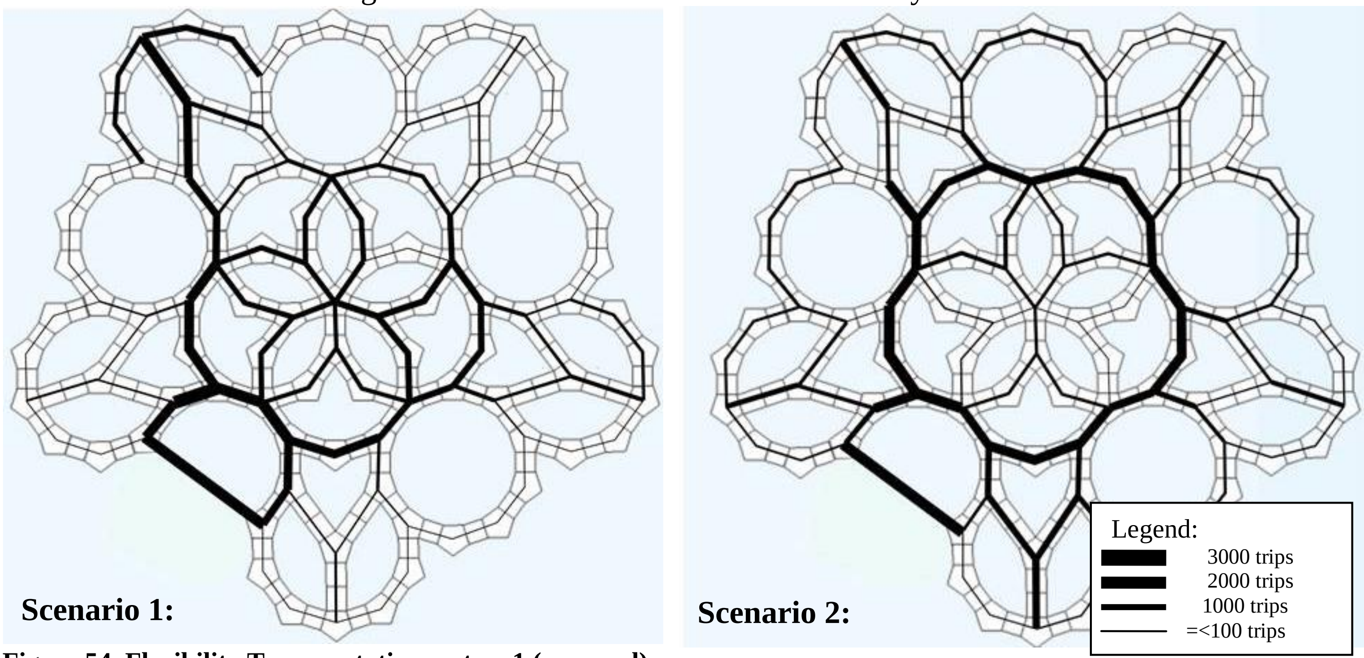


Figure 54, Flexibility Transportation system 1 (personal)

Transportation system 2 (collective)

It is theoretically possible that because of the change of the network other types of vehicles are needed. When for example a lot of people travel on one axis, it is possible to transport more people from one region to another. Given the amount of travellers in this system, it is unlikely that this problem will arise. Furthermore, the amount of more stops could lead to a change of bicycle parking. It is unlikely that this will become a big problem in this system. A disadvantage of this system is that it is however expensive to implement, so when the network needs to be changed, new lanes added or removed, this can be costly.

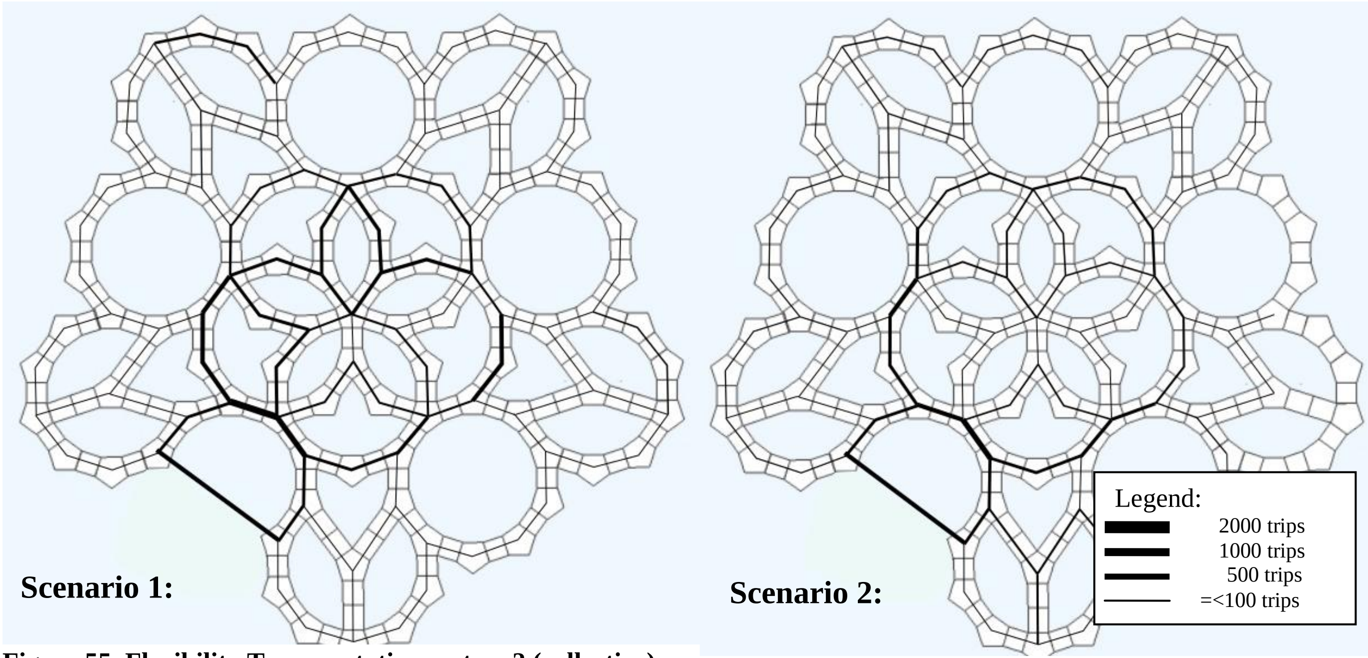


Figure 55, Flexibility Transportation system 2 (collective)

When network 2 is furthermore used, the system can cope with the changes in the city better, because more vehicles will be used. This will also offer a lot of flexibility.

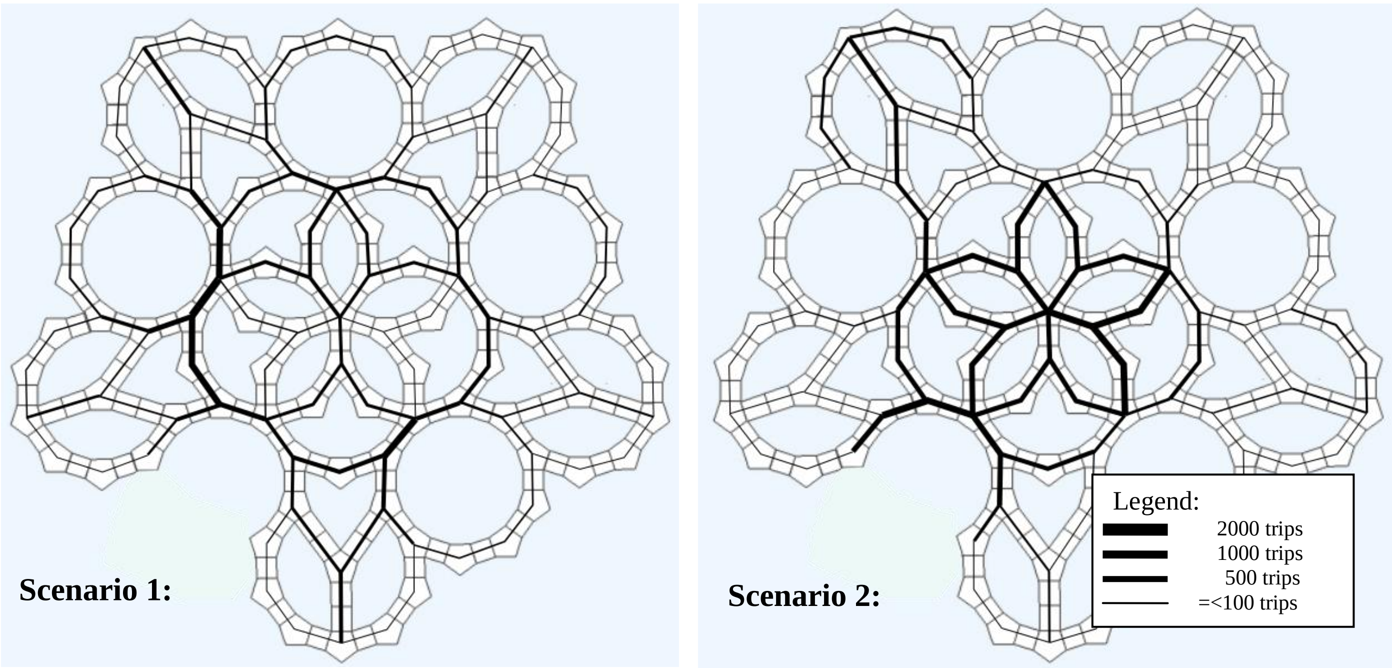


Figure 56, Flexibility Transportation system 2 (collective)

Transportation system 3 (water)

Because of the amount of water in the city and the robustness of the network, it is unlikely that a change in layout will lead to huge problems in the system. It is, however, possible that it will be necessary to replace harbours similar to the replacement of parking places in transportation system 1 (personal).

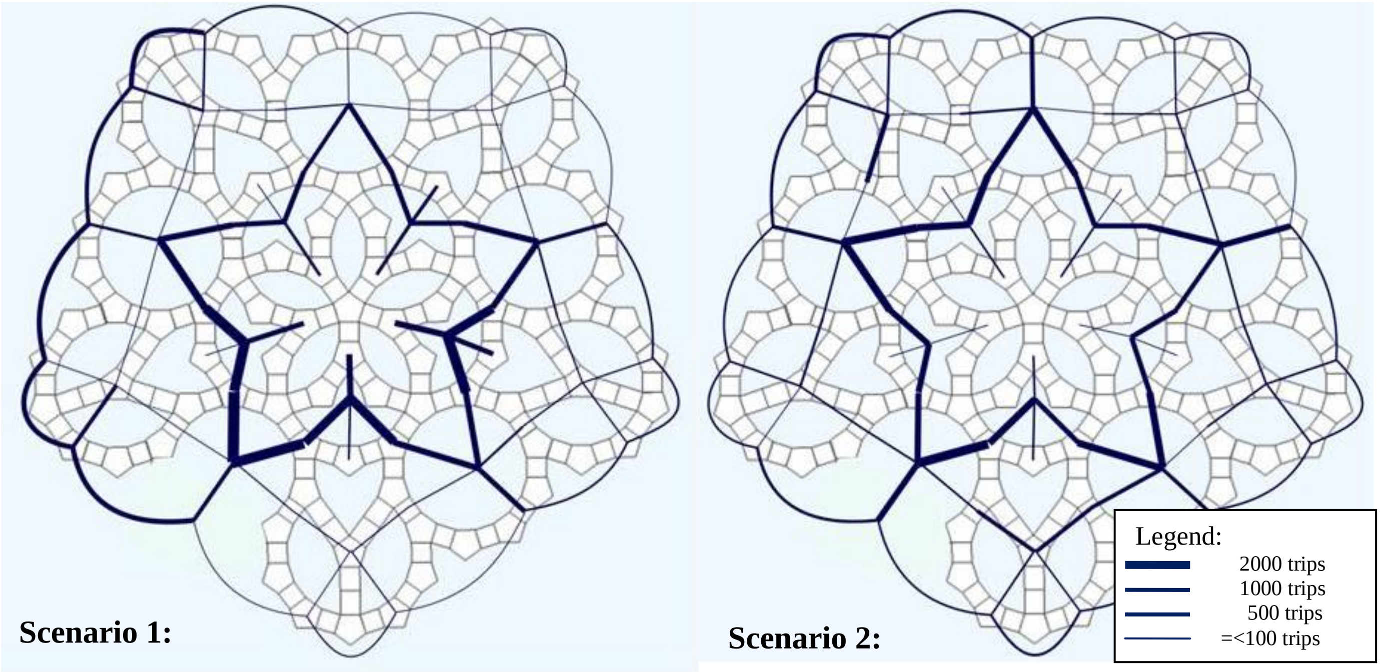


Figure 57, Flexibility Transportation system 3 (water)

Conclusion

The network in transportation system 1 (personal) seems to be robust enough to cope with changes in the layout of the city. Problems might come into being because of the placement of parking space. Depending on the vehicles used on the network in transportation system 2 (collective), it is unlikely that problems will occur. Transportation system 2 (collective) is also able to cope with changes in the city, the problems regarding mooring of boats is less than the parking capacity problems in transportation system 1 (personal), because the space of the water is not used for housing. Nothing needs to be demolished to place parking at another space, although a new harbour might need to be built. A disadvantage in transportation system 2 (collective) is the high investment costs of new links.

Table 47, Multi-criteria analysis Flexibility

Label	Score	Priority vector
Transportation system 1 (Personal)	0,9	0.25
Transportation system 2 (Collective)		
Network 1	0.8	0.22
Network 2	0.9	0.25
Transportation system 3 (Water)	1	0.28

6.9. Scalability

This criterion evaluates how the different transportation systems cope with this situation. The main question is whether the flows are too high for the transportation system. This chapter, in other words, considers whether congestions or other delays are likely to appear because of the high amount of trips in the systems.

There are different ways the city could grow. A city next to the city could be created, or the density inside the city could be increased by building more houses inside the city or by building higher buildings.
The city is, however, protected by a floating breakwater. It can be expected that the density of the city will increase until a new breakwater is built. This is comparable with how cities used to grow in the middle-ages. Cities used to grow inside the walls until they became too big and new walls were built. Because the shape of the breakwater is round, it is likely that the city will have a round shape.

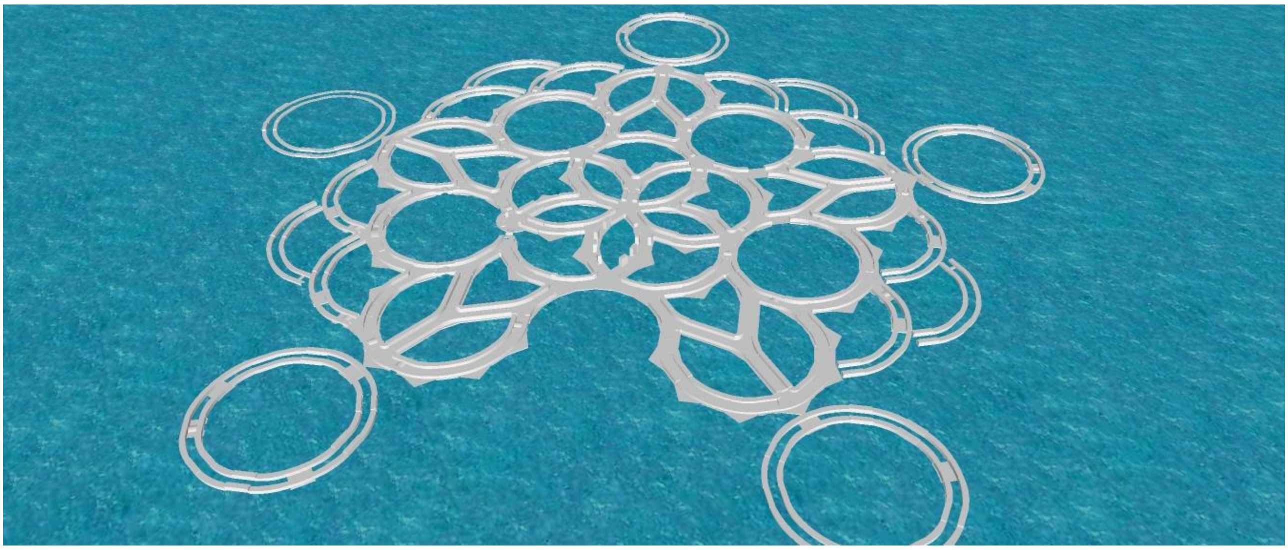


Figure 58, Expansion Seasteading city, impression

The growth of the Seasteading city is modelled by increasing the amount of inhabitants in the outer rings and by increasing the distances for a certain amount of inhabitants in these rings. The Seasteading city will grow from 25.000 to 35.000 inhabitants.

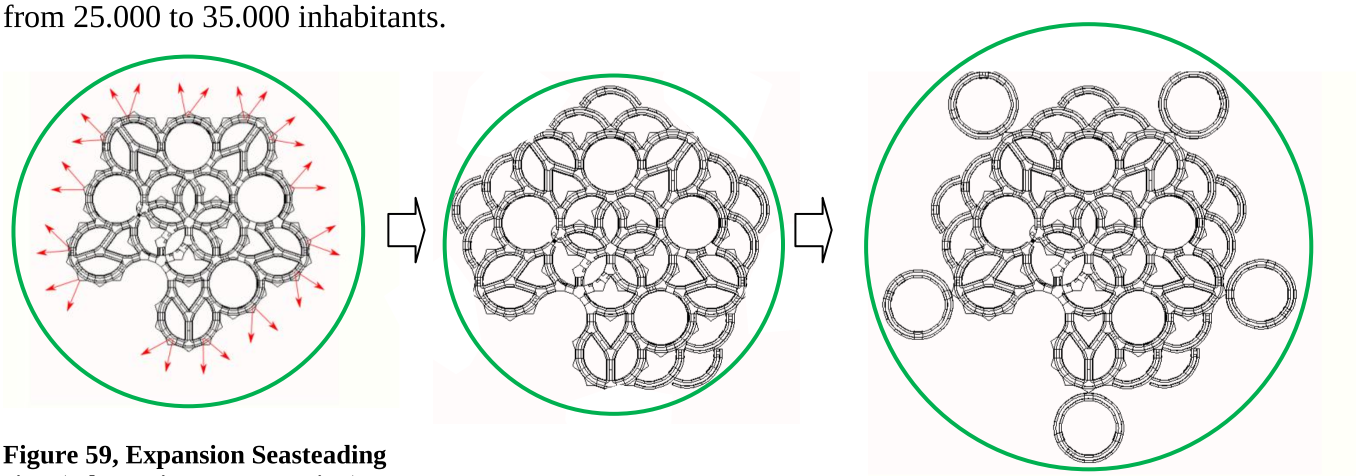


Figure 59, Expansion Seasteading city (schematic representation)

Transportation system 1 (personal)

The mode choice for transportation system 1 (personal) changes sligthly, more people will travel with this transportation mode. The average distance also increases and because of this the average travel time also increases.

