PROCESS REPORT

JÁRNGERÐUR

SINDRI SIGHVATSSON | GROUP 12 | MSC04 | INDUSTRIAL DESIGN | AALBORG UNIVERSITY | MAY - 2014

ABSTRACT

This report outlines the process of developing Járngerður, a concept for an elevated personal rapid transit system (small automated train system), envisioned for Reykjavík, Iceland, which employs a pod-car design with a built-in, innovative crane mechanism to lift and lower the pod-cars from the ground.

The system uses reserved car street parking spaces where possible, that act like stops for users to board and disembark the pod-cars.

The concept is an idea to solve the traffic problems in Reykjavík.

This report shows the research, development of the concept, as well as diving into specific chosen details of the pod-car and system. Finally a conclusion to the project is put forth, and lastly reflections on both the process and product.

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JÁRNGERÐUR

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Product Report Pages: 24

Appendix Pages: 12

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INTRODUCTION

In this section the project is introduced as well as the project structure is explained.

I INTRODUCTION & READING GUIDE

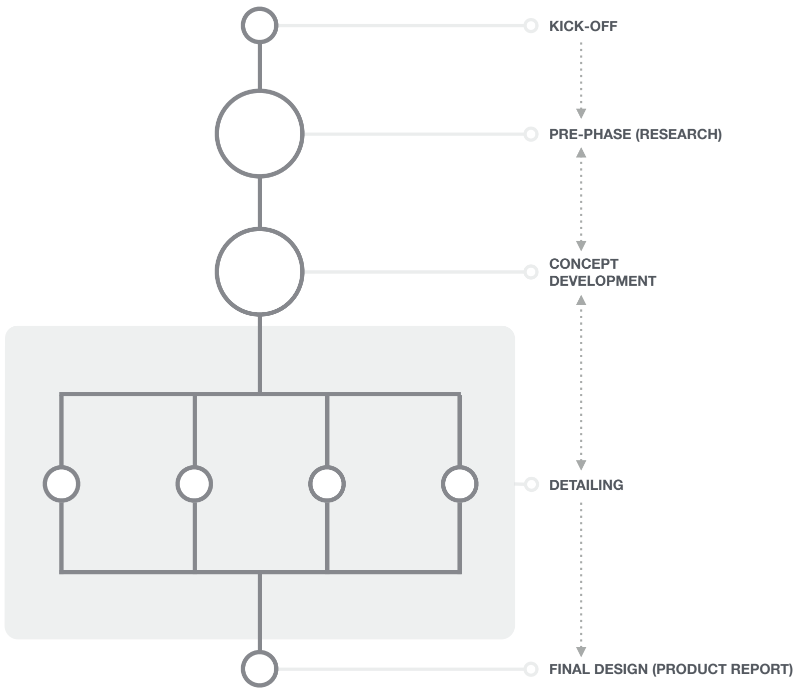
As will be shown in the next chapter, car traffic in Reykjavík, Iceland is a problem that has been building up for the last years. Usage of cars as a means of commuting has been growing steadily over the years and meanwhile the usage of public transportation has declined. This has lead to the fact that today several problems stemming from car usage have become so great that the city of Reykjavík has, for the last years, made decisions to challenge and rectify this progression. This project introduces and proposes a public transport system, so called PRT (Personal Rapid Transit), a type of small rail system, that could be a solution for Reykjavík and be a good fit for the municipality and its inhabitants, for example in regards to traffic problems, land usage, pollution and cultural habits concerning transportation and commuting. Because of this being an individual project and the brevity of it, the main focus of the project became an innovative built-in crane/lift mechanism, which virtually eliminates the need for typical large stations/stops, and allows the system to be installed in even the smallest streets in Reykjavík without large changes to the road itself in the form of stations. Selected aspects of the pod-car and the rail system were then detailed as far as time allowed, in an overview fashion.

It is important to point out that the project is of a conceptual nature. This means that it is an idea to solve the traffic problems in Reykjavík, and therefore not all the details are worked out completely and are left to the imagination. It is also necessary to point out that the proposal is not realistic, in the sense that the city of Reykjavík has no means or aspiration to set up a system like this in the foreseeable future, and therefore cost is not a a part of this project. But I hope that the proposal will in some ways raise an awareness or a discussion of unconventional ways of transportation in Reykjavík.

READING GUIDE

This process report has been set up in a linear fashion to ease the understanding of the process, even though the process was all but linear. In the next section this is explained in more detail. The process report is therefore meant to be read linearly and the accompanying product report as a supplement and a visual guide of the final proposal.

PROJECT STRUCTURE



The structure of the process was not linear in nature but can be illustrated graphically in a linear arrangement.

The first part of the project is the pre-phase which is used to frame the project. In it PRT is introduced, as well as Reykjavík and the traffic problems it has. Other relevant information to the project is also introduced in this chapter, and it concludes with a desing brief.

The pre-phase chapter then leads to the concept chapter, where the main concept development is shown and documented.

After the main concept, the detailing phase is started. In the detailing chapter, selected relevant aspects of the pod-car and the system are discussed and documented. Because of time constraints, not all aspects of the pod-car and the system could be detailed, but it was decided to focus on the most relevant aspects, and go broadly into each detail.

In the end a final design proposal was converged upon, which results are shown in the product report.

PRE-PHASE

In this section the project is put in context, PRT is introduced and explained and car traffic in Reykjavík is discussed as well as what the city's views and plans are regarding traffic and public transportation. Finally, current PRT solutions are introduced, and at the end a design brief is put forth.

PRE-PHASE

PERSONAL RAPID TRANSIT (PRT)

Personal Rapid Transit is a type of public transport that refers to a system of “small three- to six-passenger automated vehicles for the private use of the traveler and his traveling companions, but not shared with strangers; the traveler is carried nonstop and without transfers from his origin station to his destination station” (Irving, 1978).

PRT is also referred to as personal GCV (Grid-Connected Vehicle) and is categorized as a type of Automated Guide-way Transit (AGT) which is a general term covering both large and small automated vehicles, from personal people transports to large automated subway systems. A general term used for PRT is “pod-car”.

It is sometimes described as being an automatic taxi with a dedicated right of way or guide-way, or simply as a horizontal citywide elevator.

MAIN CHARACTERISTICS

The main characteristics of a PRT system are:

» Driver-less / automatic vehicles

» 1-6 passengers per vehicle

» Generally electrically driven (on-board battery or grid-powered)

» Guide-way grid network topology

» Stations located on sidings

» No stop-and-go traffic, as stopped pod-cars stay of the main guide-way and on sidings.

» Non-stop, point to point travel, no predetermined schedule and no predetermined route.

» Usually slow speed, 25-40km/h

(Anderson, 1978)

POSITIVE ASPECTS

PRT systems are lauded for several aspects that make them a desirable public transport system. Some of these aspects are the following.

Usage efficiency

Because of its personal, point to point nature, as well as not following a predefined schedule/

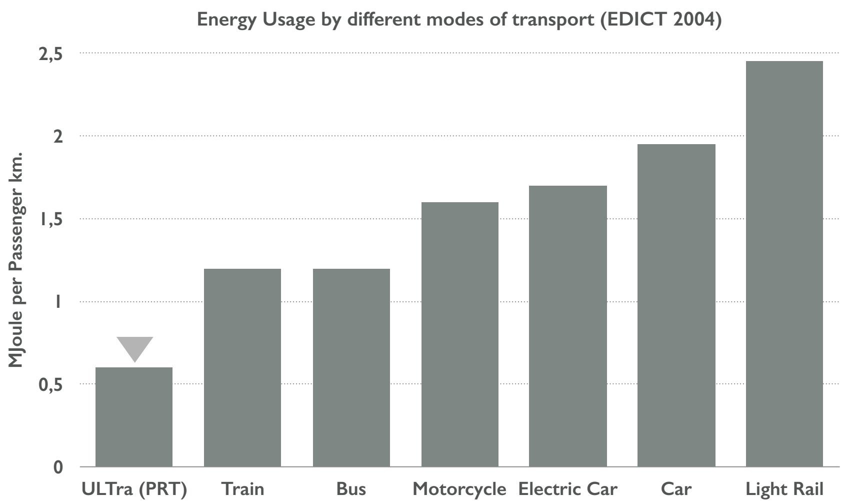
Fig. 1. Morgantown PRT.