Table 48, Characteristics transportation system 1 (personal): 25,000 and 35,000 inhabitants

	Scenario 1:		Scenario 2:	
# of inhabitants	25,000	35,000	25,000	35,000
Mode choice:	20%	21%	23%	24%
Total distance (km):	4000	5700	5200	5900
Average distance (m):	755	790	1000	1100
Total travel time (hrs):	290	443	325	500
Average travel time (min):	3.2	3.7	3.7	4.20

The amount of links with different number of trips also changes. It is however unlikely that this will lead to congestion. All links has less than 1,000 trips. Congestion problems could arise at crossings, because the absolute of amount of travellers using slow modes also increases. Furthermore, it is possible that a bigger attracts more tourists which in turn also increase the amount of travellers.

Table 49, Transportation system 1, amount of trips for 25,000 and 35,000 inhabitants

	Scenario 1:		Scenario 2:	
# of inhabitants	25,000	35,000	25,000	35,000
>1500 parking places	2	2	0	0
1000-1500 parking places	0	1	0	0
500-1000 parking places	2	6	6	11
<500 parking places	7	2	5	0

The amount of parking places increases for both scenarios. It is clear that the parking enough parking space needs to be reserved for this. The number of rings that need more than 500 parking places increases from 4 to 9 scenario 1 and from 6 to 11 in scenario 2. It is also noteworthy that the number of parking places is still better divided over the city in scenario 2. In scenario 1 there are two regions that need more than 1,500 parking places and one region that needs 1,000-1,500 parking places and in scenario 2 there are eleven regions that need 500-1,000 parking places.

Table 50, Transportation system 1 (personal), required parking places for 25,000 and 35,000 inhabitants

	Scenario 1:		Scenario 2:	
# of inhabitants	25,000	35,000	25,000	35,000
>1500 mooring places	2	2	0	0
1000-1500 mooring places	0	1	0	0
500-1000 mooring places	2	6	6	11
<500 mooring places	7	2	5	0

Transortation system 2, network 1

The modal share for this transportation system increases slightly. The distance people walk towards the stops however also increases, this increases both the total distance from 1.8 km to around 3 km for both scenarios and the average distance. The average and total travel time are also increased because of that.

Table 51, Characteristics transportation system 2 (network 1): 25,000 and 35,000 inhabitants

	Scenario 1:		Scenario 2:	
# of inhabitants	25,000	35,000	25,000	35,000
Mode choice:	5%	5%	5,5%	6%
Total distance (km):	1,800	3,000	1,800	2,900
Average distance (m):	740	850	750	885
Total travel time (hrs):	140	215	140	232
In vehicle time (min):	3.4	3.6	3.4	4.3

The amount of trips on the links is still low. Only in scenario 1 there is a link with more than 500 tips when the total amount of inhabitants is increased to 35,000. The amount of links with more than 10 trips however does increase when the city is expanded.

Table 52, Transportation system 2 (network 1), amount of trips for 25,000 and 35,000 inhabitants

	Scenario 1	Scenario 1	Scenario 2	Scenario 2
# of inhabitants	25,000	35,000	25,000	35,000
>200 trips	3	9	0	0
100-200 trips	12	20	11	27
<100 trips	145	131	149	133

It is –as stated before- not necessary to build parking places for this transportation system. However it is likely that space needs to be reserved for people that want to stall their bicycle near their house, work, stops etc. In addition it is possible that capacity problems could arise, especially in the area's for slow mode transportation when more tourists will arrive at the floating city. Other than that, it is unlikely that problems due to congestion will arise. The travel time and distance increases, but areas in the city remain reachable.

Transortation system 2, network 2

The same counts for network 2. The modal share is however higher in comparison with network 1 and the increase in modal share is also bigger when the city grows to 35,000 inhabitants. Apparantly, the system is used more, because the stops are closer to the regions at the outer ring.

Table 53, Characteristics transportation system 2 (network 2): 25,000 and 35,000 inhabitants

	Scenario 1:		Scenario 2:	
# of inhabitants	25,000	35,000	25,000	35,000
Mode choice:	16%	19%	14%	20%
Total distance (km):	2,800	4,600	3,000	4,900
Average distance (m):	765	850	937	1,076
Total travel time (hrs):	280	490	330	526
In vehicle time (min):	4.5	4.7	6	6.9

This also triggers an incease of trips on the links, as can be seen in table 21. There are a lot more links with more than 200 trips.

Table 54, Transportation system 2 (network 2), amount of trips for 25,000 and 35,000 inhabitants

	Scenario 1	Scenario 1	Scenario 2	Scenario 2
# of inhabitants	25,000	35,000	25,000	35,000
>200 trips	4	24	6	24
100-200 trips	17	59	37	59
<100 trips	143	101	123	101

Transportation system 3 (water)

The mode choice of the transportation system 3 (water) increases because of the increase of inhabitants in the outer rings of the Seasteading city. The average distance also slightly increases, together with the travel time. The total travel time increases to 2,000 hrs in scenario 1 and 2,100 hrs in scenario 2. The average travel time and the total travel time also increases.

Table 55, Characteristics transportation system 3 (water): 25,000 and 35,000 inhabitants

	Scenario 1:	Scenario 1:	Scenario 2:	Scenario 2:
# of inhabitants	25,000	35,000	25,000	35,000
Mode choice:	20%	22%	19%	23%
Total distance (km):	4,500km	8,700	5,250 km	9,700 km
Average distance (m):	1,200m	1,400	1,500 m	1,500m
Total travel time (hrs):	1,000	2,000 hrs	1,100 hrs	2,100
Average travel time (min):	18 min	20	18 min.	20

The amount of links with more than 500 trips increases from three to twenty-five. Two links have 1,000-1,500 trips. In scenario 2 the amount of links with 500-1,000 trips increases from zero to twenty-three.

Table 56, Transportation system 3 (water), intensity links

	Scenario 1:	Scenario 1:	Scenario 2:	Scenario 2:
# of inhabitants	25,000	35,000	25,000	35,000
>2000 trips	0	0	0	0
1500-2000 trips	0	0	0	0
1000-1500 trips	0	2	0	0
500-1000 trips	3	23	0	23
<500 trips	157	136	160	137

The amount of mooring places also increases in this transportation system. The amount of trips is also better divided over the different links in the network in scenario 2. In scenario 1 there are two regions that need more than 1500 mooring places and seven that need 500-100 places. In scenario 2 there are nine regions that need 500-1,000 mooring places.

Table 57, Transportation system 3 (water), amount of trips for 25,000 and 35,000 inhabitants

	Scenario 1:	Scenario 1:	Scenario 2:	Scenario 2:
# of inhabitants	25,000	35,000	25,000	35,000
>1500 mooring places	0	2	0	0
1000-1500 mooring places	2	0	0	0
500-1000 mooring places	1	7	3	9
<500 mooring places	8	2	8	2

Conclusions

It is not likely that the systems will have large problems with congestion. It is, however necessary to reserve space for parking spaces in transportation 1 and for the mooring spaces in transportation system 3 (water). Furthermore it is necessary to reserve enough space for cyclists. Problems could however occur at crossings or near bridges. The lowest score (0.8) is given to transportation 1 (personal), because of the amount of parking places that are needed. Transportation system 2 (collective) network 2 is given the highest score, because it is unlikely problems occur, but the system is widely used. Transportation 2 (network1, circle) and transportation system 3 (water) have both been given a 0.9.

Table 58, Multi-criteria analysis Scalability

Label	Score	Priority vectors
Transportation system 1	0.8	-0,22
Transportation system 2 n1	0.9	-0,25
Transportation system 2 n2	1	-0,28
Transportation system 3	0.9	-0,25

6.10. Innovative

This chapter describes the score of the different transportation systems on the criterion *innovation*. Innovation has different advantages. Technological advantages can improve the economy and society. When an experiment with new transportation systems is succesfull, for example, it is possible to implement this at other places in the world. Knowledge and technology can be sold to other places and these places can also improve because of the innovations. Another advantage is that an innovative transportation system can improve the image of an area: e.g., iconic buildings can improve the image of a place.

Transportation systems 1 (personal) contains roads for pedestrians, bicycles and faster transportation such as cars or motor bicycles. Although the vehicles themselves can be innovative, the transportation system itself is not new or differennt from other places. If electric vehicles are used at this city, it is likely that this will

also happen at other places in the world. It is therefore unlikely that the use of the proposed transportation will improve the image of the area.
Transportation system 2 (collective)consists of slow transportation and a personal-transportation network (Ultra). Although this system is implemented at several airfields such as Heathrow, it is never implemented in an urban environment. It is likely that if this system works, it will be implemented at other places in the world. Furthermore it is likely that a system like this could improve the image of the city.
Transportation system 3 (water) consists of pedestrian areas and tranportstion on water. Transportation on water in an urban envionment is not new; it is used in Venice and other historic places, for example. It is likely that transportation on water adds something to the image of the city, however, because it is rare in comparison to transportation on land.
It is unlikely that transportation system 1 will lead to an innovative transportation network that is used in other places. It is, however, possible that experiments will be done with the vehicles. It is unlikely, if this happens, that this city is the only place where it will add to a positive image o the city. Because of this, this system has been given the lowest score.
Transportation system 2 could lead to a innovative city simply because an ultra-transit network has not yet been built in an urban environment. This could also add to the image of the place as a modern sustainable community. For this reason, the score is the highest for this system.
Although the last transportation system is not new (in a way it is a very old system, given the transportation in Venice and Mexico city), it could add to the image of the place. Transportation on water does fit the characteristics of a water city. The score given for this system is therefore in between that of the other two systems. The differences between the systems are not that great; this is also reflected in the score. The final scrores can be seen in Table 59.

Table 59, Multi-criteria, Innovativeness

Label	Score	Priority vector
Transportation system 1	0,5	0,15
Transportation system 2		
Network 1	1	0,30
Network 2	1	0,30
Transportation system 3	0,75	0,26

6.11. Required space

Minimizing the required space for the transportation systems, is important because building the floating modules is expensive. Space can be used in a better way, for example to provide housing, jobs and other functions, while the water can be used for facilitating infrastructure. To calculate the scores for this criterion, the total space of the systems are measured and the priority vector is created. From the travellers of the personal modes, it is assumed that 25% will travel by car.

Table 60, Multi-criteria, required space

	Space of infrastructure on the land (m^2)
Transport system 1	
Infrastructure (car)	97,500
Parking space (bicycle)	12,000
Parking space (car)	15,000
Transport system 2	
Infrastructure (PRT)	
Network 1	27,000

Network 2	97,500
Warehouses	150
Parking space (bicycle)	15000
Transport system 3	
Parking space bicycle	12000

As can be seen in Table 61, Multi-criteria analysis, required space transportation system 1 (personal) has the most space. After this, transportationsystem 2 (collective) has the highest score. The reason for this is the required space for infrastructure and the need for parking spaces for cars and bicycles in system 1 (personal). Transport system 2 (collective) also needs space for storing the vehicles and for biycles; but less space is needed in comparison with transportation system 1 (personal). It is not taken into account that many of the roads in transportaion system 1 (personal) and transportation system 2 (collective) are already available and that it will not always be possible to build at these places. A number of streets need to be created in order to create some space in between the buildings and to assure that enough light and fresh air can enter these buildings.
The score will furthermore decrease for transportation system 2 (collective) when network 2 is used instead of network 1 from -0,14 to -0,39. The score for network 2 (collection and distribution) is similar to the score for transportation system 1 (personal).
The score for transportation system 3 (water) is higher than for the other systems, because most of the vehicles (boats) are moored in harbors and there is no infrastructure on the modules in the floating city. However, bridges must be developed for this system to function. This could also lead to lower land use, because fewer buildings can be built at the place of a bridge. This is, however, not taken into account

Table 61, Multi-criteria analysis, required space

Label	Total space (m^2)	Priority vector
Transport system 1	124,500	-0,43
Transport system 2		
Network 1	42,000	-0,14
Network 2	113,000	-0,39
Transport system 3	12,000	-0,04

6.12. Conclusions of the Multi-criteria analysis

This chapter describes the results of the multi-criteria analysis. A workshop was organized with the employess of Blue21 to gain better insight into how important people find the different criteria. Based on this, a representation was produced of what the author thinks the future inhabitants of the seasteading city will value as important. The reason for this is that it is not clear what the future inhabitants will be like, even though it is possible to make assumptions about a number of elements such as lifestyle, income, etc.
The workshop helps with understanding how different people think about transportation systems. This knowledge is used to make assumptions about the preferences of future inhabitants.
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The workshop helps with understanding how different people think about transportation systems. This knowledge is used to make assumptions about the preferences of future inhabitants.

Weights, Blue21:

The workshop held at Blue21 consists of a presentation in which the vision and design of the research was presented, together with the results of the 4-step analysis and the multi-criteria analysis. At the end of the presentation, the employees were asked to fill in a form to grade the criteria based on how important they thought they were.This also resulted in a brief discussion which gave an insight into what people think is important and why.

As one might expect, most of the criteria were given a grade of around 7. A few examples stand out, however. Safety and (especielly) emissions are seen as most important with a grade of 7.7 and 8.2, while innovation is seen as not that important.This might seem strange for an inovative company, but the reason is that the employees feel no need to innovate for the sake of innovation or for the image of the city. Furthermore, comfort is not seen as an important factor.

Table 62, Weights Blue21

costs	7.2
safety	7.7
Travel time	7.2
comfort	6
walkability	7
nuisance	7.5
emissions	8.2
flexibility	7.2
scalability	6.5
innovative	4.5
min space	6.7

The grades given by the employees of Blue21 are given in **Fout! Verwijzingsbron niet gevonden.**. These weights are plotted relatively from against each other in Table 63, Weights Blue21. The first column after the cost criteria is filed with a 1, because it is the same criteria. The safety is slightly more important so a 0,94 is given, the travel time is just as important as the costs etc. The average of these differences is taken and this is used as a weight factor for the multi criteria analysis.

Table 63, Weights Blue21

	cost	**safety**	**travel time**	**Comfort**	**walkability**	**nuisance**	**Emissions**	**flexibility**	**scalable**	**Innovative**	**min. Space**	**Average**
Costs	1,00	0,94	1,00	1,20	1,03	0,96	0,88	1,00	1,11	1,60	1,07	1,07
Safety	1,07	1,00	1,07	1,28	1,10	1,03	0,94	1,07	1,18	1,71	1,15	1,15
Travel time	1,00	0,94	1,00	1,20	1,03	0,96	0,88	1,00	1,11	1,60	1,07	1,07
Comfort	0,83	0,78	0,83	1,00	0,86	0,80	0,73	0,83	0,92	1,33	0,90	0,89
Walkability	0,97	0,91	0,97	1,17	1,00	0,93	0,85	0,97	1,08	1,56	1,04	1,04
Nuisance	1,04	0,97	1,04	1,25	1,07	1,00	0,91	1,04	1,15	1,67	1,04	1,11
Emissions	1,14	1,06	1,14	1,37	1,17	1,09	1,00	1,14	1,26	1,82	1,22	1,22
Flexibility	1,00	0,94	1,00	1,20	1,03	0,96	0,88	1,00	1,11	1,60	1,07	1,07
Scalability	0,90	0,84	0,90	1,08	0,93	0,87	0,79	0,90	1,00	1,44	0,97	0,97
Innovative	0,63	0,58	0,63	0,75	0,64	0,60	0,55	0,63	0,69	1,00	0,67	0,67
min space	0,93	0,87	0,93	1,12	0,96	0,89	0,82	0,93	1,03	1,49	1,00	1,04

This results in the multi-criteria analysis as is shown in
Table 64. According to the employees of Blue21 transportation system 2 (collective) is the best system in this specific case. This is mainly due to it's low costs in comparison with transportation 3 (water) and it's safety and lack of emissions.

Table 64, Scores Multi-criteria analysis

		1, Personal transportation		2, Collective transportation				3, Water transportation	
Criteria:		Score:	Final	Score:	Final	Score:	Final	Score:	Final
Keep the advantages of transportation systems:									
Costs:	1.07	-0.21	-0.22	-0.14	-0.15	-0.26	-0.28	-0.39	-0.42
Safety:	1.15	-0.44	-0.51	-0.06	-0.07	-0.06	-0.07	-0.44	-0.51
Travel time:	1.07	-0.23	-0.25	-0.27	-0.29	-0.25	-0.27	-0.25	-0.27
Comfort:	1.07	-0.18	-0.19	-0.29	-0.31	-0.27	-0.29	-0.26	-0.28
Improve disadvantages of the transportation systems:									
Walkability:	1.04	0.23	0.24	0.26	0.27	0.26	0.27	0.25	0.26
Nuisance:	1.04	-0.42	-0.44	-0.16	-0.17	-0.42	-0.44	0	0
Emissions:	1.22	-0.3	-0.37	0	0	0	0	-0.7	-0.85
Criteria specific for floating cities:									
Flexibility:	1.07	0.25	0.27	0.22	0.24	0.25	0.27	0.28	0.30
Scalability:	0.97	0.22	0.21	0.25	0.24	0.28	0.27	0.25	0.24
Innovative:	0.67	0.15	0.10	0.30	0.20	0.30	0.20	0.26	0.17
Required space:	1.04	-0.43	-0.45	-0.14	-0.15	-0.39	-0.41	-0.04	-0.04
Total:			-1.61		-0.18		-0.74		-1.39

Weights, interpretation author

An interpretation of the different grades is presented in this chapter. The biggest difference from the preferences of the workshop is the difference in scores between the costs and the other criteria.
The costs are given an 8, because the costs are generally high. This means that, if the cost increases a few percentages, it costs the inhabitants a lot of money. Furthermore, it can be assumed that people will generally feel that the costs are important, because in the end the economic arguments are often seen as decisive.
Flexibility and scalabity are both seen as important, because they evaluate elements related to the specific case. Scalability and flexibility are important for the Seasteading city to function as the Seasteading community proposed. Because the differences between the systems are not as big as in the costs, a score of 6 is given for these criteria. This is lower than the scores given at the work shop at Blue21.
Walkability has been given a score 4. The reason is that walkability is important for this city to function; it is also important for creating a fibrant urban environment. The score is not higher than 4 because the difference between the projects is not that big.
The score for nuisance is also set to 4 for similar reasons. It is seen as an important factor, but there are many uncertainties about how the different systems will function in the future and thus how much nuisance they create.
The safety criterion is given a 2. The reason is that the safety problems are not high and it can be assumed these will be lower than in an average situation. In the future, this can decrease still more.
The difference in travel time is also low, so a 2 is also given for this criterion.The score for comfort is also 2, because it can be assumed that, given the circumstances, the inhabitants will be more active and more willing to walk further distances than average people in similar circumstances. The people in the city will have to be relatively healthy because they know that the city is or will be placed in the open sea. Furthermore, an active lifestyle is needed for this community to survive.
The score for emissions is also set to 2. This is different than during the workshop at Blue21. The reason for giving a lower score to this criterion is not because it is seen as less important, but because it is possible that emissions will be a smaller problem in the future anyway because of the improvement in technology. On the other hand, it is also possible that, due to investments in the car industry, the difference between the output of CO_2 of cars and water transportation will be higher than it currently is, if investments in water transportation stay behind. Because of these uncertainties, a lower score is given to this criterion.