Fig. 2. ULTra PRT.

route, less time is wasted by the passengers waiting for the next transport. “Routes” in a PRT systems are direct by their nature and the pod-cars don’t stop for passengers on the way to their destination.

Energy usage

Energy efficiency is generally much better than other means of commuting and public transport in general. On the graph here to the side, a comparison of energy usage of different modes of transport is shown.



Privacy

Because the pod-cars are private as opposed to moving groups of strangers, they are in a way similar to private cars. This in turn can lead to greater usage of PRT as opposed to conventional mass transit as many people value privacy highly.

Comfort

The comfort of riding in a PRT system is generally better than in conventional public transport as the pod-cars don’t stop on the way to their destination and so on, as well as gridlocks and stop-and-go traffic is avoided, and non-existent on the PRT guide-way.

Relatively low cost

Low weight of the vehicles and smaller guide-ways and structures than are needed for a conventional rail means lower cost of the infrastructure. Generally it is also cheaper than normal road infrastructure and leads to reduction of road infrastructure and the need for parking spaces. PRT can also lessen the need for households and individuals to own a car which leads to personal/household savings.

Environmentally friendly

Because it uses less energy compared to cars, and electrical motors are more efficient then combustion engines, emission is much less compared to cars, even factoring in that the energy often comes from polluting sources (fossil-fuel power stations). PRT also generally leads to better air quality.

Less noise pollution

PRT leads to less noise pollution in urban areas as the system itself is virtually silent, and if used proportionally more, relative to cars, should lead to less noise pollution from traffic in general.

Improved safety

Using its own guide-way as opposed to being a part of the road-infrastructure leads to improved safety. Good example of this is the Morgantown PRT system where accidents involving the system are virtually non-existent.

	PRT	Personal car	Subway	Bus	Tramway	Monorail
Private/Personal	Yes	Yes	No	No	No	No
Point-to-point	Yes	Yes	No	No	No	No
Relatively small size of vehicles	Yes	Yes	No	No	No	No
On-demand	Yes	Yes	No	No	No	No
Average speed	Medium	High	High	Low	Low	High
Visual intrusion of infrastructure	Medium	High	-	High	High	Medium
Energy usage	Low	High	Low	Medium	Low	Low
Own guideway, elevated or undergr.	Yes	No	Yes	No	Mixed	Yes
Pollution	Low	High	Low	Medium	Low	Low
Cost of new infrastructure	Medium	-	High	-	Medium	Medium
Safety	Good	Medium	Good	Medium	Good	Good
Discrete stations/ stops	Yes	No	Yes	Yes	Yes	Yes
Automated	Yes	No	Some	No	No	Some

Less visually obtrusive infrastructure

Generally, PRT uses lighter and smaller infrastructure than other ways or transport as the pod-cars are compact and light, which leads to less visually obtrusive infrastructure. Another thing is that because roads have become so ubiquitous, people tend to stop seeing how visually obtrusive roads really are. PRT lessens the need for bigger roads, so indirectly it decreases obtrusive road infrastructure as well.

CRITICISM

The main criticism that PRT has received is that because it is a relatively new and unproven technology, risk and financial uncertainty is increased. Another thing is that even though a similar system has been in usage for 30 years, it is still a matter of debate if commuters would embrace such a system in large enough proportion, to make buildup of such system feasible for citywide adoption. Regulatory concerns and various political reasons also play a part in the debate (EDICT, 2004).

INFRASTRUCTURE REQUIREMENTS

Even though the infrastructure needed is light and visually unobtrusive and quite flexible in regards to setup (one lane / 2 lane), for the system to work as needed, pod-car stations/stops need to be quite close to each other (so the point-to-point nature of the system works as intended). This leads to uncertainty regarding the size of the infrastructure and its obtrusiveness as each station generally needs a relatively large area, not only for loading and offloading passengers, but for sidings as well (a part of a siding rail that facilitates deceleration and acceleration of the pod-cars, arriving at, or leaving the station).

MEANS OF TRAVEL - COMPARISON

To put a light on the differences and similarities between PRT and other ways of transport, a comparison matrix was made that can be seen on this page.

As can be observed, the similarities between PRT and the personal car are that both are private/personal, point-to-point vehicles that are relatively small and the usage is on-demand.

When we get lower on the list, the comparison gets a bit more complex, but in general the results, although subjectively-based, are that PRT compares well with other ways of transport.

FEASIBILITY

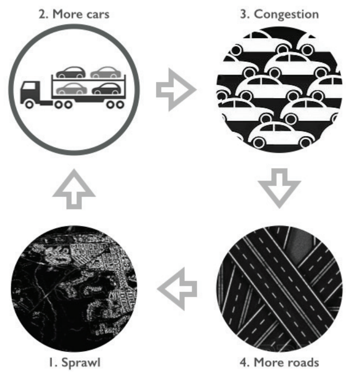
It is worth noting that in 2002-2004 a feasibility study was conducted, sponsored by the European Union, for the potential of PRT in four different cities in Europe. The results where overwhelmingly positive and amongst other, noted that PRT had the prospect to be an accessible, environmentally friendly and sustainable option in the future, and could provide a superior service compared to conventional mass transit, and in all probability would be well received by the public. The report also concluded that despite these advantages, public authorities will not commit to building PRT because of the risks associated with being one of the first public implementations (EDICT, 2004).

It is important to add that the Morgantown PRT system which is the only system that has been in use for the last 30 years, is not a true PRT system as the cars are larger and not private. This kind of system is often called GRT (Group Rapid Transit).

PRE-PHASE

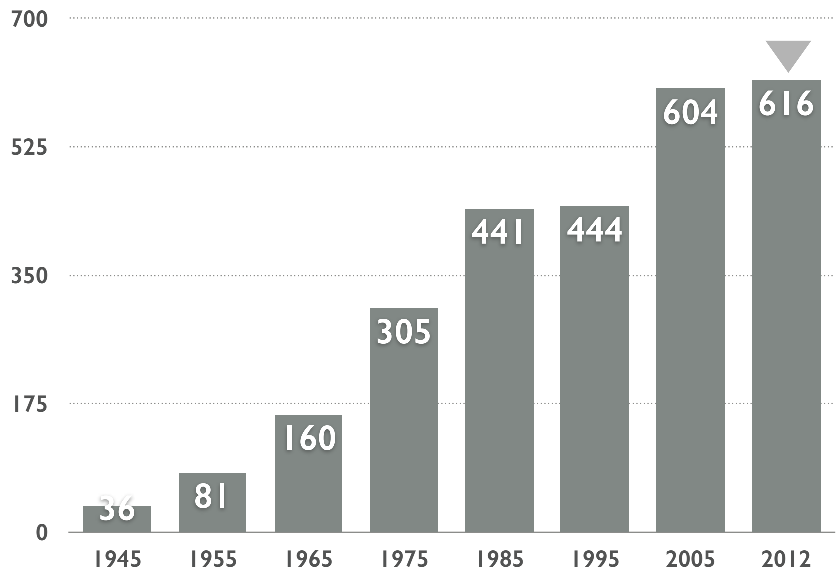
REYKJAVÍK

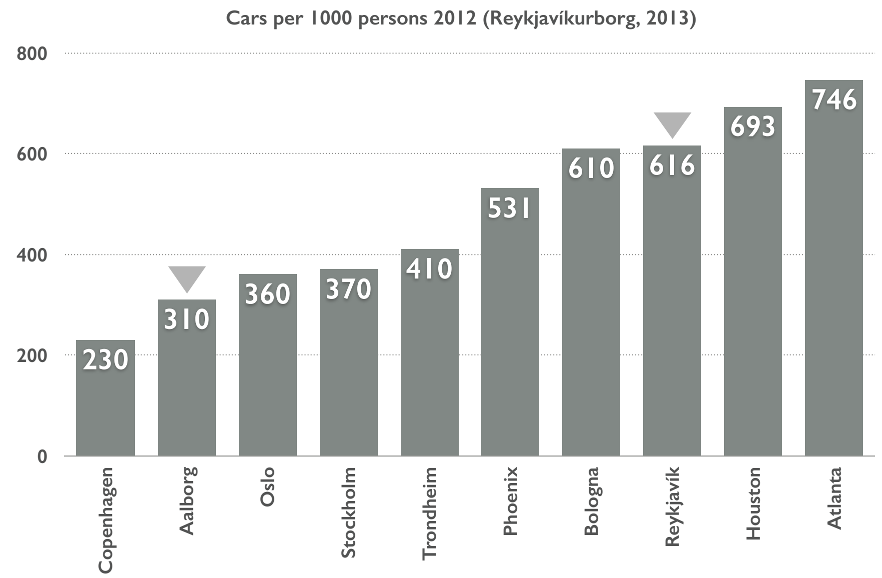
Reykjavík could be a great pilot area for PRT. For this are several reasons.



First of all, Reykjavík is a car city, that in many ways has more in common with the car cities in the United States than cities in Europe in the same size category. Car ownership has grown steadily over the years (See graphs on this and next page), and the city is stuck in a vicious traffic and infrastructure cycle, where increasing city sprawl leads to more traffic which leads to more roads being built which then again leads to more sprawl. It is not far off from Atlanta, USA in the number of cars per capita which has (in 2012) 746 cars per 1000 persons (Reykjavíkurborg, 2013). Atlanta has one of the worst traffic problems in the United States and is considered

Cars in Reykjavík per 1000 persons (Reykjavíkurborg, 2013)





one of the more polluted cities in that country (Huffingtonpost.com, 2010).

Because of the high car ownership in Reykjavík, public transportation usage has been dwindling over the years and is today one fourth of what it was around 1960 if measured in trips per person (Reykjavíkurborg, 2013).

CITY PLANS

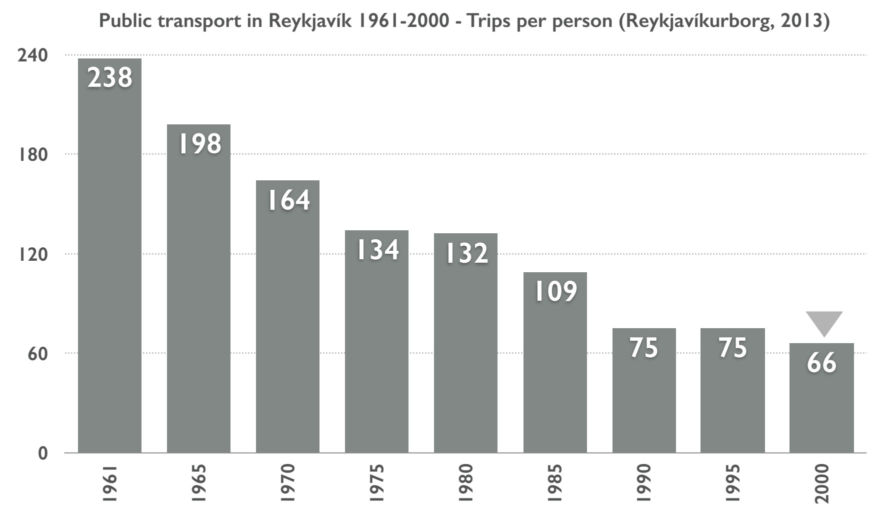
The city has made extensive plans for changes regarding transportation within the city.

Reduction of car usage

The city of Reykjavík considers car usage a problem and has made it a part of its city planning policy for the next decades to reduce the use of cars as a means of transport. A primary focus is to promote other means of transport (public transportation amongst others) and decrease the usage ratio so motorcars will consist of 58% of all usage in 2030 as opposed to 75% as it is now. The policy also dictates that all public transportation within the city will use alternative Eco-friendly fuels by the year 2030 (Reykjavíkurborg, 2013).

Reduce road infrastructure build-up

The city also aims to promote efficient and safe transportation without engaging in extensive build-up of road infrastructure as well as to reduce negative effects of increased traffic when additions to the infrastructure are evaluated (Reykjavíkurborg, 2013).



Public transportation reforms

One of the main ways to change the travel habits of the population from its affinity for the motor car is reforming the public transportation system and, in the future, plan the infrastructure for a possible light rail system (Reykjavíkurborg, 2013). This gives the idea of a PRT system some credibility as PRT is a type of a light rail system.

Reykjavík's Municipal Plan in a nutshell

- Double the usage of public transport in the next years (plan to 2030).
- Postpone buildup of large road infrastructure.
- Lower the cost of road traffic and traffic accidents.
- Promote reduced release of CO_2 in accordance with Iceland's action plan against pollution.
- Encourage bicycling.
- To examine the validity of light rail system for the Reykjavík area.

Increase city density

The plans to increase the density of the city (opposed to the urban sprawl that has been norm for the last decades) increases the potential for alternative ways to commute (public transport, cycling and walking), which furthermore decreases the need for large road infrastructure and parking spaces, which now constitute 48% of the expanse or area, of the city, which is in line with large cities in the United States (Reykjavíkurborg, 2013).

Increase usage of eco-friendly energy

The plan is also to increase the ratio of more Eco-friendly energy solutions (electricity, methane and hydrogen) to conventional energy (fossil fuels). Especially concerning public transportation (Reykjavíkurborg, 2013).

ENERGY WASTE

In Reykjavík, like other western cities, a lot of energy is wasted because of car usage. People commute to work in cars that weight up to 2000 kilograms, and the average number of persons in each car is 1,2 in Iceland, like in most of the western world. This would not be so bad if the cars were electric, but as it stands, almost all cars in Reykjavík use fossil fuels. This point is also connected to the fact that the average speed of traffic in Reykjavík is 36km/h for private cars and 22km/h for buses (Hönnun ehf., 2006). What this means is that cars spend a lot of their time in stop-and-go traffic which is extremely wasteful in relation to energy usage.

CULTURE

One of the reasons Reykjavík is a car city is that people value their privacy. Public transportation is scorned and seen mostly as transportation for young people, the elderly and underprivileged. Therefore, people invariably think that if they use the buses in Reykjavík, people will assume that they are fortune-less or in other words, poor. This is of course a highly subjective point to be made, but as a person that has been living in Reykjavík for half my life, I can attest that this is a general view.

PRT IN REYKJAVÍK

All these points support the idea of a PRT system in Reykjavík, or at least a discussion of different and unconventional solutions for transportation within the city.

Fig. 3. Reykjavík.

PRE-PHASE

PRT STATIONS / STOPS

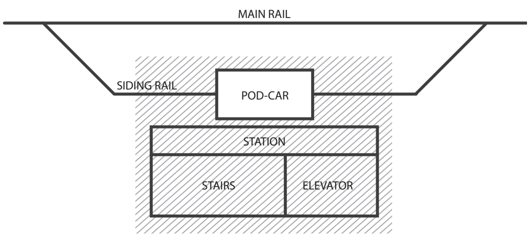
As it relates to the concept, it is important to describe PRT stations. PRT systems, just like other train systems utilize stations to load and offload passengers.

Stations usually need to support a certain number of cars, which has an effect on the size. Generally they take quite a large surface area as the stations need to be out of the way of the main rail/ traffic to not obstruct other trains or pod-cars.

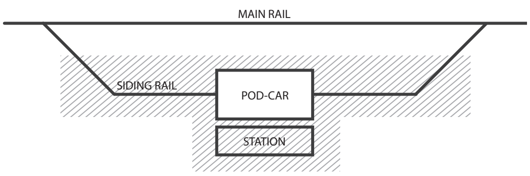
This relates to both suspended rail systems, as well as ground based. Besides needing space for traffic going by, the suspended systems need some way of getting passengers either up to the same level of the train system, or to get the train down to the ground level. Both mean that a lot of space is needed at the stations; If you bring passengers up to the same level as the train, you need stairs, and in most cases (because of concerns for the disabled) an elevator. For a system where the train comes down to the ground level, surface area is wasted because of the area which is needed for the ascending and descending sidings/side rails.