Innovative has the score of only one, because inhabitants probably do not care if the system is innovative. It is likely that the inhabitants find it more important to be able to travel from and to places at low costs and without too much nuisance. It can be assumed that the inhabitants do not find it importatn that the transportation system is innovative or adds to the image of the city.

Table 65 shows the different criteria relative to each other. The cost is considered four times as important as the safety, twice as important than walkability, etc. The average of the numbers in a row is calculated and can be seen in the last column of the table. This weight factor is used in the multi-criteria analysis.

Table 65, Weights

	cost	safety	travel time	comfort	Walkability	nuisance	emissions	flexibility	scalable	Innovative	min. Space	Average
Costs	1,00	4,00	4,00	4,00	2,00	2,00	4,00	1,33	1,33	8,00	2,00	3.06
Safety	0,25	1,00	1,00	1,00	0,50	0,50	1,00	0,33	0,33	2,00	0,50	0.77
Travel time	0,25	1,00	1,00	1,00	0,50	0,50	1,00	0,33	0,33	2,00	0,50	0.77
Comfort	0,25	1,00	1,00	1,00	0,50	0,50	1,00	0,33	0,33	2,00	0,50	0.77
Walkability	0,50	2,00	2,00	2,00	1,00	1,00	2,00	0,67	0,67	4,00	1,00	1.53
Nuisance	0,50	2,00	2,00	2,00	1,00	1,00	2,00	0,67	0,67	4,00	1,00	1.53
Emissions	0,25	1,00	1,00	1,00	0,50	0,50	1,00	0,33	0,33	2,00	0,50	0.77
Flexibility	0,75	3,00	3,00	3,00	1,50	1,50	3,00	1,00	1,00	6,00	1,50	2.30
Scalability	0,75	3,00	3,00	3,00	1,50	1,50	3,00	1,00	1,00	6,00	1,50	2.30
Innovative	0,13	0,50	0,50	0,50	0,25	0,25	0,50	0,17	0,17	1,00	0,25	0.38
min space	0,50	2,00	2,00	2,00	1,00	1,00	2,00	0,67	0,67	4,00	1,00	1.53

The extra focuss on the costs of the system and the flexibility and scalibility, interestingly does'nt change the final result. The transportation system 2 (collective) is still the best option for these case studies.

Table 66, Scores Multi-criteria analysis

		1, Personal transportation		**2, Collective transportation**				**3, Water transportation**	
Criteria:		Score:	Final	Score:	Final	Score:	Final	Score:	Final
Keep the advantages of transportation systems:									
Costs:	3.06	-0.21	-0.64	-0.14	-0.43	-0.26	-0.80	-0.39	-1.19
Safety:	0.77	-0.44	-0.34	-0.06	-0.04	-0.06	-0.04	-0.44	-0.34
Travel time:	0.77	-0.23	-0.18	-0.27	-0.21	-0.25	-0.19	-0.25	-0.19
Comfort:	0.77	-0.18	-0.14	-0.29	-0.22	-0.27	-0.21	-0.26	-0.20
Improve disadvantages of the transportation systems:									
Walkability:	1.53	0.23	0.35	0.26	0.40	0.26	-0.80	0.25	0.39
Nuisance:	1.53	-0.42	-0.64	-0.16	-0.24	-0.42	-0.04	0	0
Emissions:	0.77	-0.30	-0.23	0	0	0	-0.19	-0.7	-0.54
Criteria specific for floating cities:									
Flexibility:	2.30	0.25	0.58	0.22	0.51	0.25	0.58	0.28	0.64
Scalability:	2.30	0.22	0.51	0.25	0.575	0.28	0.64	0.25	0.58
Innovative:	0.38	0.15	0.06	0.30	0.11	0.30	0.11	0.26	0.09
Required space:	1.53	-0.43	-0.66	-0.14	-0.21	-0.39	-0.60	-0.04	-0.06
Total:			-1.34		0.23		-0.75		-0.82

Conclusions.

Based on the workshop and on the interpretation of the author collective transport is most important. Personal transportation was not chosen both because of the criteria related to minimizing the current disadvantages such emmissions, walkability and emission and because it does not make use of the elements related to specific casestudy, such as flexibility and scalability. The emphasis on the cost criterion furthermore decreased the score of transportation system 3 (water).

7

Conclusions

This chapter describes the conclusions of the report, offers an evaluation of the research approach and the different elements of this project. The chapter ends with recommendations for further research.

7.1 Conclusions

Because of land scarcity, floating cities will be needed in the future. Most urbanisation is in delta areas, and the Earth's surface consists of 70% of water. Floating cities, however, require new infrastructure and transportation systems for the inhabitants. A method has been developed, based on the basic design cycle, to design and evaluate transportation systems in such cities.

How to design personal transportation systems in a floating city and
Because the type of floating cities does not yet exists, it is necessary to use a research by design method. Different transportation systems should be designed and -because of the number of uncertainties- it is also necessary to create variants of the city.
Based on literature research and analytical thinking a design method has been developed. This method is based on the basic design cycle. The basic design cycle consists of an analysis, a synthesis, a simulation and an evaluation. The Seasteading city is chosen as a case study for this research project.

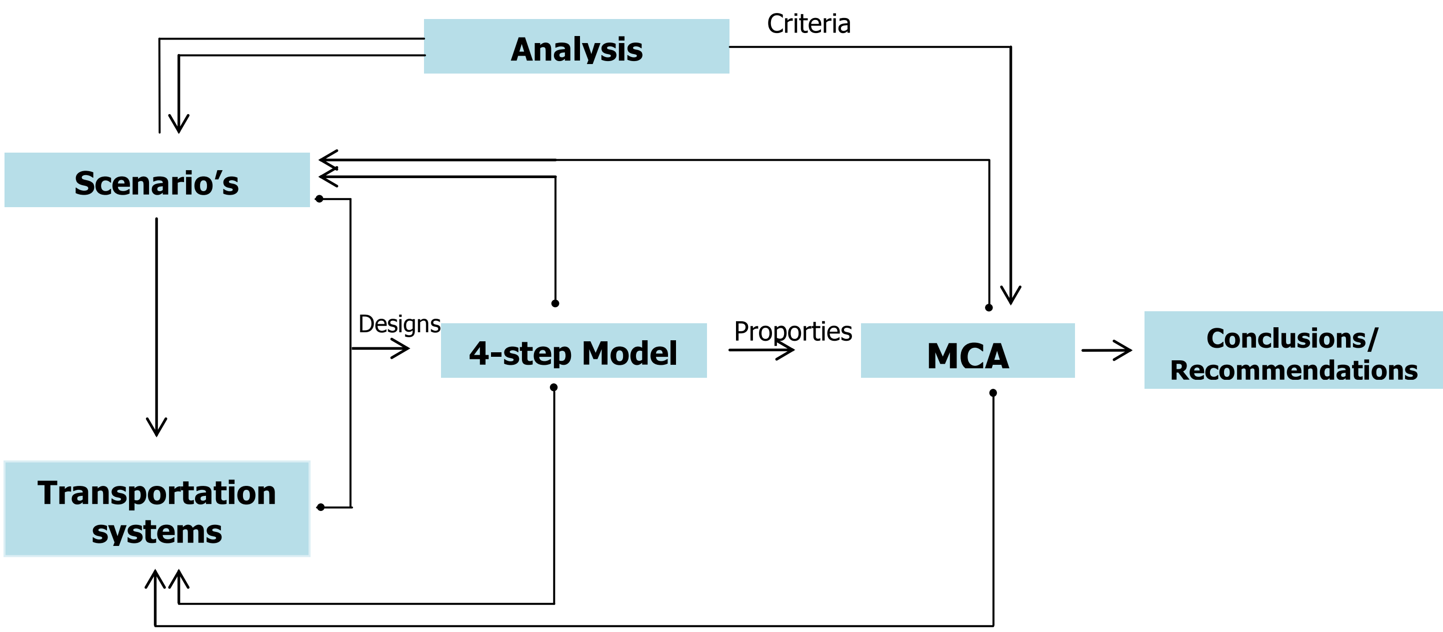

Figure 60, Research approach

How to evaluate these designs?
At the first step of the approach, the analysis, criteria for the designs are developed on which the designs are created and evaluated. Selecting the criteria is always a bit arbitrary, but it should be important that it reflects the important elements of the projects. The following criteria were selected: Costs, safety travel time comfort walkability, nuisance, emissions, flexibility, scalability, innovative, required space.

The second step consists of creating scenario's and transportation systems
Two scenarios are created, one concentrated scenario, in which regions are specialized in certain services, and a scenario in which the functions are dispersed over the city like a scrambled egg. Both scenarios are suitable for the future city. Dividing the functions over the city has advantages, because the traffic loads and the parking places are better divided over the city, but the travel distances could become longer.
For this report, three different systems are chosen: a system that focusses on personal systems, another system that focusses on collective transportation and a system that focusses on water transportation. All transportation systems also have a slow-mode network.
The third step consists of a 4-step analysis. This sub-model provides input for the evaluation method and tests if the capacity of the transportation systems matches the demand.
The fourth step, the multi criteria analysis, is chosen to evaluate the scenarios in combination with the transportation systems. The combination of the scenario and transportation system will be evaluated on the chosen criteria.

Results
As stated before, the Seateading city was chosen as a case study, scenarios and transportation systems were based on their ideas and on the criteria from the analysis. Based on the 4-step model, it can be concluded that scenario 1 has more roads with high-travel loads and more regions with a high requirement for parking. From the three transportation systems, transportation system 1 (personal) has the highest amount of users. The slow modes however, have more users, even in this transportation system. The biggest distances are travelled with transportation system 3 (water).
Congestion problems at the links are not likely. Problems at crossings, on the other hand, are possible. Problems near the bottlenecks near bridges are also possible when the water transportation systems are used. Furthermore, enough parking and mooring places has to be created by the development of the Seasteading city.

Table 67, overview characteristics transportation systems

	Transportation system 1 (personal)		**Transportation system 2 (network 1)**		**Transportation system 2 (network 2)**		**Transportation system 3 (water, personal)**		**Transportation system 3 (water, collective)**	
	Sc. 1	Sc. 2	Sc. 1	Sc. 2	Sc. 1	Sc. 2	Sc. 1	Sc. 2	Sc. 1	Sc. 2
Modal share (basic)	76%	76%	89%	90%	84%	86%	75%	75%	75%	75%
Modal share (specific transportation systems)	24%	24%	11%	10%	16%	14%	19%	19%	5 %	5%
Distance (average) (meters)	900	1,000	740	750	765	937	1,200	1,500	1,200	1,500
In vehicle time (average, in minutes)	3.2	3.7	3,4	3,4	4,5	6	7,2	8	9	10
Travel time (average, in minutes)	11,5	11,9	12,8	13,7	11,8	12,2	11,8	12,6	-	-

Table 68, Requirement of the parking and mooring places of the transportation systems

	Transportation system 1 (personal)		Transportation system 2 (network 1)		Transportation system 2 (network 2)		Transportation system 3 (water, personal)		Transportation system 3 (water, collective)	
>1500 parking/mooring places	2	0	2	0	2	0	1	0	0	0
1000-1500 parking/mooring	0	0	4	2	4	2	3	0	2	0
500-1000 parking/mooring	2	6	13	19	13	19	12	10	1	3
<500 parking/mooring places	7	5	50	56	50	56	46	52	8	8

The 4-step model can be seen as an input for the multi criteria analysis. This analysis method evaluates the different transportation systems on the proposed criteria. This is done in combination with the scenarios. The criteria are based on the research questions. Two sets of weights have been created for the multi-criteria analysis. One set was made by the employees of Blue21. Another was made by the author based on what future inhabitants would find important. Transportation system 2 (collective) scores best on both sets, especially the combination of this transportation system with network 1 scores well.

Table 69, Conclusion multi-criteria analysis

	Transportation system 1, Personal	Transportation system 2, Collective		Transportation system 3, Water
Advantages of transportation systems	-1,30	-0,90	-1,24	-1,93
Disadvantages of transportation systems	-0,53	0,15	-0,25	-0,15
Criteria floating cities	0,48	0,98	0,73	1,26

Table 69, Conclusion multi-criteria analysis show the sum of the scores of the sub-criteria in the multi-criteria analysis. The scores are combined with the weights of the author. The best scores are shown in dark blue color and the worse score in light blue. Transportation system 1 (personal) scores badly overall. Transportation system 2 (collective) scores well, especially in combination with network 1. Transportation system 3 (water) scores well on criteria related to floating cities.

How to keep advantages of current transportation systems:
Transportation system 2 (collective) scores best on these criteria. Especially the combination of transportation system 2 (collective) and network 1 scores well. This is mainly due to the low costs for this network. Transportation system 2 (collective) is also the safest system. Personal transportation is less safe than automated vehicles, based on the current data about casualties in transportation. It is however likely that Personal transportation will become safer in the future due to technical improvements.
Transportation system 1 (personal) offers the most comfort from the three transportation systems. People walk the shortest distances in this transportation system. Transportation system 1(personal) is also the fastest system of them all, although the distances in the city are so low that inhabitants probably will not care much about the differences in travel times. This could, however, be different if the distances and the travel times are higher, when the city is bigger or more spread out.

How to overcome disadvantages of current transportation systems:
Transportation system 2 (collective) scores best on criteria related to improving the disadvantages of transportation systems. This system has the highest score on walkability and has the lowest CO_2 emissions. Personal transportation might become more environmentally friendly, but it seems unlikely that everyone will buy environmental friendly cars, E-bikes, scooters, etc. Water transportation is furthermore less fuel efficient. Transportation 3 (water), causes the least nuisance, because it is further away from the housing areas than the other transportation systems. The water on the other hand could carry the noise further than what would happen on land, so the score of this transportation system could be underrated.

How to incorporate criteria related to floating cities
Transportation system 1 (personal) scores bad on these criteria, mainly because of the problems with parking places. Network 1 of transportation system 2 (collective) scores well on the criterion required space, but the second network is more flexible and can adapt better to an expanding city. The second system is also more innovative than the other systems, although it is arguable that this criterion is not very important for future inhabitants and of the Seasteading city.
Transportation system 3 (water) scores best on these criteria, mainly because it takes up little space inside the city, because it is flexible and can adapt to an expanding city. A disadvantage is however that mooring spaces should be taken into consideration. This is however less of a problem than the parking places in transportation system 1 (personal).

It can be concluded that based on the scale of the city and the specific characteristics of the project that a collective transportation system with small vehicles will be best for this city. What, however, should be taken into consideration is that this does not necessary need to be an automated system. It is for example also possible to create a system with slow transportation in combination with a good taxi service.

Evaluation
Beside an exploratory research into personal transportation in floating cities, this research also tests the research approach, so an evaluation of the process is needed. A critical reflection is made for all the steps of the research approach. At first the analysis will be evaluated, followed by step 2, the design of the scenario's, the design of the transportation systems, after this, the third step (the four-step model) and the fourth step, the multi criteria analysis will be evaluated.
Based on the first step, the analysis, criteria were proposed and the research approach was further defined. There is always something arbitrary about the choice of criteria in general, because the amount of criteria should be enough to be able to research the subject properly, but there should also be not too much criteria for the project to remain clear. The choice of criteria should, furthermore, reflect the elements that are important for the process. The choice of criteria has resulted in a clear research and it was able to say something about the subject, which is surrounded with a lot of uncertainties.
The choice of criteria can therefore be considered adequate, although the criterion "innovative" turned out to be considered not important by both Blue21 and the author of this paper. Leaving this criterion out of the research paper was on the other hand not an option, because this kind of criterion are often created when new infrastructure is developed.
The scenarios have made it also able to analyse the transportation in future floating cities, and can therefore be considered as sufficient. The choice of the case study (the Seasteading city) resulted in the choice of creating a design for the "red group" of people (the activity). Designs created for other groups will turn out different. It is for example thinkable that a design for the blue group (power) will result in floating villas or a floating city for the super-rich. A design for the green or yellow group would have resulted in a more conservative floating city.
It is furthermore likely that creating a design near another city would also result in another kind of city. When small floating cities are located near bigger cities, it is likely that a strong connection between the cities will arise. Creating more designs was not possible in the given timeframe and can be considered as a recommendation for further research.
Choosing other kind of transportation systems was also possible, but based on this research is possible to identify a number of effects. If for example a moving sidewalk is considered for such a system, a number of effects can already be assumed. Because it also a collective transportation system, it is for example likely that there are no capacity problems at the links and there are no parking spaces. Other effects that are not easy to generalise -such as the costs- can be calculated using the same method that has been used in the multi criteria analysis for the different criteria.
The goal of choosing transportation systems that differ from each other was to be able to get insight into the situation and to be able to say something about other transportation systems. This had been achieved by the research, although there are always transportation systems that don't fit the categories well. Air based

transportation is an example for this kind of transportation systems. The choice was made not to research these kind of systems, because it was considered as not realistic. If, for some reason, someone would like information about this, the same method can be used to research those kind of transportation systems.
Another interesting research topic would be to analyse the possibility of creating a collective transportation system. It is chosen not to do this, during the research, because it would have led to four variants instead of three (while it is desirable to minimize the amount of systems) and because the amount of travellers did not justify creating a fourth system. The amount of passengers is too little to operate ferries, so a system of collective water transportation with small vehicle is needed, similar to the collective transportation system on land. This system does not yet exist in an urban environment.
The chosen methodology for the four-step model is simple, but also sufficient. The sub-model gives insight into the future situation of transportation systems in floating cities. It is clear where commuters will be in the system and how busy links will be and where problems can be expected in a future floating city. The 4-step model furthermore provided input for the four step model.
Whether the transportation systems have too much capacity on the other hand, is difficult to say because one of the basic assumptions is that the systems should be robust. Robust systems always have some extra capacity. It is however possible to research when systems become unstable, for example by taking out links until the moment the system does not function anymore. Alternatively it is possible to monetize the effects of having too much capacity against the effect of having a system that is not robust enough. It is however necessary to develop a design of such a city further and make it more concrete. This was considered as not possible in the given timeframe.
In addition to this, it would also be recommended to research the situations at the crossings in such a city and perform an assignment that takes congestion into account. Before this can be done, more information about the behavior of future inhabitants needs to be available. Modelling these elements with standard coefficients based on the current situation, only makes the research more complicated instead of creating more insight into the future situation.
The source on which the mode choice parameters are based are, in addition to this, also old. A newer research, however, was not found. The values, furthermore, needed to be changed anyway, so it did not matter that much for the research project that the initial source was old. It would however be recommended to research the preferred choice for transportation mode for future inhabitants of a floating city.