In both cases, a lot of surface area is used for stations, and when space and area is of short supply, as it is in some of the small tight streets in Reykjavík, this can be a problem when it comes to setting up a PRT system. This is further substantiated by the fact that one of the factor controlling the selection of bus-routes by Strætó BS (the Reykjavík public transport) is sizes of streets; if they are large enough to support buses driving through, and if they can stop there.

This leaves an opportunity for a solution to this problem. This will be described later in the report.



ELEVATED PRT: ELEVATED STATION



ELEVATED PRT: GROUND STATION

PRE-PHASE

G

GRID LOOP NETWORK TOPOLOGY

Most PRT systems employ the track guideway as a grid loop network topology. This type of infrastructure is a grid of rails, where each point in the grid is a either a merge point, diverge point, or both, to facilitate point-to-point travel (prtconsulting.com, n.d.).

Because of the added complexity of a bi-directional rail, in relation to a point-to-point rail system, generally this kind of network is single directional.

For a grid loop network to work as intended, it has to be of certain density. If the density of the grid reaches a certain threshold, using the system should have close to the same travel time as a bi-directional track.

Two types of this kind of grid layouts exist. The first one (Type A) uses a series of loops with no overpasses, which means that no direct route can be taken over grid points. The second type (Type B) incorporates overpasses. In short terms this means that the second choice leads to more direct routes between points (prtconsulting.com, n.d.).

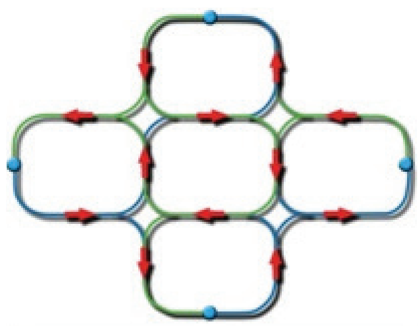


Fig. 4. Type A Guide-way.

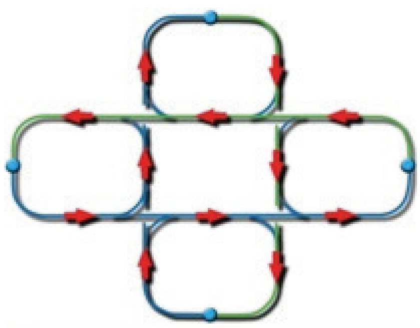


Fig. 5. Type B Guide-way.

PRE-PHASE

THE USER: FOCUS GROUP

The potential users of a PRT system in the city can be categorized into two groups. The ones that already use the public transportation system in Reykjavík, and those that use cars to get around.

The first group is not of great interest in relation to this project, as they would continue using whatever public transportation is in place in the city. The second group is more interesting as they are the ones that a PRT system would try to win over.

Even though the author of this report has an idea of what the problems are with the current public transportation in Reykjavík and what would persuade car users to use public transportation, a focus group was held with persons who have used the public transportation in Reykjavík, but don't on a daily basis (all being car owners) to get some input from individuals who didn't know PRT nor what the project was about beforehand.

Three discussion topics were used:

- Why don't you use Strætó more, and why do you think so few people use Strætó?
- What would need to change for you to take the bus more?
- Would you use public transport that is available at the time when you need it, and it was a private bus/car? And it would not stop on the way to your destination?

The results can be seen in Appendix A, but the main points are condensed here below:

Why don't you use Strætó more, and why do you think so few people do?

- Inefficient when it comes to time. Travel takes too long.
- Waiting for the bus can take very much time.
- In many cases, one or two bus changes are needed to get to the destination.
- Lack of privacy.
- Bus stops/shelters generally not good.
- At peak traffic times/rush hour, too many people on the bus.
- Routes often not logical.
- Annoying to be dependent on a time and route schedule.

What would need to change for you to take the bus?

- The bus shelters. Because you have to wait there for sometimes 30 minutes, they should be better.
- That you didn't need to walk such a distance to your stop.
- If you didn't have to wait as long for the bus.
- If it was quick between places.
- If you didn't need to change bus-lines so often.
- If it was easier to take belongings with you on the bus (groceries, bikes, etc.).

In relation to the third question, PRT was explained to the persons and the general view was very positive, which was not surprising as PRT basically ammends many of the problems people have with public transportation.

PRE-PHASE

O

OBSERVATION (REYKJAVÍK PUBLIC TRANSPORT)

An observation trip was done with a Strætó bus to try to find anything particular in the usage of the city buses that had been overlooked. Two trips were done in two different times. On a busy time (8 in the morning on a friday) and idle time (Saturday afternoon). The resulting points are some of the thoughts recorded while using Strætó BS buses.

THOUGHTS

- The route map is quite clear and easy to understand. Website gives a real-time information of the position of each bus.
- Bus is 7 minutes late to arrive, compared to the schedule. My stop does not have a shelter and because of the wind, it is quite uncomfortable.
- Driver starts driving while I am still paying the fare. Which means I have to hold on to a handrail.
- Bus is clean and seems new.
- Passengers are typically young or elderly. Very few other users.
- Acceleration and deceleration of the bus can be annoying. Driver seems to be in a hurry.
- Lady with a baby carriage needs to stand and hold on to the carriage.
- Engine sound is quite loud.
- Seats are generally quite comfortable.
- Mumbling weird person in the seat behind me. Uncomfortable and distracting.
- Sometimes difficult for the driver to get into a lane again after stopping at a bus stop. Some cars are reluctant to allow the bus to enter the lane.
- The bus is half full even though it is a busy time of day (between 8-9 in the morning) and traffic is heavy.
- Older lady with shopping bags enters the bus. She stores them on the seat beside her because there is no other place to store them.
- Large group of tourists enters the bus and proceed to ask

the driver about directions. The bus is stop at a bus station while he converses with them.

- Very slow traffic.

- Bus is cold. It is heated but does not seem to keep up with the frequently opening doors.

- Man tries to use an iPad but is having problems because of the movement of the bus.

- Distance between stops seem to be disparate and varied. Sometimes the distance is quite large, sometimes very small.

- Driver misses a stop. Probably distracted. Passenger needs to go off at the next stop.

- Door closes on a passenger with two suitcases when he is exiting the bus. Driver does not notice until passengers have yelled at him to open the door again.

- It is difficult to work on the bus (in my case, writing) as the bumps and speed of the bus make it hard.

- Very few passengers are left in the bus on the last leg of the route. Seems like a waste.

- To announce to the driver that you want to get off you have to press a button. In my case I had to stand up to press the button as there wasn't one close to my seat.

- Doors sometimes stay open a small while after the bus takes off from a bus stop. Because it is cold outside, this is very annoying.