A multi-criteria analysis is chosen as an evaluation method for this research. The advantage of a multi-criteria analysis above a cost-benefit analysis is that if the benefits are not always that clear and easy to monetize, it is always possible to give the elements a certain score. A multi criteria analysis can cope better with intangible and soft criteria than a cost benefit analysis. (Paolo Beria, ea., 2012)
In addition to this, a multi criteria is also transparent. It clearly states which scores and weights have been used and when readers disagree with the research, they can develop scores and weights themselves and although cost-benefit analyses should also be transparent, it is sometimes difficult to determine how scores are calculated if these calculations are complex.
The weights are developed by a workshop of the employees and by the author. It could be recommendable to develop weights, based on the future inhabitants of a floating city. It is however unclear who these inhabitants will be. It is therefore recommended to do more research about this, or perform a Multi-criteria analysis together with future inhabitants or other actors, when such a project would become reality in the future.
The multi –criteria have yielded insight into a situation with a lot of uncertainties and the results are generalizable, so it can be considered sufficient. It is however possible to research a number of criteria more thoroughly.
The method to analyze the costs has for example shown which transportation systems more expensive than others, but it is not that precise. It is difficult to calculate certain costs, because it is not yet known what the costs for certain elements will be in floating cities. An example of this is the floating bridge. Further research is needed to refine this.

The criterion safety could also be researched in more depth. Because of the small timeframe of this research, only the data about casualties in current situations were used. Researching the behavior of future inhabitants of floating cities could generate more insight into the safety of the transportation systems. It is on the other hand not likely that this will lead to a drastic difference in result. On land, automated systems are saver than non-automated systems, operated by the commuters themselves. It is therefore likely that the score would be similar for such floating cities.
The way travel time was calculate was pretty straightforward. The shortest travel time was calculated. The only recommendations that can be given is to take congestion into account. It is however necessary to know more about the behavior of the inhabitants of the city. The criterion required space was also calculated in a logical and straightforward way, the surface of the transportation systems are simply compared to each other. The same thing can be said about the criterion comfort. It is however possible to make a distinction between different modes and vehicles, when the comfort levels of these systems are known. The same thing can be said about the criterion nuisance, a differentiation on the modes is possible when more information about the nuisances caused by these vehicles are known.
The walkability methodology furthermore was calculated, based on a methodology developed by professional and based on scientific research. It can however be researched in more depth.
The emission criterion furthermore could also be researched into more depth, due to the short time frame, only the output of CO_2 was taken into account. It is recommended to research other forms of emissions too.
Innovation could also be researched in more depth, although the criterion turned out to be not as important by both the author and the employees of Blue21.
The effects of flexibility and scalability were also researched in an adequate way. It is however recommended for further research if the transportation systems are also adaptable for even bigger cities (50-100,000 inhabitants)

The analysis of the 4-step model and the multi-criteria analysis have yielded insight into the situation. The model is easy to interpret, and transparent. On the other hand, the model is imprecise. It is difficult to accurately simulate the lifestyle of inhabitants in a future floating city. It is possible that developments will lead to differences in lifestyle. If inhabitants for example order everything via the internet, trips to shops are no longer necessary. These elements can also be seen as part of the vision of the designers and the clients. The model can be tuned and changed to reflect the vision of future projects. The combination furthermore of creating different scenarios and transportation systems, simulate these and analyse the results is a way to get insight into the situation and to generate a wide overview of the situation.

7.2 Recommendations

Almost all research leads to new research, especially when it is exploratory research into future situations. Recommendations for further research into floating cities are numerous, because many elements come together in creating cities. It is, for example, important to further investigate floating cities in technical, sociological and economic perspectives. The water quality and other ecological elements should also be taken into account. On the other hand, the elements of floating cities—such as floating buildings and infrastructure—already exist. In this chapter, a selection of recommendations related to this thesis is selected.

Developing more scenarios and scenarios for other kinds of inhabitants could generate more insight into the future situation. One recommendation is to create a scenario in which the harbours are placed all over the city or at the outer rings of the city.
Another option is to create a scenario in which the floating community is placed near another city. It is likely that the transportation system will be different when there is a clear connection between the floating city and a nearby city. A third option is to generate designs for the different groups (red, blue, green and yellow).
It is also recommendable to research the behaviour of the future inhabitants of the floating city. This way better constants for mode choice can be obtained and the capacity at crossings or at links can be calculated. This way different assignment methods can be used to incorporate the effect of congestion on the system.

The design of the transportation systems are, furthermore, robust. This was one of the starting points for the design. Calculating if the transportation system are not too big is a recommendation for further research. Although the multi criteria analysis yielded insight into the future situation of transportation systems in floating cities, a number of subjects will be recommended for further research.
It would be necessary to research more about the costs of the transportation systems. One example is calculating the costs for floating bridges in such a city. Secondly it would be necessary to calculate other emissions than CO2 emissions.
It is also recommended that transportation cities of 50,000 to 100,000 inhabitants or more be studied. The scalability of the systems is evaluated up to 35,000 inhabitants, but it is recommended that it be determined whether the results are also valid for cities with considerable larger sizes. When furthermore more information about the behaviour of the inhabitants is known, this can also improves the multi-criteria analysis.
Furthermore it is a possibility to perform a cost benefit analysis, when there is more information about the project and the future situation available. A cost benefit analysis could generate input for the decision making when the situation is clearer and tangent effects are more important.
In addition to this it is also recommendable to perform a multi-criteria analysis together with future inhabitants, or to perform more research about future inhabitants of floating cities.
This report analyses the transport of inhabitants in a floating city. A study into the freight transportation from, in and to such a city is also recommended. Furthermore, it is not advisable to completely ignore the need for leisure transportation. If, for example, water transportation is neither useful for daily commuting nor too expensive, it remains possible that inhabitants will want to use it for leisure purposes. Freight transportation must also be implemented, and water provides one alternative for freight transportation.

The methodology described in this report could help to generate more insight into the transportation of the floating city, and could guide future designs of floating cities. Creations of variants of transportation systems, layouts of the city, a 4-step model and a multi-criteria analysis could be useful. It is, however, recommended, that a more advanced programming language be used to create a more advanced software environment.
Furthermore the behaviour of the inhabitants could be researched in greater depth so it will be possible to measure the effects of congestion on the system. In addition to this a robustness study can be performed. The proposed methodology furthermore also yield more insight into future situations, so it is recommendable to also analyse more designs. At last it could be recommendable to research the transportation of freight in the future floating city.

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Appendix A, Rich picture of the inhabitants, guests and tourists

This chapter describes a number of rich pictures created for the developing of the model and to distinguish the different categories of people who are travelling to or in the Seasteading city. The sketch pictures describe three different types of people with their own relation with the Seasteading city: inhabitants, guest workers and tourists.

As can be seen in Figure 61 inhabitants need to be able to go to their jobs, go shopping, bring their child to the day-care and visit friends and relatives. Some of the inhabitants will also need to go to the educational facilities.

These are both students that study at a high school, but also workers that need to be re-educated. There is also space for facilities regarding recreation.. It is assumed that the contact between people (eg. students and teachers or colleagues) will still be necessary in the future, even when it is technically possible to work at home in the future.

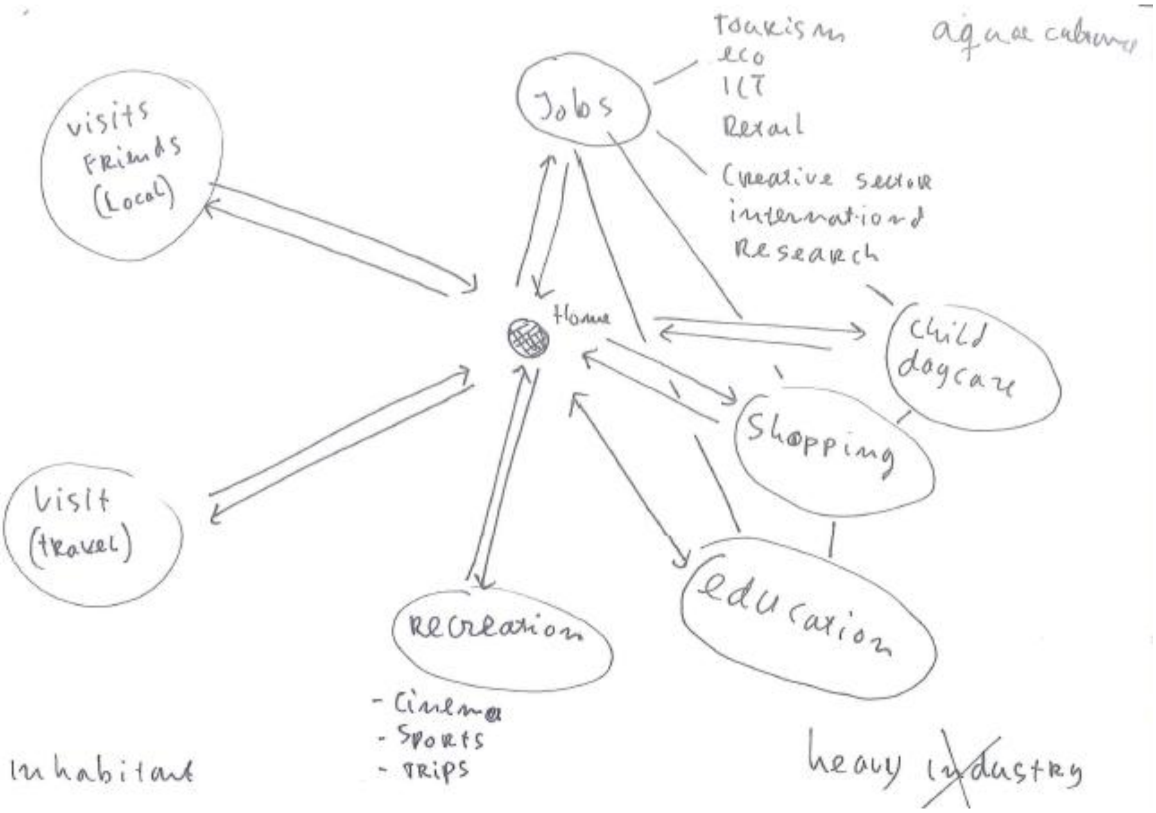


Figure 61, Activities inhabitants

The second category consists of people from a nearby city that will travel to the island to work into the Seasteading community. It is also possible that these people buy certain things in the city and visit relatives, go to friends or relatives and to certain recreational facilities, such as restaurants.

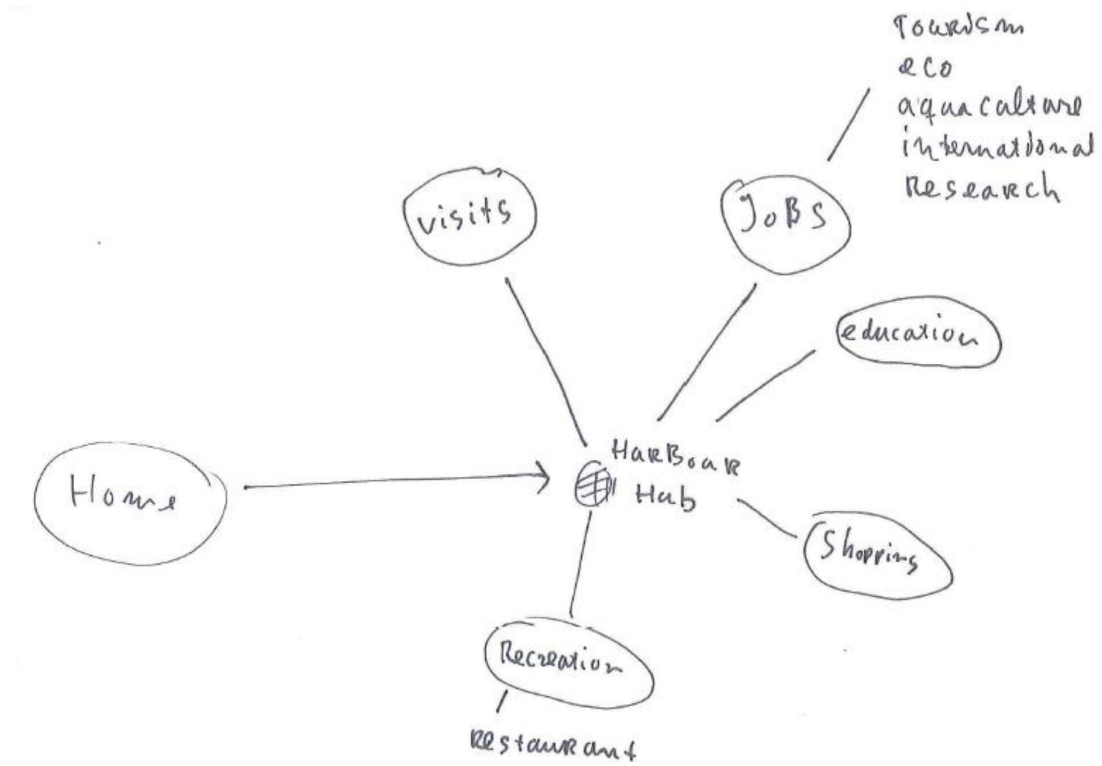


Figure 62, Activities Guest worker

The third category is the tourists. These tourists arrive at the harbour or another place nearby or in the Seasteading city. These tourists will go to their hotel, local recreation and day trips ad excursion. It is also possible that these people visit families and friends in the city. Furthermore it is possible that they will travel through the Seasteading city with the purpose of seeing the city, it's most important sites and to experience the atmosphere of the city

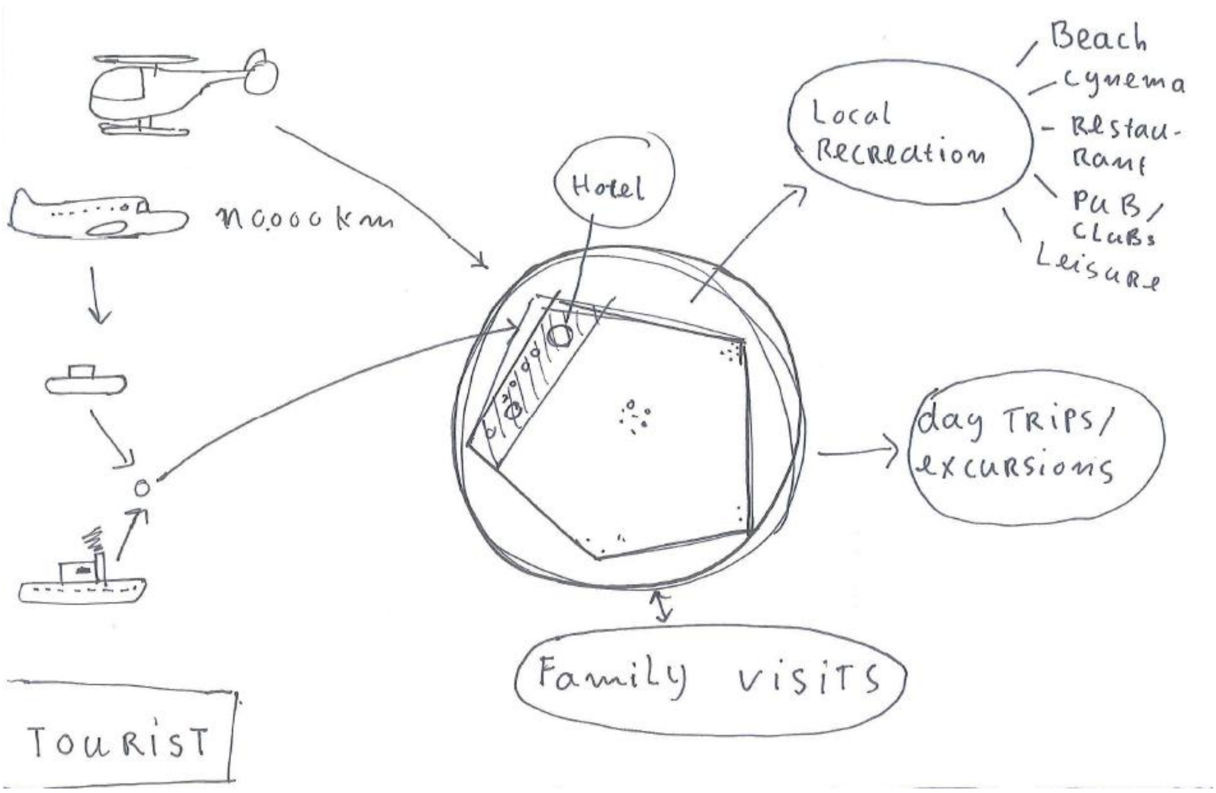


Figure 63, Activities tourists

Appendix B, Travel times

Table 70 shows the average walking time between the zones in the different regions. A walking speed of 3,6 km/hrs.

Table 70, Walking time between regions (min)

	1	2	3	4	5	6	7	8	9	10	11
1	5	11	18	22	28	29	28	22	18	11	17
2	11	5	11	17	22	25	28	25	22	17	13
3	18	11	5	11	18	22	28	29	28	22	17
4	22	17	11	5	11	17	22	25	28	25	14
5	28	22	18	11	5	11	18	22	28	29	17
6	29	25	22	17	11	5	11	17	22	25	14
7	28	28	28	22	18	18	5	11	18	22	17
8	22	25	29	25	22	22	11	5	11	17	14
9	18	22	28	28	28	28	18	11	5	11	17
10	11	17	22	25	29	29	22	17	11	5	14
11	17	13	17	14	17	17	17	14	17	14	6

Table 71 shows the average travel time from zone to zone per region. The calculation is based on a travel time of 14,4 km/hrs. Two additional minutes are taken into account for parking and getting the bicycle.

Table 71, Cycling time between regions (min)

	1	2	3	4	5	6	7	8	9	10	11
1	5	7	8	10	11	11	11	10	8	7	8
2	7	5	7	8	9	10	11	10	9	8	7
3	8	7	5	7	8	10	11	11	11	10	8
4	10	8	7	5	7	8	9	10	11	10	7
5	11	9	8	7	5	7	8	10	11	11	8
6	11	10	10	8	7	5	7	8	9	10	7
7	11	11	11	9	8	8	5	7	8	10	8
8	10	10	11	10	10	10	7	5	7	8	7
9	8	9	11	11	11	11	8	7	5	7	8
10	7	8	10	10	11	11	10	8	7	5	7
11	8	7	8	7	8	8	8	7	8	7	5

The travel time of personal transportation is calculated on the base of a speed of 30 km/h. Three additional minutes are taken into account for parking and getting the car, scooter etc. ready to drive.