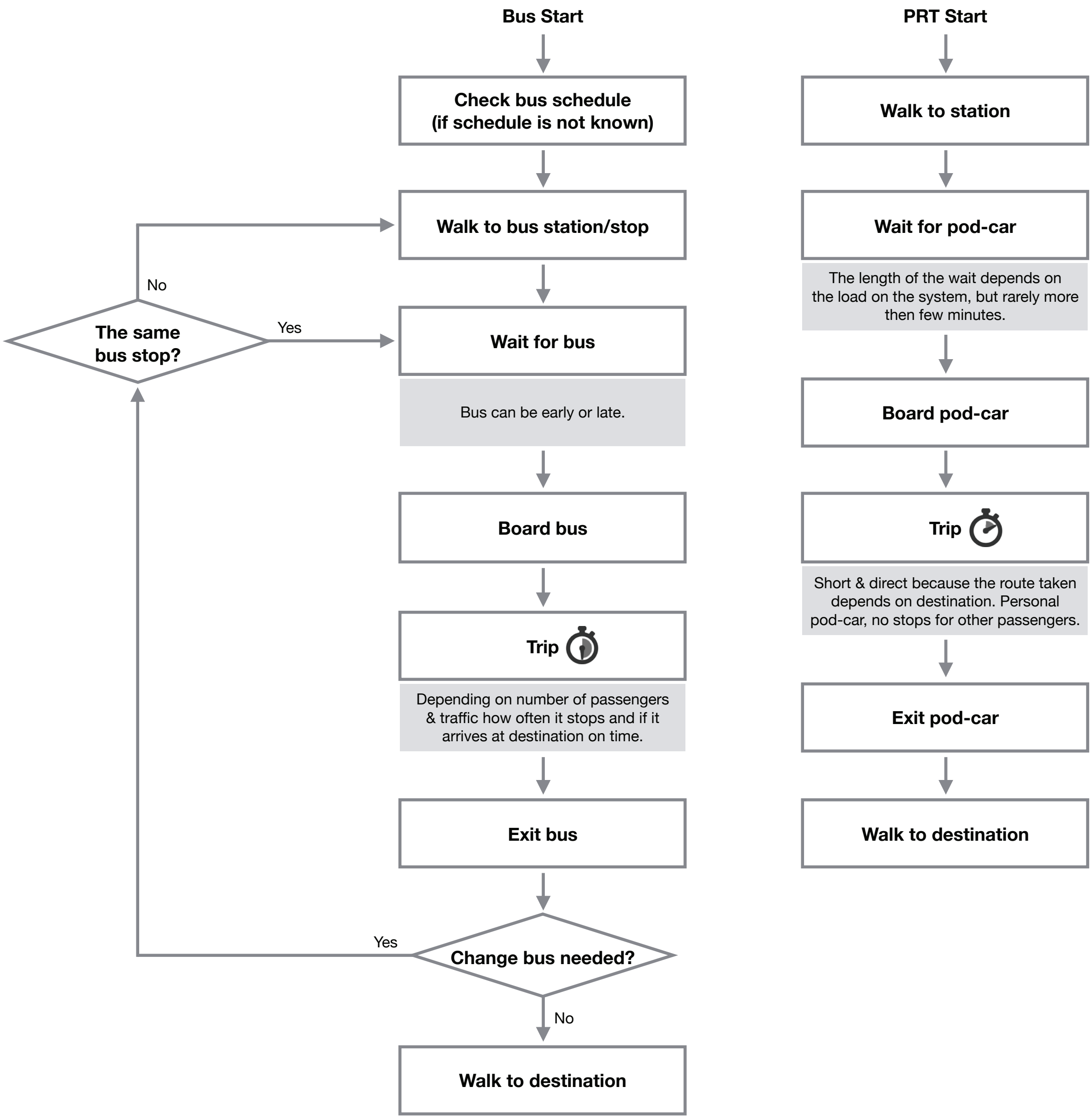
- Bus travels fast on a Saturday. Almost uncomfortably fast.

No specific surprises were found during the observation, but it was necessary to experience the current public transportation for the purpose of this project.

PRE-PHASE

USAGE SCENARIO - COMPARISON

To understand the different usage scenarios of taking a bus and using a PRT system a simple side to side comparison is made between typical bus trip and a typical PRT pod-car trip. For a system with more frequent stops, the walk to a station would be shorter.



PRE-PHASE

CURRENT PRT SYSTEMS

Many different PRT designs exist but three are the most known. These are CyberCab, ULTra and Vectus. A short description of each of these three design is here below.

CyberCab

CyberCab is the PRT design by the 2getthere company, which was planned to be used by a large scale PRT system designed for the city of Masdar, Abu Dhabi. Recent development has put this system on hold. The CyberCab accommodates 6 persons, and has space for a wheelchair and other belongings. It is ground-based (not elevated) and uses an on-board battery instead of taking power from the grid. Maximum speed of the pod-cars is 40km/h. The design uses rubber tires on an open concrete guide-way. The system employs large stations (2getthere.eu, n.d.).

Fig. 6. CyberCab.

Fig. 7. CyberCab station.

ULTra

ULTra is a design by ULTra Global PRT. The design is probably the most known of all PRT system as it is used at London's Heathrow Airport. The pod-cars feature seating for four people and travel at 40km/h. Like CyberCab, it is battery powered, employing rubber tires on an open guide-way. Guide-way is a ground-based and elevated mixture. Stations are notably large, like the

CyberCab system. The Heathrow system uses 21 pod-cars and three stations, but further expansion of the system is planned (ultraglobalprt.com, n.d.).

Vectus

Vectus is a design by POSCO. The pod-cars can carry four persons, as well as a wheelchair, and utilize light elevated steel guide-ways. Currently the system is not in use anywhere, but a 40 pod-car system with 2 stations is being prepared in South Korea. The speed of the pod-cars is 45km/h (vectusprt.com, n.d.).

FEW BUT LARGE STATIONS

All the designs employ large stations/stops, and relatively few stations, compared to the length of the guide-ways. As the CyberCab Masdar system was put on hold, only a test track remains, which employs 2 stations on a 1,5 km. long guide-way. The ULTra system in Heatrow has 3 stations on a 3,8 km. long guide-way, and Vectus uses 2 stations on 5,3 km. long guide-way. As stated, the stations for each of the systems are relatively large with the exception of the Vectus design, which is quite smaller than the other two, but still takes up on a considerable area.

SUSPENDED SYSTEMS

No suspended systems (having the rail or guide-way above the pod-cars) have been developed to fully operational status, but many concepts and some prototypes exist. All suspended concepts, with overhead-rail employ either elevated stations or siding rails that lead the pod-car to the ground when approaching stations.

Fig. 8. ULTra.

Fig. 9. ULTra station.

Fig. 10. Vectus.

Fig. 11. Vectus station.

PRE-PHASE

DESIGN BRIEF

D

After researching PRT and the problems with traffic in Reykjavík, investigating the public transportation system in Reykjavík, as well as looking at the current offerings of PRT on the market, a short design brief was assembled.

It was decided to put the focus on the problem with stations and the space they take, considering that the small city streets in Reykjavík could not easily support normal stations, or at least the stations could not be put up everywhere where needed, but would need to be placed in streets which are large enough to support them (See photo on the next page of a typical small street in Reykjavík). This would make the system much less useful, as users would need to walk greater distances to make use of the system.

PROBLEM STATEMENT

City streets in the downtown area of Reykjavík tend to be small and would have difficulty supporting large stations for a PRT system. Thus a solution that can reduce or eliminate the need for normal sized stations is desirable.

MISSION

To provide a conceptual PRT system for the city of Reykjavík, that can do without large stations/stops as to be able to make the system work in even the smallest streets in Reykjavík.

VISION

To provide a conceptual idea of a public transportation, for the city of Reykjavík, Iceland, which is able to persuade commuters, and other inhabitants of Reykjavík to use public transportation, rather than their cars.

VARIOUS CRITERIA

- Minimal changes to current road infrastructure. No new lanes or changes to the roads themselves.
- Use renewable energy (electricity).
- Have a simple and understandable user interface.
- Support the transportation of three or four individuals or two individuals and belongings, to be a viable alternative to the private car.
- Support the transportation of baby-carriages, bicycles and

wheelchairs (accessibility), to be useful to the majority of commuters and inhabitants.

- Conform aesthetically to the environment.

All other considerations are not a focus.

THE CONCEPT

This section explains the concept, and the development of the defining part of the proposal.

THE CONCEPT

SELECTING THE CONCEPT

In the first part of the project work, I ended up with a concept that was a bit too conventional as the premises of this project was supposed to have a conceptual factor. It was decided to widen the scope and find some conceptual basis that would differentiate the project from the conventional PRT systems in some way and add value to the idea. This is reflected in the design brief in the last chapter.

The first decision that was made was to have the infrastructure elevated to address the criteria of minimal changes to the roads themselves. Generally there are three possibilities for rail infrastructure; Elevated, Ground-based or underground. Because of the requirement of being able to set up the system in streets where space is at premium, as well as to use less space opposed to adding or change the lanes of the roads already in place, an elevated concept was chosen. It should also be noted that underground is not an option, even though it would lead to the least disturbance to the environment, as the tunneling for a PRT system would be prohibitively expensive and would be difficult to set up for a PRT system as the tunnels needed would have to be extensive because of the grid-nature of a PRT infra-

Elevated

- No drastic changes needed for current infrastructure.Can be added to current infrastructure relatively easily.
- Cost usually low, but depends on many factors, including size of infrastructure needed.
- Visual disturbance depends on size and design of infrastructure.
- Elevated is further categorized into top-of-rail and suspended-rail.

On-ground

- Changes to current infrastructure usually needed.
- Integration with current traffic needed.

Underground

- Expensive drilling or tunneling needed before setting up any kind of rail or road.
- Least visual disturbance to the environment.

structure.

The decision of using an elevated infrastructure led to the obvious problem of getting the users of the system into the pod-cars, without using conventional large stations with stairs and elevators.

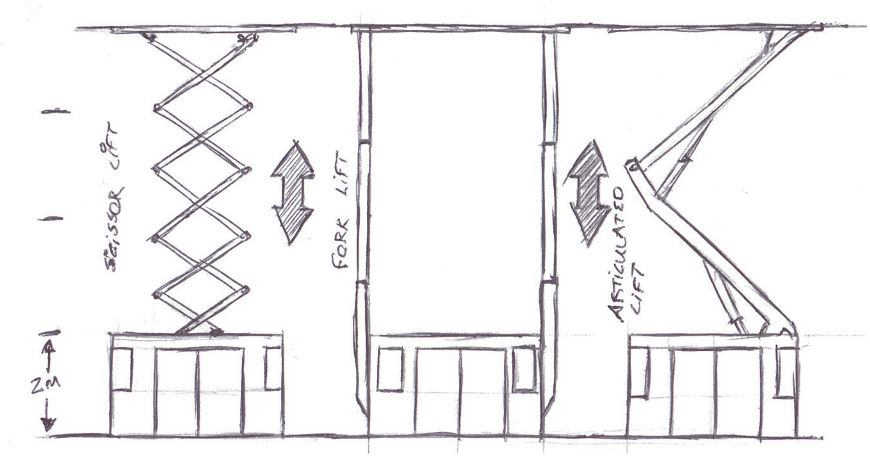
This led to the idea of using a crane/lift mechanism as a part of the pod-car, to elevate it to the track and lower it to ground level, and use car parking spaces as stops or a “landing strip”. And from this came the idea of using parallel dual train tracks, one which would be used for normal pod-car traffic (“go” track), and one “stop” track which would act like a siding track, where the pod-cars can move to when decelerating, stopping and descending, as well as ascending and accelerating, and when up to traffic speed, move over to the “go” track.

This choice of using a crane mechanism led to having the pod-cars suspended underneath a rail, rather than on top of an elevated rail.

After researching lift mechanisms briefly, three different crane mechanisms were looked at as options:

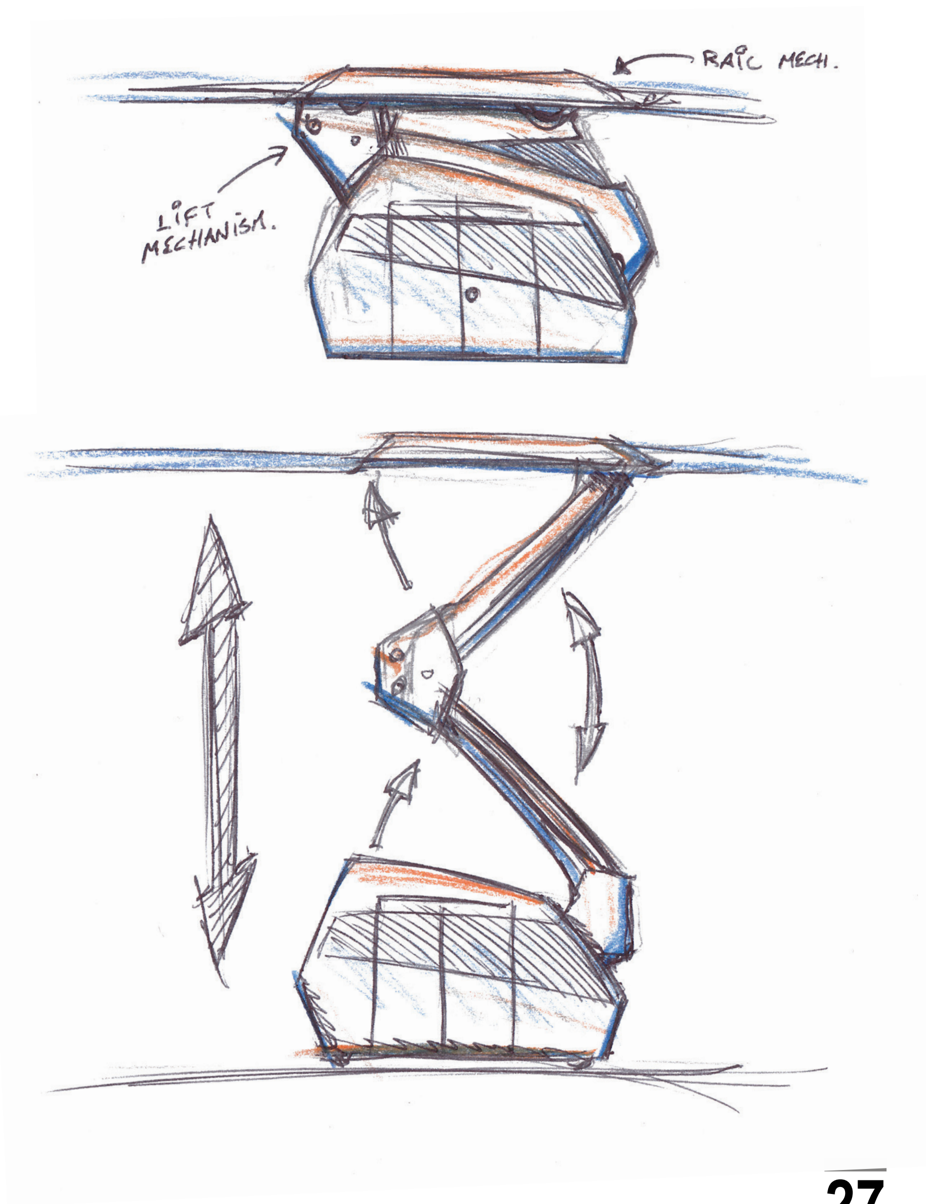
- Scissor lift mechanism
- Fork lift mechanism
- Articulated lift mechanism

To choose between the options, an engineer was consulted (Einarsson, 2014). His general opinion was that either a fork lift or articulated lift mechanisms could be used. Scissor lift would probably need the most moving parts, and not have as much structural integrity as the other two.



From the two options left, the articulated lift mechanism was chosen on the basis that it would be aesthetically more interesting, and more challenging as a project.

The development of the crane mechanism, which became the defining aspect of the project, is documented in the next section.



THE CONCEPT

DEVELOPING THE CRANE MECHANISM

After it was decided to use a crane mechanism to elevate and lower the pod-car, the mechanism that could fit the need of being able to flaten out as much as possible was researched. By looking at different kinds of crane mechanisms, a so called “cherry picker” (also known as boom lift) crane mechanism was chosen.

To understand the mechanism a visit to a crane rental service was undertaken. There I was allowed to play with a cherry picker crane, and could take photos, as well as sketch, to figure out the structure. It took some time to understand it, because even if it looked quite simple, the behaviour of the mechanism was quite difficult to decipher, amongst other, because of the fact that it moves slowly when operating.

What was found out is that a cherry picker crane has a few elements in order to function. These elements can be seen on the sketches on page 30. It has two kinds of beams, bigger and thicker load bearing beams, that handle great majority of the load, smaller balance beams, that balance the crane so it always moves in a way, keeping the crane knees level (making them not turn or roll, but be fixed in relation to the horizon), as well as keeping what it is supporting level, which in our case is a pod-car. The crane knees act as a connector to the next section up. It also needs small connectors in the knees, that make the sections move in tandem with each other (called tandem beams on the sketches). Lastly, the cranes have hydraulic pistons that push the knees apart. On the observed cranes, the tubes moving the hydraulic fluid to the pistons were sometimes hidden inside the load bearing beams , although often the smaller cranes had the tubes on the exterior of the beams.