Table 72, Travel time (personal transportation modes)

	1	2	3	4	5	6	7	8	9	10	11
1	5	5	6	6	7	7	7	6	6	5	5
2	5	5	5	6	6	6	7	6	6	6	5
3	6	5	5	5	6	6	7	7	7	6	5
4	6	6	5	5	5	6	6	6	7	6	5
5	7	6	6	5	5	5	6	6	7	7	5
6	7	6	6	6	5	5	5	6	6	6	5
7	7	7	7	6	6	6	5	5	6	6	5
8	6	6	7	6	6	6	5	5	5	6	5
9	6	6	7	7	7	7	6	5	5	5	5
10	5	6	6	6	7	7	6	6	5	5	5
11	5	5	5	5	5	5	5	5	5	5	5

The travel time for collective transportation, is calculated by using a travel speed of 30 km/hrs, a waiting time of 5 minutes. Furthermore people walk or cycle from their homes to the stops.

Table 73, Travel time (collective transportation modes)

	1	2	3	4	5	6	7	8	9	10	11
1	9	12	12	13	13	14	13	13	12	12	13
2	12	9	10	11	11	12	12	12	11	11	11
3	12	10	9	12	12	13	13	14	14	14	14
4	13	11	12	9	10	11	11	12	12	12	11
5	13	11	12	10	9	11	11	12	12	13	12
6	14	12	13	11	11	9	10	11	11	12	11
7	13	12	13	11	11	11	9	11	11	12	12
8	13	12	14	12	12	12	11	9	10	11	11
9	12	11	14	12	12	12	11	10	9	12	13
10	12	11	14	12	13	13	12	11	12	9	11
11	13	11	14	11	12	12	12	11	13	11	9

The travel time for the personal water transportation is calculated in a similar way as the personal transportation on land. People, however, also need to get to the mooring places. Getting the boat ready is estimated to take 3 minutes and the average speed is around 18 km/hrs.

Table 74, Travel times water transport (Personal transportation mode)

	1	2	3	4	5	6	7	8	9	10	11
1	9	10	11	12	13	14	13	11	11	10	11
2	10	9	9	10	11	13	13	12	11	10	7
3	11	9	9	10	11	12	13	13	13	12	11
4	12	10	10	11	11	12	13	14	15	15	10
5	13	11	11	11	9	10	11	11	13	14	11
6	14	13	12	12	10	11	11	12	13	15	10
7	13	13	13	13	11	11	9	9	11	12	11
8	11	12	13	14	11	11	9	10	11	12	10
9	11	11	13	15	13	13	11	11	9	9	11
10	10	10	12	15	14	14	12	12	9	10	10
11	11	7	11	10	11	11	11	10	11	10	8

The travel time for the collective water transportation is calculated in a similar way. An extra of 5 minutes waiting time is added to this mode.

Table 75, Travel times water transport (collective transportation mode)

	1	2	3	4	5	6	7	8	9	10	11
1	15	16	17	18	19	20	19	17	17	16	18
2	16	15	15	16	17	19	19	18	17	16	14
3	17	15	15	16	17	18	19	19	19	18	18
4	18	16	16	17	17	18	19	20	21	21	16
5	19	17	17	17	15	16	17	17	19	20	18
6	20	19	18	18	16	17	17	18	19	21	16
7	19	19	19	19	17	17	15	15	17	18	18
8	17	18	19	20	17	17	15	16	17	18	16
9	17	17	19	21	19	19	17	17	15	15	18
10	16	16	18	21	20	20	18	18	15	16	16
11	18	14	18	16	18	18	18	16	18	16	14

Appendix C, Model

This chapter describes and presents the 4-step model as created by the author of this thesis. The parts of the model will be explained using the schematic overview of the 4-step model.

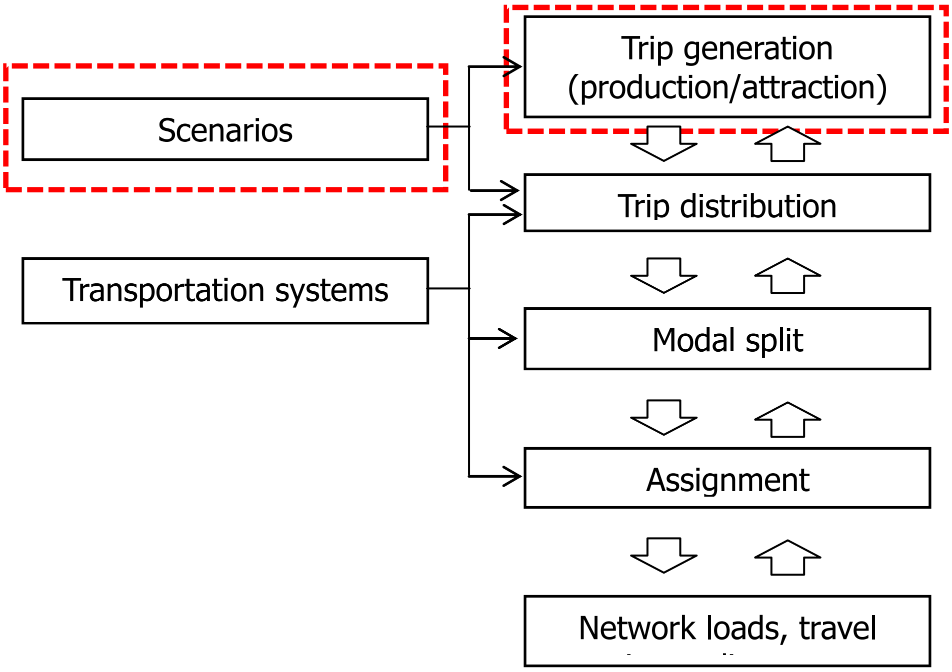


Figure 64, overview 4-step model

Zones

The size of the zones is important for the model. The model needs to be detailed enough to function (to be able to show the traffic flows), but it is also necessary that people can understand the model. When the zones are too small, the relations become unclear. In figure Figure 65, Regions the different regions of the city are shown, in Figure 66, Zonesthe different zones.

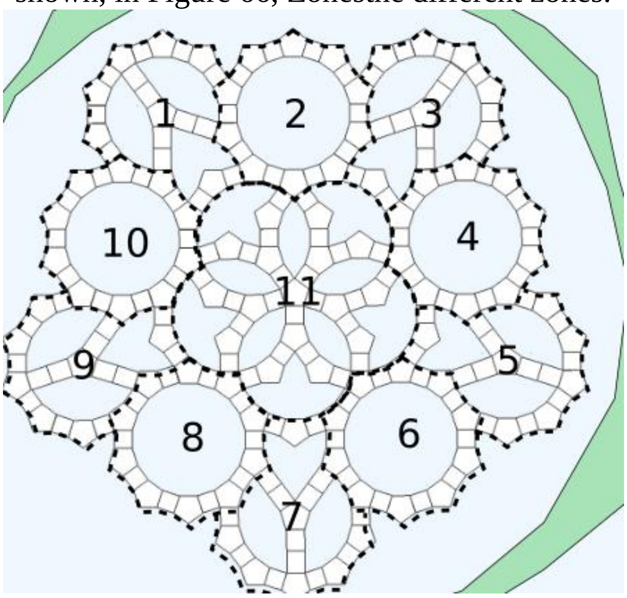


Figure 65, Regions

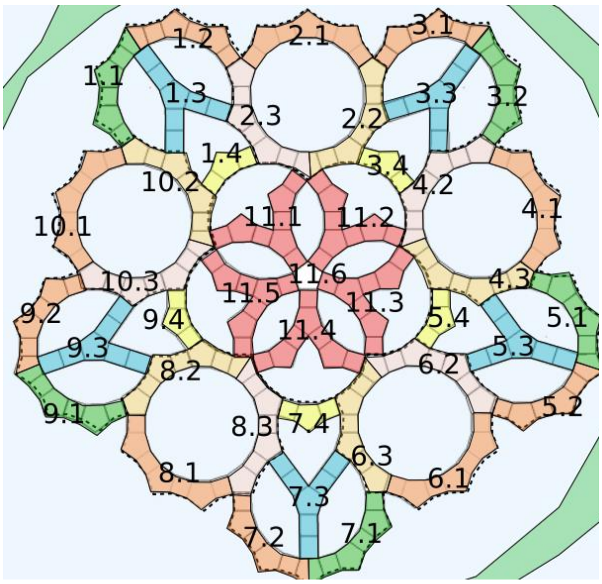


Figure 66, Zones

Scenarios and trip generation

The modules of scenario 1 and scenario 2 are inserted into excel. The amount and the type of modules are inserted in excel per zone.

	housing	hotels	shops/restaurants	clubs	ICT/creative	Jobs(other)	daycare	educatio	higher education	total
1.1	6	3	0,5							9,5
1.2	6	4	0,5							10,5
1.3	5	2								7
1.4	2						1			3
1. total:	19	9	1	0	0	0	1	0	0	30
2.1	20									20
2.2	6,5									6,5
2.3	6,5									6,5
2. total:	33	0	0	0	0	0	0	0	0	33
3.1	9,5									9,5
3.2	9,5									9,5
3.3	8									8
3.4	4						1			5
Total:	31	0	0	0	0	0	1	0	0	32
4.1	19									19
4.2	7									7
4.3	6						2			8
Total:	32	0	0	0	0	0	2	0	0	34
5.1	9,5							1	1	11,5
5.2	9,5									9,5
5.3	6						2			8
5.4	0							0	3	3
Total:	25	0	0	0	0	0	2	1	4	32
6.1	19									19
6.2	7									7
6.3	7									7
Total:	33	0	0	0	0	0	0	0	0	33
7.1	9,5									9,5
7.2	5,5									5,5
7.3	6									6
7.4	3									3
Total:	24	0	0	0	0	0	0	0	0	24
8.1	1		0							1
8.2	3		7							10
8.3	0		7							7

Figure 67, excerpt of the insertion of the modules into excel

The modules are multiplied with the program per module. When extra program is needed, for example at the harbour place, this can also be putted in an excel table.

module:	inhabitar	Tourist	Traveller
housing	80	0	0
hotel	0	300	0
shops	60	0	0
clubs	80	0	0
ICT/creativ	80	0	0
Jobs(other)	80	0	0
Daycare	40	0	0
education	40	0	0
higher edu	40	0	0

Figure 68, production per module

module:	Jobs	shoppers	Tourist	educatio	Daycare
housing	0	0	0	0	0
hotel	30	0	150	0	0
shops	20	100	10	0	0
clubs	5	0	0	0	0
ICT/creativ	153,93	0	0	0	0
Jobs(other)	1	0	0	0	0
Daycare	2	10	0	0	25
education	20	0	0	50	0
higher edu	50	0	0	100	0
Leisure (oth	1	0	1	0	0

Figure 69, attraction per module

Jobs (other)	Leisure (oth	Guest	Students
0	10	0	0
0	10	0	0
0	10	0	0
0	10	0	0
0	10	0	0
0	10	0	0
0	10	0	0
0	10	0	0
0	10	0	0
0	10	0	0
0	10	0	0
0	10	0	0
0	10	0	0

Figure 70, extra program

Trip generation

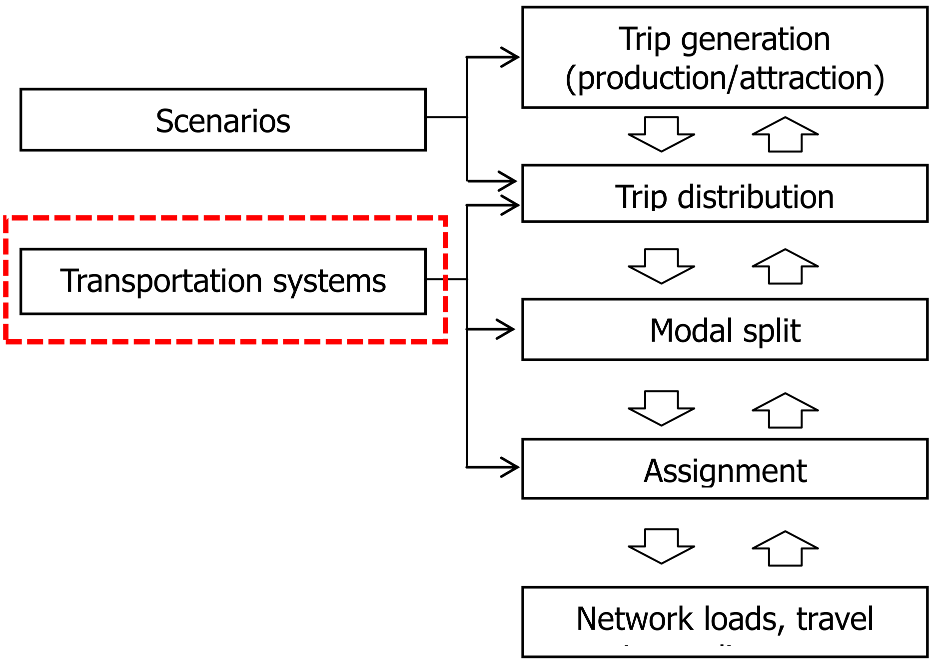
The amount of inhabitants, tourists, guest workers, and children is collected in a table with the production and the attraction potential. An excerpt of the production can be seen in Figure 71 and an excerpt of the attraction in Figure 72.

region:	inhabitants	Tourist	Guest	Children	Harbor
1.1	190	900	0	4,75	
1.2	190	1200	0	4,75	
1.3	400	600	0	10	
1.4	200	0	0	5	
2.1	560	0	0	14	
2.2	520	0	0	13	
2.3	520	0	0	13	
3.1	440	0	0	11	
3.2	440	0	0	11	
3.3	640	0	0	16	
3.4	360	0	0	9	
4.1	480	0	0	12	
4.2	560	0	0	14	
4.3	560	0	0	14	
5.1	520	0	0	13	
5.2	440	0	0	11	
5.3	560	0	0	14	
5.4	120	0	0	3	
6.1	480	0	0	12	

Figure 71, production

region:	Jobs	shoppers	Leisure	education	Daycare	Supermarkets
1.1	100	50	465	0	0	1
1.2	130	50	615	0	0	1
1.3	60	0	310	0	0	0
1.4	2	10	10	0	25	0
2.1	0	0	10	0	0	0
2.2	0	0	10	0	0	0
2.3	0	0	10	0	0	0
3.1	0	0	10	0	0	0
3.2	0	0	10	0	0	0
3.3	0	0	10	0	0	0
3.4	2	10	10	0	25	0
4.1	0	0	10	0	0	0
4.2	0	0	10	0	0	0
4.3	4	20	10	0	50	0
5.1	70	0	10	150	0	0
5.2	0	0	10	0	0	0
5.3	4	20	10	0	50	0
5.4	150	0	10	300	0	0
6.1	0	0	10	0	0	0
6.2	0	0	10	0	0	0

Figure 72, attraction



Transportation systems

The networks can be represented in links and nodes. There is a different network for the transportation on land and on water. The basic transportation system uses the network in Figure 73. The personal and the public transportation system use parts of this network. The water transportation is modelled by the network in Figure 74.

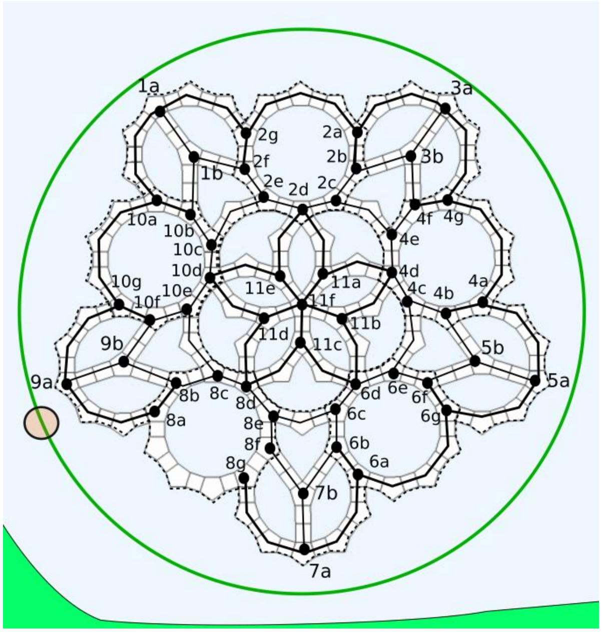


Figure 73, network basic transportation system

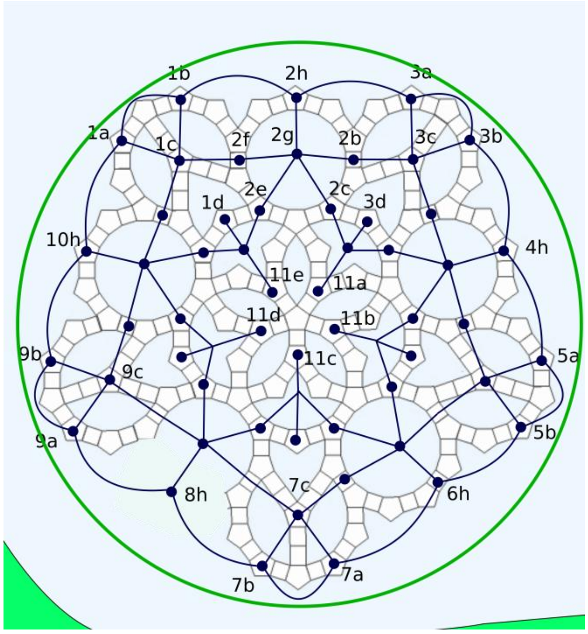


Figure 74, network water transportation

The shortest routes between zones are found by analytical thinking in combination with the solver of excel (shortest path route).

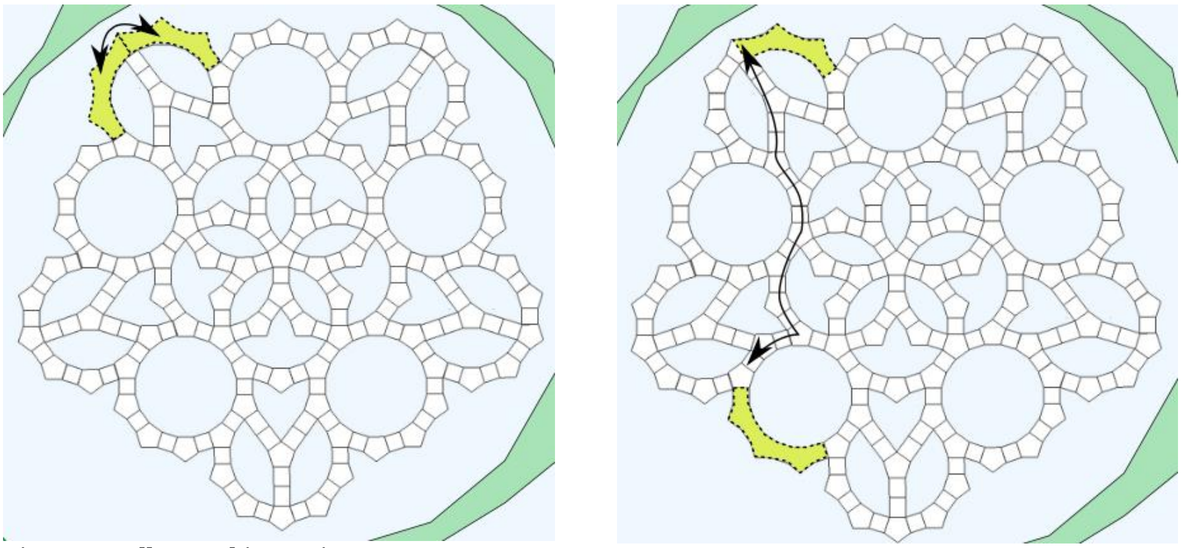


Figure 75, all or nothing assignment

The networks are represented in excel by a list of binary code. If a one is in the list, this means the link is part of the route between two zones. The symmetric form of the Seasteading city is used to create routes between all the zones. In Figure 76, an excerpt can be seen of such a network is given. The routes from zone 1,1 to other zones are shown.

1.1				1.1	1.2	1.3	1.4	2.1	2.2	2.3	3.1	3.2	3.3	3.4	4.1	4.2	4.3	5.1	5.2	5.3	5.4	6.1
1.1	1a	10a		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	10a	1a		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.2	1a	2g		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	2g	1a		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.3a	1a	1b		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	1b	1a		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.3b	1b	2f		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	2f	1b		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.3c	1b	10b		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	10b	1b		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.4	2e	10c		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	10c	2e		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2.1	2a	2g		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	2g	2a		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2.2a	2a	2b		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	2b	2a		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2.2b	2b	2c		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	2c	2b		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2.2c	2c	2d		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	2d	2c		0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	0
2.3a	2d	2e		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	2e	2d		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2.3b	2e	2f		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	2f	2e		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2.3c	2f	2g		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	2g	2f		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3.1	2a	3a		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	3a	2a		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3.2	3a	4g		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Figure 76, list of routes

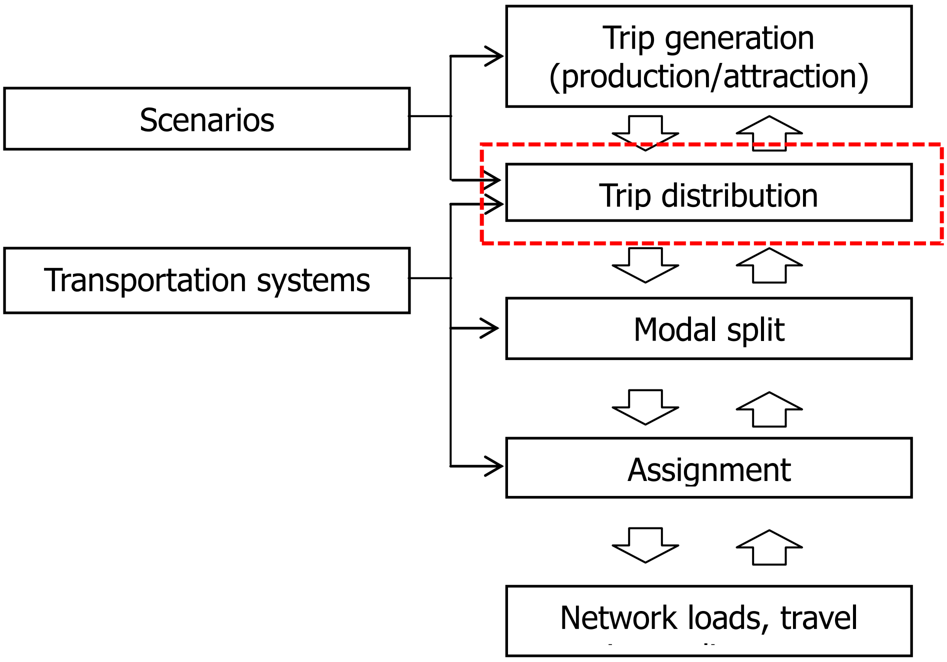
The shortest routes between the different zones are saved for the different networks. There is a data set for the basic transportation system, transportation system 1 (personal) etc. Buttons are created so the user can switch between the networks and scenarios.

Distance:
The distances between the zones are calculated by multiplying the links of a network with the relative of those particular links. In figure.. an except is shown of a table of the distance between the zones.

0	353	353	353	353	353	353	353	353	353	353	353	353	353	353	353	353	353	353	353	353	353	353	353	35
353	0	353	353	353	353	353	353	353	353	353	353	353	353	353	353	353	353	353	353	353	353	353	353	35
184	184	0	184	184	184	184	184	184	184	184	184	184	184	184	184	184	184	184	184	184	184	184	184	18
184	184	184	0	184	184	184	184	184	184	184	184	184	184	184	184	184	184	184	184	184	184	184	184	18
473	473	473	473	0	473	473	473	473	473	473	473	473	473	473	473	473	473	473	473	473	473	473	473	47
193	193	193	193	193	0	193	193	193	193	193	193	193	193	193	193	193	193	193	193	193	193	193	193	19
193	193	193	193	193	193	0	193	193	193	193	193	193	193	193	193	193	193	193	193	193	193	193	193	19
353	353	353	353	353	353	353	0	353	353	353	353	353	353	353	353	353	353	353	353	353	353	353	353	35
353	353	353	353	353	353	353	353	0	353	353	353	353	353	353	353	353	353	353	353	353	353	353	353	35
184	184	184	184	184	184	184	184	184	0	184	184	184	184	184	184	184	184	184	184	184	184	184	184	18
184	184	184	184	184	184	184	184	184	184	0	184	184	184	184	184	184	184	184	184	184	184	184	184	18
473	473	473	473	473	473	473	473	473	473	473	0	473	473	473	473	473	473	473	473	473	473	473	473	47
193	193	193	193	193	193	193	193	193	193	193	193	0	193	193	193	193	193	193	193	193	193	193	193	19
193	193	193	193	193	193	193	193	193	193	193	193	193	0	193	193	193	193	193	193	193	193	193	193	19
353	353	353	353	353	353	353	353	353	353	353	353	353	353	0	353	353	353	353	353	353	353	353	353	35
353	353	353	353	353	353	353	353	353	353	353	353	353	353	353	0	353	353	353	353	353	353	353	353	35
184	184	184	184	184	184	184	184	184	184	184	184	184	184	184	184	0	184	184	184	184	184	184	184	18
184	184	184	184	184	184	184	184	184	184	184	184	184	184	184	184	184	0	184	184	184	184	184	184	18
473	473	473	473	473	473	473	473	473	473	473	473	473	473	473	473	473	473	0	473	473	473	473	473	47
193	193	193	193	193	193	193	193	193	193	193	193	193	193	193	193	193	193	193	0	193	193	193	193	19
193	193	193	193	193	193	193	193	193	193	193	193	193	193	193	193	193	193	193	193	0	193	193	193	19
353	353	353	353	353	353	353	353	353	353	353	353	353	353	353	353	353	353	353	353	353	0	353	353	35
353	353	353	353	353	353	353	353	353	353	353	353	353	353	353	353	353	353	353	353	353	353	0	353	35
184	184	184	184	184	184	184	184	184	184	184	184	184	184	184	184	184	184	184	184	184	184	184	184	
184	184	184	184	184	184	184	184	184	184	184	184	184	184	184	184	184	184	184	184	184	184	184	184	18
473	473	473	473	473	473	473	473	473	473	473	473	473	473	473	473	473	473	473	473	473	473	473	473	47
193	193	193	193	193	193	193	193	193	193	193	193	193	193	193	193	193	193	193	193	193	193	193	193	19
193	193	193	193	193	193	193	193	193	193	193	193	193	193	193	193	193	193	193	193	193	193	193	193	19
353	353	353	353	353	353	353	353	353	353	353	353	353	353	353	353	353	353	353	353	353	353	353	353	35
353	353	353	353	353	353	353	353	353	353	353	353	353	353	353	353	353	353	353	353	353	353	353	353	35
184	184	184	184	184	184	184	184	184	184	184	184	184	184	184	184	184	184	184	184	184	184	184	184	18
184	184	184	184	184	184	184	184	184	184	184	184	184	184	184	184	184	184	184	184	184	184	184	184	18
473	473	473	473	473	473	473	473	473	473	473	473	473	473	473	473	473	473	473	473	473	473	473	473	47
193	193	193	193	193	193	193	193	193	193	193	193	193	193	193	193	193	193	193	193	193	193	193	193	19
193	193	193	193	193	193	193	193	193	193	193	193	193	193	193	193	193	193	193	193	193	193	193	193	19
278	278	278	278	278	278	278	278	278	278	278	278	278	278	278	278	278	278	278	278	278	278	278	278	27
278	278	278	278	278	278	278	278	278	278	278	278	278	278	278	278	278	278	278	278	278	278	278	278	27
278	278	278	278	278	278	278	278	278	278	278	278	278	278	278	278	278	278	278	278	278	278	278	278	27
278	278	278	278	278	278	278	278	278	278	278	278	278	278	278	278	278	278	278	278	278	278	278	278	27
278	278	278	278	278	278	278	278	278	278	278	278	278	278	278	278	278	278	278	278	278	278	278	278	27
63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	6

Figure 77, Excerpt of a distance table

The travel times are calculated in the same way (only the travel time is used instead of the distance). Furthermore extra time (for example to get the bike/car) is added when needed.
Travel times:



Trip distribution

The trip distribution is calculated by using the trip generation (the production and attraction potential). A choice can be made between scenario 1 and 2. The following formulas are used:

Work:

Both the amount of inhabitants (that goes to their work) and the guest workers (that arrive in the harbour) will be multiplied by the attraction potential, which in turn will be calculated by dividing the amount of jobs by the total amount of jobs.

$$X_{ij} = \frac{A(jobs)_j}{\sum A(jobs)_j} \times A(workers)_i$$

$$A\ workers = \ 0{,}4\ * \mathrm{A}(inhabitants)_i$$

$$X_{ij} = \frac{A(jobs)_j}{\sum A(jobs)_j} \times A(guestworkers)_i$$

Shoppers:

The amount of trips by shoppers is calculated in a similar way. The amount of shoppers is calculated by multiply the inhabitants by 0,04. The attraction potential Is calculated by the amount of shops in the zone by the total amount of shops in the city

$$X_{ij} = \frac{A(shops)_j}{\sum A(Shops)_j} \times A(shoppers)_i$$

$$A\ (shoppers)_i = \ 0{,}04\ * \mathrm{A}(inhabitants)_i$$

Tourists:

The trip of tourists are calculated by multiplying the attraction potential (leisure) by the production potential (amount of tourists).

$$X_{ij} = \frac{A(Leisure)_j}{\sum A(Leisure)_j} \times A(tourists)_i$$

Students:
The amount of trips of students is calculated in the same way. Tourists make up of 20% of the inhabitants of the city.

$$X_{ij} = \frac{A(Education)_j}{\sum A(Education)_j} \times A(students)_i$$

$Students_i$ = 0,2 * $Inhabitants_i$

Children:

$$X_{ij} = \frac{A(DayCare)_j}{\sum A(DayCare)_j} \times A(children)_i$$

$Children_i$ = 0,04 * $Inhabitants_i$

In Figure 78 an excerpt of the result of this process is shown. The total flow of travellers are from and to zones are collected in one table

	Total	1.1	1.2	1.3	1.4	2.1	2.2	2.3	3.1	3.2	3.3
1.1	159	13	37	18	1	1	1	1	1	1	1
1.2	183	31	22	24	1	1	1	1	1	1	1
1.3	66	12	16	7	1	0	0	0	0	0	0
1.4	16	0	1	0	0	0	0	0	0	0	0
2.1	226	5	6	2	2	0	0	0	0	0	0
2.2	44	1	1	0	1	0	0	0	0	0	0
2.3	44	1	1	0	0	0	0	0	0	0	0
3.1	83	2	2	1	1	0	0	0	0	0	0
3.2	83	2	2	1	1	0	0	0	0	0	0
3.3	44	0	0	0	0	0	0	0	0	0	0
3.4	34	0	0	0	0	0	0	0	0	0	0
4.1	211	2	2	0	1	0	0	0	0	0	0
4.2	47	0	0	0	0	0	0	0	0	0	0
4.3	48	0	0	0	0	0	0	0	0	0	0
5.1	92	1	1	0	0	0	0	0	0	0	0
5.2	86	1	1	0	0	0	0	0	0	0	0
5.3	40	0	0	0	0	0	0	0	0	0	0
5.4	11	0	0	0	0	0	0	0	0	0	0
6.1	223	1	1	0	0	0	0	0	0	0	0
6.2	64	0	1	0	0	0	0	0	0	0	0
6.3	64	0	1	0	0	0	0	0	0	0	0
7.1	126	1	1	0	0	0	0	0	0	0	0
7.2	62	0	1	0	0	0	0	0	0	0	0
7.3	39	0	0	0	0	0	0	0	0	0	0
7.4	26	0	0	0	0	0	0	0	0	0	0
8.1	339	16	21	10	0	0	0	0	0	0	0
8.2	63	2	2	0	1	0	0	0	0	0	0
8.3	40	1	1	0	0	0	0	0	0	0	0
9.1	57	1	1	0	1	0	0	0	0	0	0
9.2	101	2	2	1	1	0	0	0	0	0	0
9.3	25	1	1	0	0	0	0	0	0	0	0
9.4	19	1	1	0	0	0	0	0	0	0	0
10.1	191	5	5	2	2	0	0	0	0	0	0
10.2	60	1	1	0	1	0	0	0	0	0	0
10.3	86	1	1	0	1	0	0	0	0	0	0

	3.4	4.1	4.2	4.3	5.1	5.2	5.3	5.4	6.1	6.2	6.3	7.1	7.2
1.1	1	0	0	1	2	0	1	3	0	0	0	0	0
1.2	1	0	0	1	2	0	1	3	0	0	0	0	0
1.3	1	0	0	0	1	0	0	2	0	0	0	0	0
1.4	0	0	0	0	1	0	0	1	0	0	0	0	0
2.1	2	0	0	2	7	0	2	14	0	0	0	0	0
2.2	0	0	0	1	4	0	1	8	0	0	0	0	0
2.3	1	0	0	1	4	0	1	8	0	0	0	0	0
3.1	1	0	0	2	7	0	2	14	0	0	0	0	0
3.2	1	0	0	2	7	0	2	14	0	0	0	0	0
3.3	1	0	0	1	5	0	1	10	0	0	0	0	0
3.4	0	0	0	1	3	0	1	5	0	0	0	0	0
4.1	2	0	0	4	14	0	4	32	0	0	0	0	0
4.2	1	0	0	1	4	0	1	8	0	0	0	0	0
4.3	1	0	0	1	5	0	1	8	0	0	0	0	0
5.1	1	0	0	2	4	0	2	16	0	0	0	0	0
5.2	1	0	0	2	6	0	2	14	0	0	0	0	0
5.3	0	0	0	0	4	0	1	9	0	0	0	0	0
5.4	0	0	0	0	1	0	0	1	0	0	0	0	0
6.1	1	0	0	2	14	0	4	32	0	0	0	0	0
6.2	0	0	0	0	4	0	1	8	0	0	0	0	0
6.3	0	0	0	0	4	0	1	8	0	0	0	0	0
7.1	0	0	0	1	7	0	2	15	0	0	0	0	0
7.2	0	0	0	0	4	0	1	8	0	0	0	0	0
7.3	0	0	0	0	1	0	0	1	0	0	0	0	0
7.4	0	0	0	0	0	0	0	1	0	0	0	0	0
8.1	0	0	0	0	1	0	0	2	0	0	0	1	1
8.2	0	0	0	0	1	0	0	2	0	0	0	0	0
8.3	0	0	0	0	1	0	0	1	0	0	0	0	0
9.1	0	0	0	0	1	0	0	2	0	0	0	0	0
9.2	0	0	0	0	2	0	1	5	0	0	0	0	0
9.3	0	0	0	0	0	0	0	0	0	0	0	0	0
9.4	0	0	0	0	0	0	0	0	0	0	0	0	0
10.1	1	0	0	1	2	0	0	4	0	0	0	0	0
10.2	1	0	0	1	4	0	1	9	0	0	0	0	0
10.3	1	0	0	1	4	0	1	9	0	0	0	0	0

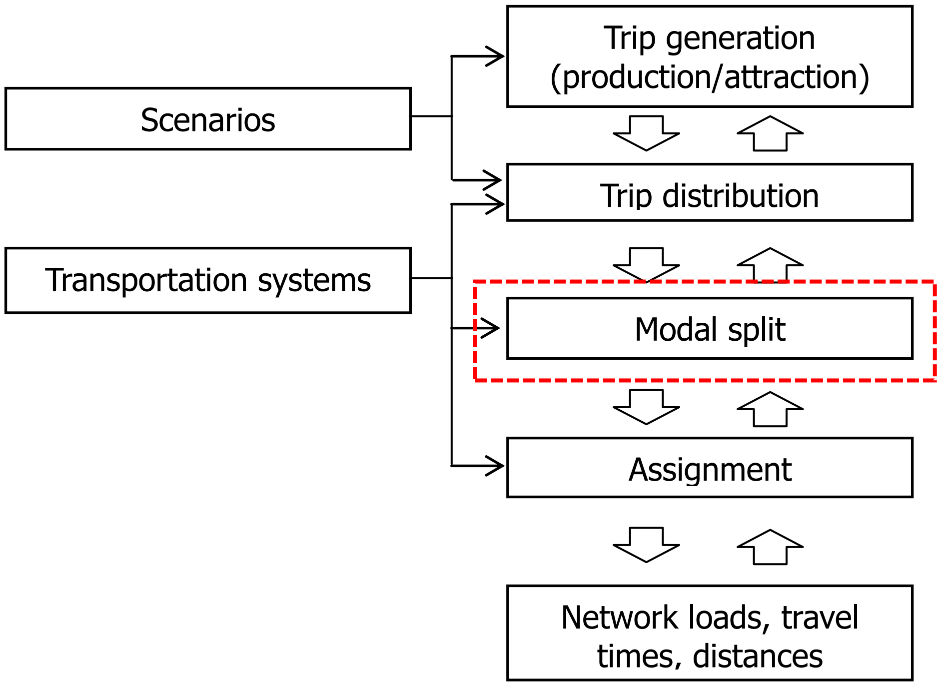
Figure 78, excerpt trips generation table

This data is collected in a table for the regions. The total amount of trips for production or attraction is used per region.