All distances or lengths of the beams need to be exact, as well as the positions of where everything connects together, as

Images from visit to crane rental

to make all sections/knees stay level.

At the crane rental, there were a few types of these “cherry pick-er” cranes, but all of them used a variation of this same mecha-nism.

STRENGTH

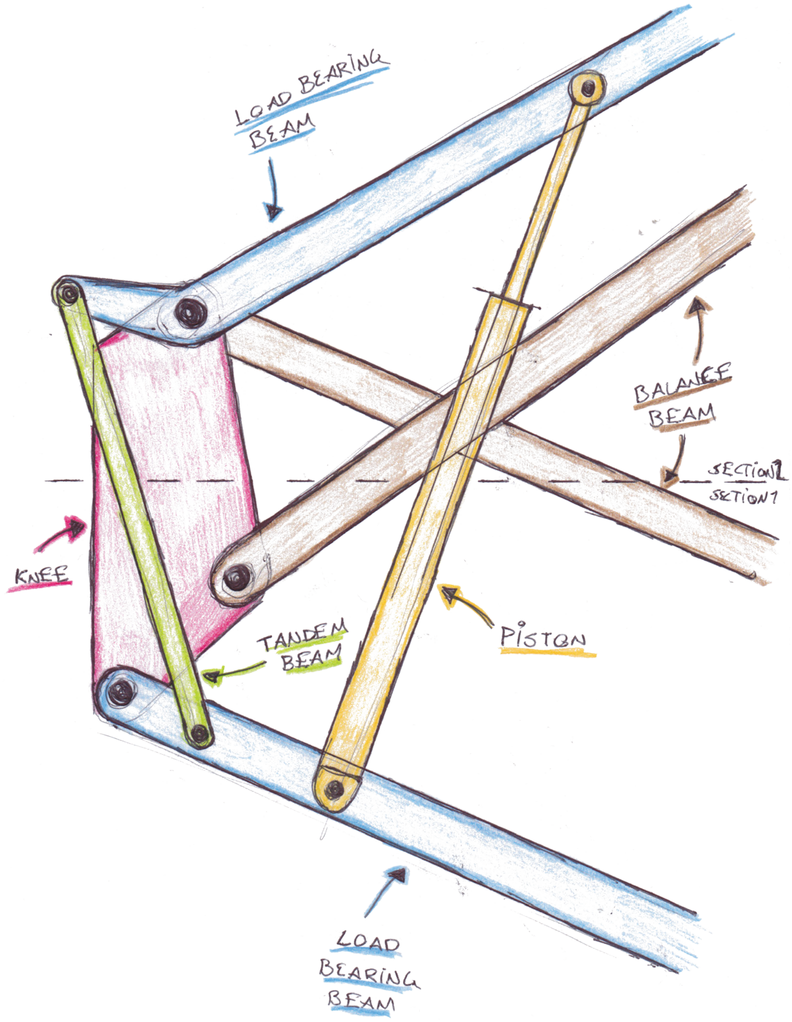
The majority of the cranes ob-served had a S.W.L. (Safe work-ing load) weight of between 200 to 500kg. The largest ones that didn’t have a long topmost sec-tion, and were used for lifting objects, as well as persons, had

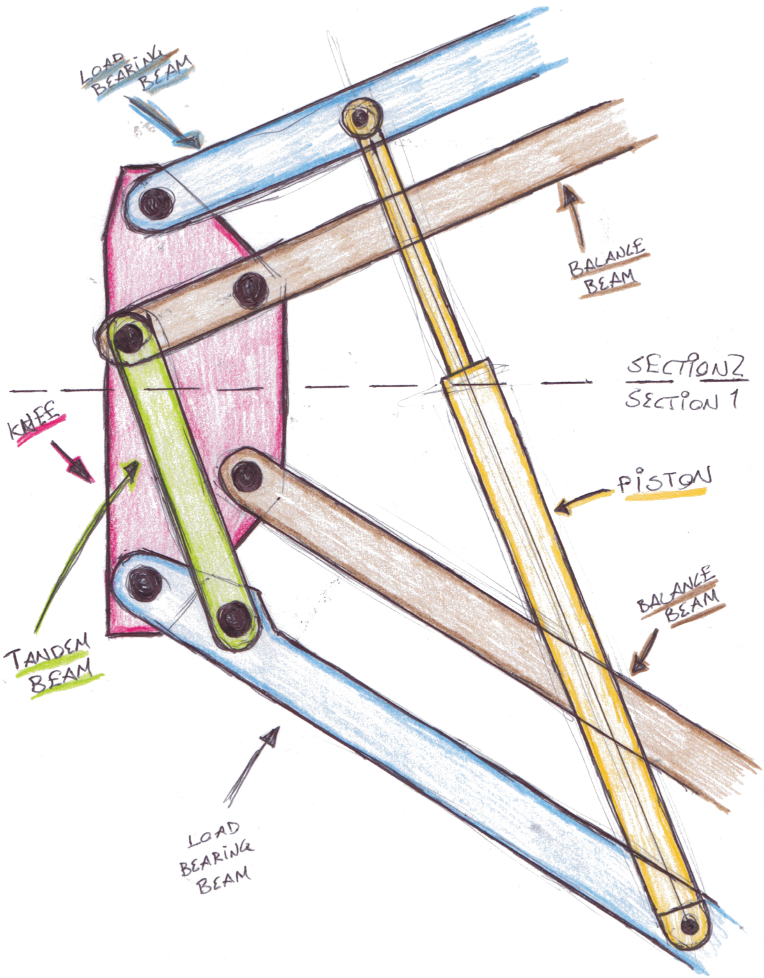
Hydraulic pump

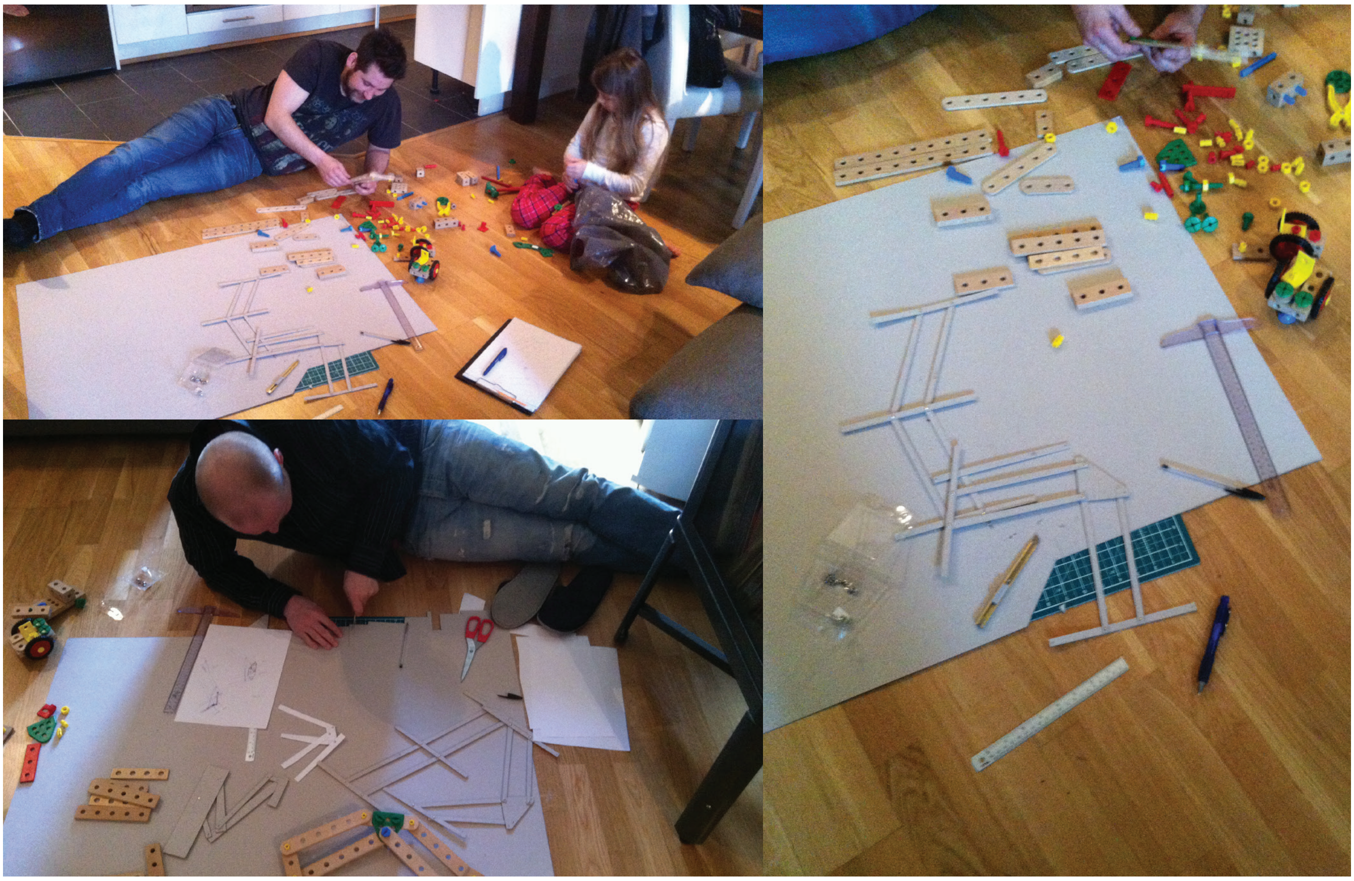
a S.W.L. of up to 1200kg. One surprising revelation was that the hydraulic pump needed for even the large cranes was relatively small. All the observed cranes were diesel powered but we were assured by the professional working at the facility that elec-tric powered cranes were also existing.