	1	2	3	4	5	6	7	8	9	10	11
1	186	4	8	2	17	1	2	93	5	4	102
2	21	0	3	4	49	0	0	15	0	0	221
3	14	0	3	5	70	0	0	11	0	0	142
4	7	0	3	6	78	0	0	22	0	0	191
5	5	0	2	4	60	0	0	29	0	0	129
6	4	0	1	2	77	0	0	76	0	0	191
7	5	0	0	1	40	0	0	87	0	0	119
8	55	0	1	1	9	1	4	132	4	1	234
9	15	0	1	0	13	0	0	66	0	0	107
10	21	0	2	3	35	0	0	69	0	0	206
11	15	0	2	7	55	0	0	143	0	0	253
	349	5	26	35	502	2	6	744	9	5	1892

Figure 79, trip generation

Mode choice:



The mode choice is calculated with the constants of Figure 80, constants mode choice a logit function. The choice of transportation modes is calculated relatively from the personal transportation system.

	preferenc	Costs/km	travel time sm/fast	travel time pt/fast
Slow mod	1,25	-0,05	-1,1	0,08
Faster mo	0	0	0	0
PT	0	-0,002	0,5	-1,2

Figure 80, constants mode choice

When the basic transportation system in combination with the transportation system 1 (personal) is chosen, the formula becomes:

$$P_{basic\ transportation} = \frac{e^{1,25\,-\,0,05 * L\,+\,0,08 * \frac{Tcollective}{Tpersonal}\,-\,1,1 * \frac{T_{basic}}{Tpersonal}}}{1 + e^{1,25\,-\,0,05 * L\,+\,0,08 * \frac{Tcollective}{Tpersonal}\,-\,1,1 * \frac{T_{basic}}{Tpersonal}}}$$

When the personal transportation is used:

$$P_{personal} = 1 - P_{basic\ transportation}$$

When the basic transportation system in combination with the transportation system 2 (collective) is chosen, the formula becomes:

$$P_{basic\ transportation} = \frac{e^{1,25\,-\,0,05 * L\,+\,0,08 * \frac{Tcollective}{Tpersonal}\,-\,1,1 * \frac{T_{basic}}{Tpersonal}}}{e^{1,25\,-\,0,05 * L\,+\,0,08 * \frac{Tcollective}{Tpersonal}\,-\,1,1 * \frac{T_{basic}}{Tpersonal}} + e^{0\,-\,0,002 * L - 1,2 * \frac{Tcollective}{Tpersonal} + 0,5 * \frac{T_{basic}}{Tpersonal}}}$$

When the transportation system 2 (collective) is used:

$$\frac{e^{0-0,002*L-1,2*\frac{Tcollective}{Tpersonal}+0,5*\frac{T_{basic}}{Tpersonal}}}{e^{1,25-0,05*L+0,08*\frac{Tcollective}{Tpersonal}-1,1*\frac{T_{basic}}{Tpersonal}}+e^{0-0,002*L-1,2*\frac{Tcollective}{Tpersonal}+0,5*\frac{T_{basic}}{Tpersonal}}}$$

When the basic transportation system in combination with the transportation system 3 (water) is chosen, the travel times of water transportation will be used for the mode choice model. The formula becomes:

$$\frac{e^{1,25-0,05*L+0,08*\frac{Tcollective}{Tpersonal}-1,1*\frac{T_{basic}}{Tpersonal}}}{1+e^{1,25-0,05*L+0,08*\frac{Tcollective}{Tpersonal}-1,1*\frac{T_{basic}}{Tpersonal}}+e^{0-0,002*L-1,2*\frac{Tcollective}{Tpersonal}+0,5*\frac{T_{basic}}{Tpersonal}}}$$

The formula for the transportation system 3 (water) in combination with the personal is:

$$P_{personal\ transportation}=1-P_{basic\ transportation}-P_{collective\ transportation}$$

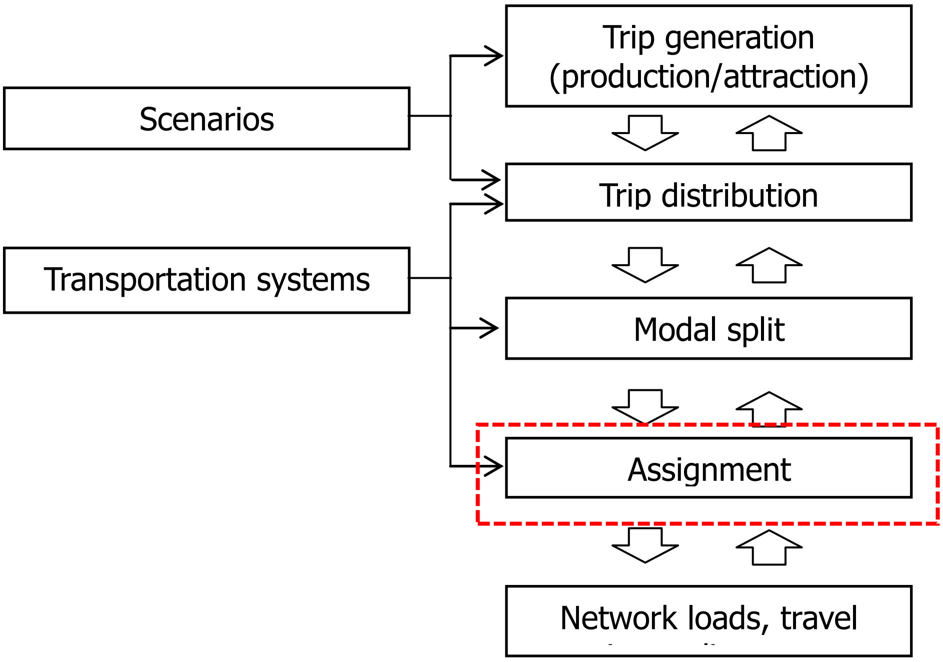
And the combination of the transportation system 3 (water) in combination with the collective mode is:

$$\frac{e^{0-0,002*L-1,2*\frac{Tcollective}{Tpersonal}+0,5*\frac{T_{basic}}{Tpersonal}}}{1+e^{1,25-0,05*L+0,08*\frac{Tcollective}{Tpersonal}-1,1*\frac{T_{basic}}{Tpersonal}}+e^{0-0,002*L-1,2*\frac{Tcollective}{Tpersonal}+0,5*\frac{T_{basic}}{Tpersonal}}}$$

The mode choice of all the routes in the Seasteading city is collected in a table. An excerpt of such table is shown in Figure 81.

1.1	1.2	1.3	1.4	2.1	2.2	2.3	3.1	3.2	3.3	3.4	4.1	4.2	4.3	5.1	5.2	5.3	5.4	6.1	6.2	6.3	7.1	7.2	7.3	7.4	8.1
0,0978	0,2192586	0,2182	0,207	0,1946	0,202	0,2011	0,1929	0,192	0,22	0,2083	0,0728	0,056	0,0589	0,0745	0,0745	0,0698	0,0659	0,0306	0,0194	0,0194	0,0745	0,0745	0,0698	0,0659	0,0
0,1815	0,0977621	0,2182	0,207	0,1946	0,202	0,2011	0,1929	0,192	0,22	0,2083	0,0728	0,056	0,0589	0,0745	0,0745	0,0698	0,0659	0,0306	0,0194	0,0194	0,0745	0,0745	0,0698	0,0659	0,0
0,1425	0,1425407	0,1312	0,1764	0,1585	0,1571	0,154	0,1595	0,1529	0,1805	0,1676	0,059	0,0391	0,0423	0,0613	0,0613	0,0539	0,0501	0,0268	0,014	0,014	0,0138	0,0138	0,0083	0,0077	0,
0,1553	0,1552551	0,1764	0,1235	0,1893	0,1571	0,154	0,1595	0,1595	0,1805	0,1676	0,059	0,0391	0,0423	0,0613	0,0613	0,0539	0,0501	0,0268	0,014	0,014	0,0138	0,0138	0,0083	0,0077	0,
0,2093	0,2093042	0,2451	0,231	0,1018	0,2459	0,2258	0,2098	0,2107	0,2431	0,2306	0,0989	0,0842	0,0871	0,1001	0,1001	0,0994	0,0944	0,0484	0,0351	0,0371	0,0328	0,0328	0,0273	0,0259	0,0
0,1567	0,156655	0,1785	0,1645	0,1577	0,1145	0,1738	0,1519	0,1519	0,1738	0,1617	0,1628	0,1571	0,16	0,1615	0,1616	0,183	0,1702	0,0478	0,029	0,029	0,0532	0,0532	0,0454	0,0423	0,0
0,1543	0,1543416	0,1762	0,1617	0,1577	0,1526	0,1145	0,1889	0,1567	0,1785	0,1645	0,1648	0,16	0,1626	0,1635	0,1635	0,1846	0,1723	0,0503	0,0319	0,0347	0,0533	0,0533	0,0454	0,0423	0,0
0,1929	0,1929238	0,22	0,2083	0,1971	0,2001	0,202	0,0978	0,2193	0,2182	0,207	0,1946	0,202	0,2011	0,1929	0,192	0,22	0,2083	0,0728	0,056	0,0589	0,0745	0,0745	0,0698	0,0659	0,0
0,192	0,1920043	0,2193	0,2083	0,1971	0,2001	0,202	0,1815	0,0978	0,2182	0,207	0,1946	0,202	0,2011	0,1929	0,192	0,22	0,2083	0,0728	0,056	0,0589	0,0745	0,0745	0,0698	0,0659	0,0
0,04	0,0399677	0,0301	0,0276	0,0534	0,0229	0,0294	0,1425	0,1293	0,1312	0,1764	0,1585	0,1571	0,154	0,1595	0,1529	0,1805	0,1676	0,059	0,0391	0,0423	0,0613	0,0613	0,0539	0,0501	0,0
0,04	0,0399677	0,0301	0,0276	0,059	0,0261	0,0294	0,1553	0,146	0,1764	0,1235	0,1893	0,1571	0,154	0,1595	0,1595	0,1805	0,1676	0,059	0,0391	0,0423	0,0613	0,0613	0,0539	0,0501	0,0
0,0783	0,078333	0,0739	0,0696	0,0989	0,0842	0,0871	0,2093	0,2072	0,2451	0,231	0,1018	0,2459	0,2258	0,2107	0,2107	0,2431	0,2306	0,0989	0,0842	0,0871	0,1001	0,1001	0,0994	0,0944	0,0
0,043	0,0429929	0,0335	0,0308	0,0491	0,0277	0,031	0,1567	0,1475	0,1785	0,1645	0,1577	0,1145	0,1738	0,1519	0,1519	0,1738	0,1617	0,1628	0,1571	0,16	0,1615	0,1616	0,183	0,1702	0,0
0,0456	0,0456093	0,0365	0,0337	0,0521	0,0309	0,0342	0,1543	0,1445	0,1762	0,1617	0,1577	0,1526	0,1145	0,1889	0,1567	0,1785	0,1645	0,1648	0,16	0,1626	0,1635	0,1635	0,1846	0,1723	0,0
0,0745	0,0745084	0,0698	0,0659	0,0936	0,0676	0,0707	0,1929	0,1893	0,22	0,2083	0,1971	0,2001	0,202	0,0978	0,2193	0,2182	0,207	0,1946	0,202	0,2011	0,1929	0,192	0,22	0,2083	0,0
0,0745	0,0745084	0,0698	0,0659	0,0936	0,0676	0,0707	0,192	0,1882	0,2193	0,2083	0,1971	0,2001	0,202	0,1815	0,0978	0,2182	0,207	0,1946	0,202	0,2011	0,1929	0,192	0,22	0,2083	0,0
0,0138	0,0138458	0,0083	0,0077	0,0248	0,0075	0,0088	0,04	0,0303	0,0301	0,0276	0,0534	0,0229	0,0294	0,1425	0,1425	0,1312	0,1764	0,1585	0,1571	0,154	0,1595	0,1529	0,1805	0,1676	0,
0,0138	0,0138418	0,0083	0,0077	0,0248	0,0075	0,0088	0,04	0,0303	0,0301	0,0276	0,059	0,0261	0,0294	0,1553	0,1553	0,1764	0,1235	0,1893	0,1571	0,154	0,1595	0,1595	0,1805	0,1676	0,
0,0328	0,0328336	0,0273	0,0259	0,0484	0,0351	0,0371	0,0783	0,0692	0,0739	0,0696	0,0989	0,0842	0,0871	0,2093	0,2093	0,2451	0,231	0,1018	0,2459	0,2258	0,2107	0,2107	0,2431	0,2306	0,0
0,0532	0,0532418	0,0454	0,0423	0,0135	0,0053	0,0063	0,043	0,0334	0,0335	0,0308	0,0491	0,0277	0,031	0,1567	0,1567	0,1785	0,1645	0,1577	0,1145	0,1738	0,1519	0,1519	0,1738	0,1617	0,
0,0533	0,0532562	0,0454	0,0423	0,0122	0,0045	0,0045	0,0456	0,036	0,0365	0,0337	0,0521	0,0309	0,0342	0,1543	0,1543	0,1762	0,1617	0,1577	0,1526	0,1145	0,1889	0,1567	0,1785	0,1645	0,
0,0745	0,0745084	0,0698	0,0659	0,0306	0,0194	0,0194	0,0745	0,0658	0,0698	0,0659	0,0936	0,0676	0,0707	0,1893	0,1929	0,22	0,2083	0,1971	0,2001	0,2195	0,0978	0,2193	0,2182	0,207	0,
0,0716	0,0715842	0,0663	0,0625	0,0286	0,0175	0,0175	0,0716	0,0626	0,0663	0,0625	0,0909	0,0637	0,0668	0,1908	0,1908	0,219	0,2075	0,1961	0,1988	0,2192	0,1794	0,0978	0,2167	0,2041	0,
0,0503	0,0503254	0,042	0,0391	0,0268	0,014	0,014	0,0138	0,0095	0,0083	0,0077	0,0248	0,0075	0,0088	0,04	0,04	0,0301	0,0276	0,0534	0,0229	0,0336	0,1425	0,1425	0,1312	0,1764	0,
0,0503	0,0503254	0,042	0,0391	0,0268	0,014	0,014	0,0138	0,0095	0,0083	0,0077	0,0248	0,0075	0,0088	0,04	0,04	0,0301	0,0247	0,059	0,0261	0,0336	0,1553	0,1553	0,1764	0,1235	0,
0,0734	0,0734304	0,0679	0,0638	0,0446	0,031	0,033	0,0295	0,0236	0,0238	0,0225	0,0446	0,031	0,033	0,0734	0,0734	0,0679	0,0638	0,0943	0,0783	0,0885	0,2082	0,2082	0,2467	0,2314	0,
0,1627	0,1627731	0,184	0,1715	0,0478	0,029	0,029	0,0532	0,044	0,0454	0,0423	0,0135	0,0053	0,0063	0,043	0,043	0,0335	0,0308	0,0491	0,0277	0,0353	0,1567	0,1567	0,1785	0,1645	0,
0,1646	0,1645771	0,1856	0,1736	0,0503	0,0319	0,0347	0,0533	0,044	0,0454	0,0423	0,0122	0,0045	0,0045	0,0456	0,0456	0,0365	0,0337	0,0521	0,0309	0,0388	0,1543	0,1543	0,1762	0,1617	0,
0,1918	0,1907799	0,2197	0,2075	0,0697	0,0524	0,0553	0,0716	0,0626	0,0663	0,0625	0,0286	0,0175	0,0175	0,0716	0,0716	0,0663	0,0625	0,0909	0,0637	0,0732	0,1918	0,1893	0,2191	0,2058	0
0,1929	0,1920043	0,22	0,2083	0,0728	0,056	0,0589	0,0745	0,0658	0,0698	0,0659	0,0306	0,0194	0,0194	0,0658	0,0745	0,0698	0,0659	0,0936	0,0676	0,077	0,1882	0,192	0,2193	0,2083	0,
0,1595	0,152906	0,1805	0,1676	0,059	0,0391	0,0423	0,0503	0,041	0,042	0,0391	0,0268	0,014	0,014	0,0138	0,0138	0,0083	0,0077	0,0248	0,0075	0,0099	0,04	0,04	0,0301	0,0276	0,0
0,1595	0,1595253	0,1805	0,1676	0,059	0,0391	0,0423	0,0503	0,041	0,042	0,0391	0,0268	0,014	0,014	0,0138	0,0138	0,0083	0,0067	0,0248	0,0075	0,0099	0,04	0,04	0,0301	0,0247	0,
0,2093	0,2093042	0,2451	0,231	0,0989	0,0842	0,0871	0,0783	0,0692	0,0739	0,0696	0,0484	0,0351	0,0371	0,0328	0,0328	0,0273	0,0259	0,0484	0,0351	0,04	0,0783	0,0783	0,0739	0,0696	0,0
0,1567	0,156655	0,1785	0,1645	0,1628	0,0038	0,16	0,1627	0,1553	0,184	0,1715	0,1689	0,0072	0,166	0,1694	0,1694	0,1896	0,1787	0,1705	0,0084	0,1867	0,1627	0,1628	0,184	0,1715	0,

Figure 81, excerpt mode choice table



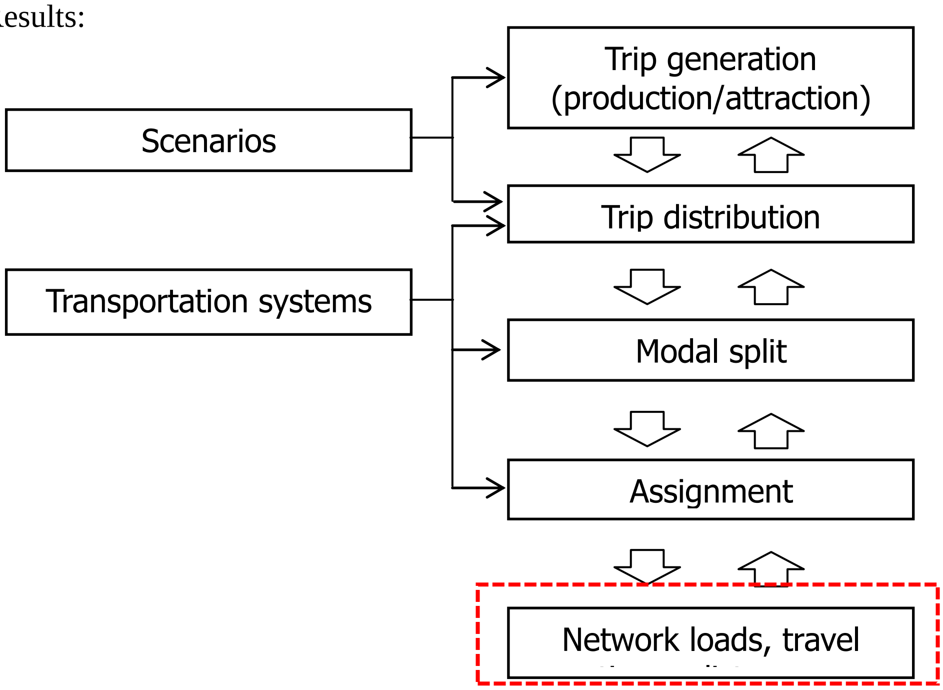
Assignment:

The results of the mode choice will be multiplied by the volumes from and to zones, the flows. These flows are multiplied by the tables that resulted from the all or nothing assignment. The data is later collected and represented in a table with all the trips for the different links in the network.

	1.1	1.2	1.3	1.4	2.1	2.2	2.3	3.1	3.2	3.3	3.4	4.1	4.2	4.3	5.1	5.2	5.3	5.4	6.
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
22,169	0	0	0	0	0	0	0	0	0	0	0	2,0332	0,6178	0,631	0,7985	0,8217	1,0462	1,3858	
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
22,169	0	0	0	0	0	0	0	0	0	0	0	2,0332	0,6178	0,631	0,7985	0,8217	1,0462	1,3858	
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	

Figure 82, excerpt table with trips per link

Results:



In Figure 82, an except can be seen of the table that includes the sum of all trips between the regions.

1.1	1a	10a	59	1.1	1a	10a	27	1.1	1a	10a	0	1.1	1a	10a	86		86
	10a	1a	59		10a	1a	27		10a	1a	0		10a	1a		86	86
1.2	1a	2g	69	1.2	1a	2g	40	1.2	1a	2g	0	1.2	1a	2g	109		109
	2g	1a	69		2g	1a	40		2g	1a	0		2g	1a		109	109
1.3a	1a	1b	24	1.3a	1a	1b	42	1.3a	1a	1b	0	1.3a	1a	1b	66		66
	1b	1a	24		1b	1a	42		1b	1a	0		1b	1a		66	66
1.3b	1b	2f	24	1.3b	1b	2f	42	1.3b	1b	2f	0	1.3b	1b	2f	66		66
	2f	1b	24		2f	1b	42		2f	1b	0		2f	1b		66	66
1.3c	1b	10b	24	1.3c	1b	10b	42	1.3c	1b	10b	0	1.3c	1b	10b	66		66
	10b	1b	24		10b	1b	42		10b	1b	0		10b	1b		66	66
1.4	2e	10c	6	1.4	2e	10c	10	1.4	2e	10c	127	1.4	2e	10c	144		144
	10c	2e	6		10c	2e	10		10c	2e	125		10c	2e		142	142
2.1	2a	2g	80	2.1	2a	2g	75	2.1	2a	2g	0	2.1	2a	2g	156		156
	2g	2a	80		2g	2a	75		2g	2a	0		2g	2a		155	155
2.2a	2a	2b	22	2.2a	2a	2b	29	2.2a	2a	2b	0	2.2a	2a	2b	52		52
	2b	2a	22		2b	2a	29		2b	2a	0		2b	2a		52	52
2.2b	2b	2c	22	2.2b	2b	2c	29	2.2b	2b	2c	0	2.2b	2b	2c	52		52
	2c	2b	22		2c	2b	29		2c	2b	0		2c	2b		52	52
2.2c	2c	2d	22	2.2c	2c	2d	29	2.2c	2c	2d	114	2.2c	2c	2d	165		165
	2d	2c	22		2d	2c	29		2d	2c	126		2d	2c		178	178
2.3a	2d	2e	22	2.3a	2d	2e	31	2.3a	2d	2e	136	2.3a	2d	2e	189		189
	2e	2d	22		2e	2d	31		2e	2d	127		2e	2d		180	180
2.3b	2e	2f	22	2.3b	2e	2f	31	2.3b	2e	2f	0	2.3b	2e	2f	53		53
	2f	2e	22		2f	2e	31		2f	2e	0		2f	2e		53	53
2.3c	2f	2g	22	2.3c	2f	2g	31	2.3c	2f	2g	0	2.3c	2f	2g	53		53
	2g	2f	22		2g	2f	31		2g	2f	0		2g	2f		53	53
3.1	2a	3a	42	3.1	2a	3a	29	3.1	2a	3a	0	3.1	2a	3a	71		71

Figure 83, results of the 4-step model

The total distance is calculated by multiplying the volumes of the routes by the distances of the distance of the different links in the routes.

	module 1.1	module 1.2	module 1.3	module 1.4	module 2.1	module 2.2	module 2.3	module 3.1	module 3.2	module 3.3	module 3.4	module 4.1	module 4.2	module 4.3	module 5.1	module 5	module 5.3	module 5.4	module 6.1	module 6.2	module 6.3	module 7.1	module 7.	module 7	module 7	module 8	module 8	module 8	module 9	modul
module 1.1	0	353	353	353	353	353	353	353	353	353	353	353	353	353	353	353	353	353	353	353	353	353	353	353	353	353	353	353	353	3
module 1.2	353	0	353	353	353	353	353	353	353	353	353	353	353	353	353	353	353	353	353	353	353	353	353	353	353	353	353	353	353	3
module 1.3	184	184	0	184	184	184	184	184	184	184	184	184	184	184	184	184	184	184	184	184	184	184	184	184	184	184	184	184	184	1
module 1.4	184	184	184	0	184	184	184	184	184	184	184	184	184	184	184	184	184	184	184	184	184	184	184	184	184	184	184	184	184	1
module 2.1	473	473	473	473	0	473	473	473	473	473	473	473	473	473	473	473	473	473	473	473	473	473	473	473	473	473	473	473	473	4
module 2.2	193	193	193	193	193	0	193	193	193	193	193	193	193	193	193	193	193	193	193	193	193	193	193	193	193	193	193	193	193	1
module 2.3	193	193	193	193	193	193	0	193	193	193	193	193	193	193	193	193	193	193	193	193	193	193	193	193	193	193	193	193	193	1
module 3.1	353	353	353	353	353	353	353	0	353	353	353	353	353	353	353	353	353	353	353	353	353	353	353	353	353	353	353	353	353	3
module 3.2	353	353	353	353	353	353	353	353	0	353	353	353	353	353	353	353	353	353	353	353	353	353	353	353	353	353	353	353	353	3
module 3.3	184	184	184	184	184	184	184	184	184	0	184	184	184	184	184	184	184	184	184	184	184	184	184	184	184	184	184	184	184	1
module 3.4	184	184	184	184	184	184	184	184	184	184	0	184	184	184	184	184	184	184	184	184	184	184	184	184	184	184	184	184	184	1
module 4.1	473	473	473	473	473	473	473	473	473	473	473	0	473	473	473	473	473	473	473	473	473	473	473	473	473	473	473	473	473	4
module 4.2	193	193	193	193	193	193	193	193	193	193	193	193	0	193	193	193	193	193	193	193	193	193	193	193	193	193	193	193	193	1
module 4.3	193	193	193	193	193	193	193	193	193	193	193	193	193	0	193	193	193	193	193	193	193	193	193	193	193	193	193	193	193	1
module 5.1	353	353	353	353	353	353	353	353	353	353	353	353	353	353	0	353	353	353	353	353	353	353	353	353	353	353	353	353	353	3
module 5.2	353	353	353	353	353	353	353	353	353	353	353	353	353	353	353	0	353	353	353	353	353	353	353	353	353	353	353	353	353	3
module 5.3	184	184	184	184	184	184	184	184	184	184	184	184	184	184	184	184	0	184	184	184	184	184	184	184	184	184	184	184	184	1
module 5.4	184	184	184	184	184	184	184	184	184	184	184	184	184	184	184	184	184	0	184	184	184	184	184	184	184	184	184	184	184	1
module 6.1	473	473	473	473	473	473	473	473	473	473	473	473	473	473	473	473	473	473	0	473	473	473	473	473	473	473	473	473	473	4
module 6.2	193	193	193	193	193	193	193	193	193	193	193	193	193	193	193	193	193	193	193	0	193	193	193	193	193	193	193	193	193	1
module 6.3	193	193	193	193	193	193	193	193	193	193	193	193	193	193	193	193	193	193	193	193	0	193	193	193	193	193	193	193	193	1
module 7.1	353	353	353	353	353	353	353	353	353	353	353	353	353	353	353	353	353	353	353	353	353	0	353	353	353	353	353	353	353	3
module 7.2	353	353	353	353	353	353	353	353	353	353	353	353	353	353	353	353	353	353	353	353	353	353	0	353	353	353	353	353	353	3
module 7.3	184	184	184	184	184	184	184	184	184	184	184	184	184	184	184	184	184	184	184	184	184	184	184	0	184	184	184	184	184	1
module 7.4	184	184	184	184	184	184	184	184	184	184	184	184	184	184	184	184	184	184	184	184	184	184	184	184	0	184	184	184	184	1
module 8.1	473	473	473	473	473	473	473	473	473	473	473	473	473	473	473	473	473	473	473	473	473	473	473	473	473	0	473	473	473	4
module 8.2	193	193	193	193	193	193	193	193	193	193	193	193	193	193	193	193	193	193	193	193	193	193	193	193	193	193	0	193	193	1
module 8.3	193	193	193	193	193	193	193	193	193	193	193	193	193	193	193	193	193	193	193	193	193	193	193	193	193	193	193	0	193	1
module 9.1	353	353	353	353	353	353	353	353	353	353	353	353	353	353	353	353	353	353	353	353	353	353	353	353	353	353	353	353	0	3
module 9.2	353	353	353	353	353	353	353	353	353	353	353	353	353	353	353	353	353	353	353	353	353	353	353	353	353	353	353	353	353	
module 9.3	184	184	184	184	184	184	184	184	184	184	184	184	184	184	184	184	184	184	184	184	184	184	184	184	184	184	184	184	184	1
module 9.4	184	184	184	184	184	184	184	184	184	184	184	184	184	184	184	184	184	184	184	184	184	184	184	184	184	184	184	184	184	1
module 10.1	473	473	473	473	473	473	473	473	473	473	473	473	473	473	473	473	473	473	473	473	473	473	473	473	473	473	473	473	473	4
module 10.2	193	193	193	193	193	193	193	193	193	193	193	193	193	193	193	193	193	193	193	193	193	193	193	193	193	193	193	193	193	1
module 10.3	193	193	193	193	193	193	193	193	193	193	193	193	193	193	193	193	193	193	193	193	193	193	193	193	193	193	193	193	193	1
module 5.1	278	278	278	278	278	278	278	278	278	278	278	278	278	278	278	278	278	278	278	278	278	278	278	278	278	278	278	278	278	2
module 5.2	278	278	278	278	278	278	278	278	278	278	278	278	278	278	278	278	278	278	278	278	278	278	278	278	278	278	278	278	278	2
module 5.3	278	278	278	278	278	278	278	278	278	278	278	278	278	278	278	278	278	278	278	278	278	278	278	278	278	278	278	278	278	2
module 5.4	278	278	278	278	278	278	278	278	278	278	278	278	278	278	278	278	278	278	278	278	278	278	278	278	278	278	278	278	278	2
module 5.5	278	278	278	278	278	278	278	278	278	278	278	278	278	278	278	278	278	278	278	278	278	278	278	278	278	278	278	278	278	2
module 5.6	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	6

Figure 84, Distances

The travel times are calculated by multiplying the flows over the different routes by the travel times. The average distance and travel time is calculated by dividing the total by the total amount of trips.

total:	3253	Average:	4,293731	total:	13968	232,7952									
	13968	1.2	1.3	1.4	2.1	2.2	2.3	3.1	3.2	3.3	3.4	4.1	4.2	4.3	5
1.1	6	16	11	2	24	8	8	8	1	7	7	21	6	6	
1.2	19	19	17	3	23	8	8	8	1	6	7	31	6	6	
1.3	8	15	6	1	14	5	5	5	0	4	4	13	3	3	
1.4	1	1	1	0	5	2	2	2	0	2	1	2	1	1	
2.1	10	12	13	5	27	17	19	17	0	15	14	27	17	17	
2.2	3	3	3	1	15	3	4	4	0	4	3	5	3	3	
2.3	3	3	3	1	15	4	3	3	0	4	4	5	3	3	
3.1	5	6	6	2	26	8	8	4	0	7	6	8	6	5	
3.2	5	6	6	2	27	9	9	7	0	7	6	8	6	6	
3.3	3	3	3	1	18	3	4	5	0	3	4	5	4	3	
3.4	1	2	1	0	10	2	2	2	0	2	2	2	2	2	
4.1	26	39	29	7	91	27	28	19	1	17	16	13	12	14	
4.2	3	3	3	1	15	3	3	4	0	4	4	5	2	3	
4.3	3	3	3	1	17	3	4	5	0	4	4	5	3	2	
5.1	7	8	9	3	43	11	11	8	0	7	7	9	6	6	
5.2	6	8	9	3	41	10	11	8	0	7	6	8	6	6	
5.3	2	2	1	0	14	2	2	4	0	4	3	6	2	2	
5.4	0	0	0	0	1	0	0	0	0	0	0	0	0	0	
6.1	10	12	13	4	74	19	20	23	0	23	19	28	18	18	
6.2	4	4	5	2	9	1	2	5	0	4	3	5	2	2	
6.3	11	19	9	1	6	1	1	5	0	4	3	11	2	2	
7.1	7	9	12	3	28	8	8	11	0	13	9	14	9	7	
7.2	4	4	5	2	14	3	3	6	0	6	5	7	4	4	

Figure 85, Travel times

Appendix D, sensitivity analysis of the 4-step model

In this chapter a sensitivity analysis of the constants of the mode choice is performed. The constants are both increased and decreased by 25 % and 50%. The results show the effects of these changes on the total amount of travellers of the basic transportation system.

Basic transportation in combination with personal transportation system 1

The change of volumes for the basic transportation mode in combination with transportation system 1 (personal) is shown in Table 76. As can be seen in the table, the effect for the amount of travellers is high for the constant regarding the preference and the travel time with personal transportation. The reason is probably that these constants are larger than the other constants. Furthermore the difference between transportation system 1 (personal) and transportation system 2 (collective) is lower than transportation system 1 (personal) and the basic transportation system.

Table 76, Mode choice constants, basic transportation, in combination with the personal transportation system

	-50%	-25%	100%	+125%	+150%
Preference constant	72%	86%	100%	114%	127%
Cost/km	100%	100%	100%	100%	100%
Basic/Personal (travel time)	72%	86%	100%	114%	128%
Colective/personal (travel time)	96%	98%	100%	102%	104%

The difference between the amounts of trips for the basic transportation system in combination with transportation system 2 (collective) is less high. The difference is probably due to the fact that the mode choice is already higher for the basic transportation system.

Table 77, Mode choice constants, basic transportation, in combination with the collective transportation system

	-50%	-25%	100%	+125%	+150%
Preference constant	91%	96%	100%	103%	106%
Cost/km	100%	100%	100%	100%	100%
Basic/Personal (travel time)	90%	96%	100%	103%	106%
Colective/personal (travel time)	99%	100%	100%	100%	101%

The change of volumes for the basic transportation mode in combination with transportation system 3 (water) is similar to those of the other transportation systems. The difference is highest for the preference constant and the effect will be lower when the constants are higher.

Table 78, Sensitivity analysis, mode choice constants basic transportation in combination with water transportation

	-50%	-25%	100%	+125%	+150%
Preference constant	76%	88%	100%	111%	120%
Cost/km	100%	100%	100%	100%	100%
Basic/Personal (travel time)	88%	94%	100%	106%	111%

Colective/personal (travel time)	98%	99%	100%	101%	102%

The influence of the travel times on the total amount of trips for basic transportation system is shown in Table 79, Sensitivity analysis travel times The influence of the speed parameter decreases when the speed increases. The biggest change happens, when the speed of the basic transportation system is altered. Especially the speed of the basic transportation system in combination with transportation system 1 (personal) has a considerable effect on the outcome.

Table 79, Sensitivity analysis travel times

	-50%	**-25%**	**100%**	**+125%**	**+150%**
Speed basic transport system (system 1)	63%	87%	100%	108%	113%
Speed transport system 1 (Personal)	103%	101%	100%	99%	99%
Speed basic transport system (system 2)	76%	94%	100%	103%	103%
Speed transport system 2 (Collective)	102%	101%	100%	100%	99%
Speed basic transport system (system 2)	82%	94%	100%	103%	106%
Speed transport system3 (Water, personal)	101%	101%	100%	99%	99%
Speed transport system3 (Water, collective)	102%	101%	100%	99%	99%

Appendix E, sensitivity analysis of the multi-criteria analysis

It is possible that the outcome of an multi-criteria analysis is affected by the magnitude of the weights. A simple sensitivity analysis however shows that this is unlikely in this case. The weights are increased by 50%, 150% and 200%, but the results are still the same.

		Personal	Collective	Water
costs	0,5	-0,36	-0,56	-0,61
	1	-0,72	-1,12	-1,22
	1,5	-1,08	-1,68	-1,84
	2	-1,44	-2,24	-2,45
safety	0,5	-0,19	-0,01	-0,19
	1	-0,37	-0,02	-0,37
	1,5	-0,56	-0,03	-0,56
	2	-0,74	-0,04	-0,74
Travel time	0,5	-0,12	-0,12	-0,12
	1	-0,24	-0,25	-0,25
	1,5	-0,36	-0,37	-0,37
	2	-0,48	-0,49	-0,49
comfort	0,5	-0,10	-0,14	-0,14
	1	-0,20	-0,28	-0,29
	1,5	-0,30	-0,42	-0,43
	2	-0,40	-0,55	-0,57
walkability	0,5	0,24	0,27	0,26
	1	0,47	0,54	0,52
	1,5	0,71	0,81	0,78
	2	0,95	1,08	1,04
nuisance	0,5	-0,55	-0,21	0,00
	1	-1,10	-0,43	0,00
	1,5	-1,65	-0,64	0,00
	2	-2,20	-0,85	-0,01
emissons	0,5	-0,13	0,00	-0,26
	1	-0,25	0,00	-0,51
	1,5	-0,38	0,00	-0,77
	2	-0,50	0,00	-1,03
flexibility	0,5	0,43	0,34	0,34
	1	0,85	0,68	0,68
	1,5	1,28	1,02	1,02
	2	1,70	1,36	1,36
scalability	0,5	0,34	0,43	0,43
	1	0,68	0,85	0,85
	1,5	1,02	1,28	1,28
	2	1,36	1,70	1,70
innovative	0,5	0,04	0,09	0,06

	1	0,09	0,17	0,13
	1,5	0,13	0,26	0,19
	2	0,17	0,34	0,26
min space	0,5	-0,58	-0,14	-0,04
	1	-1,16	-0,28	-0,08
	1,5	-1,75	-0,42	-0,12
	2	-2,33	-0,56	-0,17