UNDERSTANDING THE MECHANISM

Even after the visit to the crane rental, and seeing the mecha-nism in action, there was still a lot of confusion to how exactly it



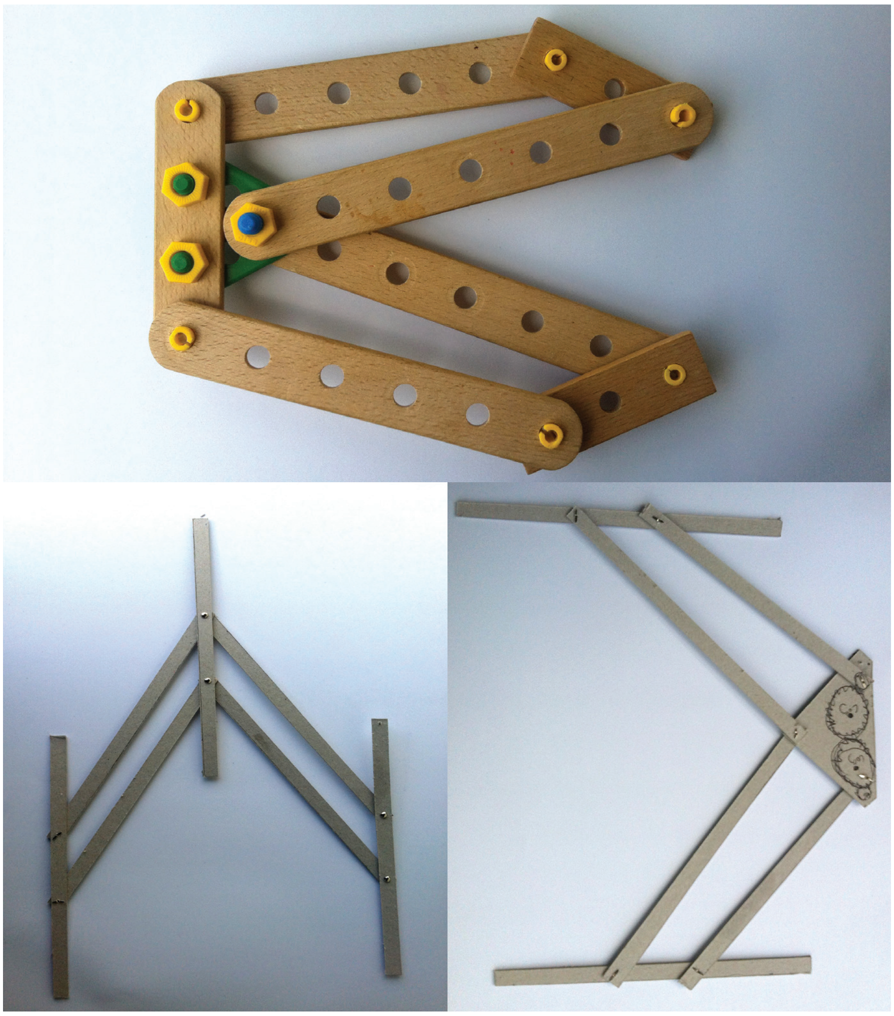




Modeling with the little helpers

worked. Even thought the mechanism seemed simple, the confusion stemmed from the distances between connectors on the knees and beams. The different items and connectors can be seen on the two sketches.

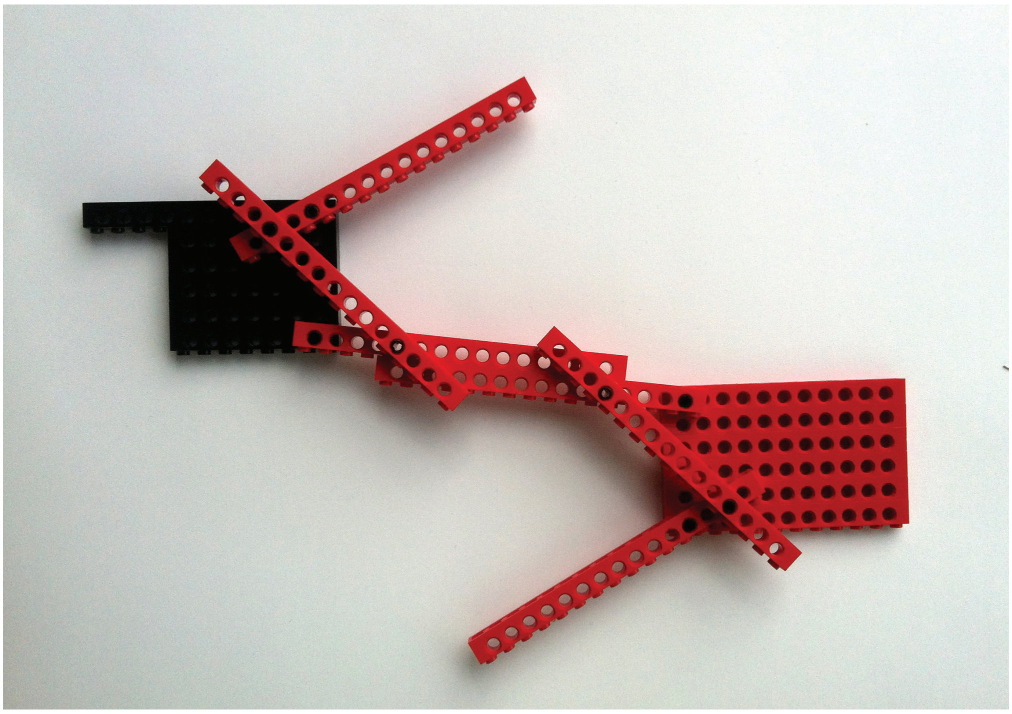
To understand how everything worked together, models were made. First I started with simple paper and toy models. The number of knees doesn't matter as each knee is supposed to be level in relation to each other so the focus was on understanding a mechanism with one knee only. Early on, the plan was also to actually use only one knee on the pod-car, but because the length of the whole crane would have been slightly longer, as it was the most logical way to mount the crane at the top of the center of mass of the pod-car, two knees were used in the end (this was found out when starting to test model in Solidworks).



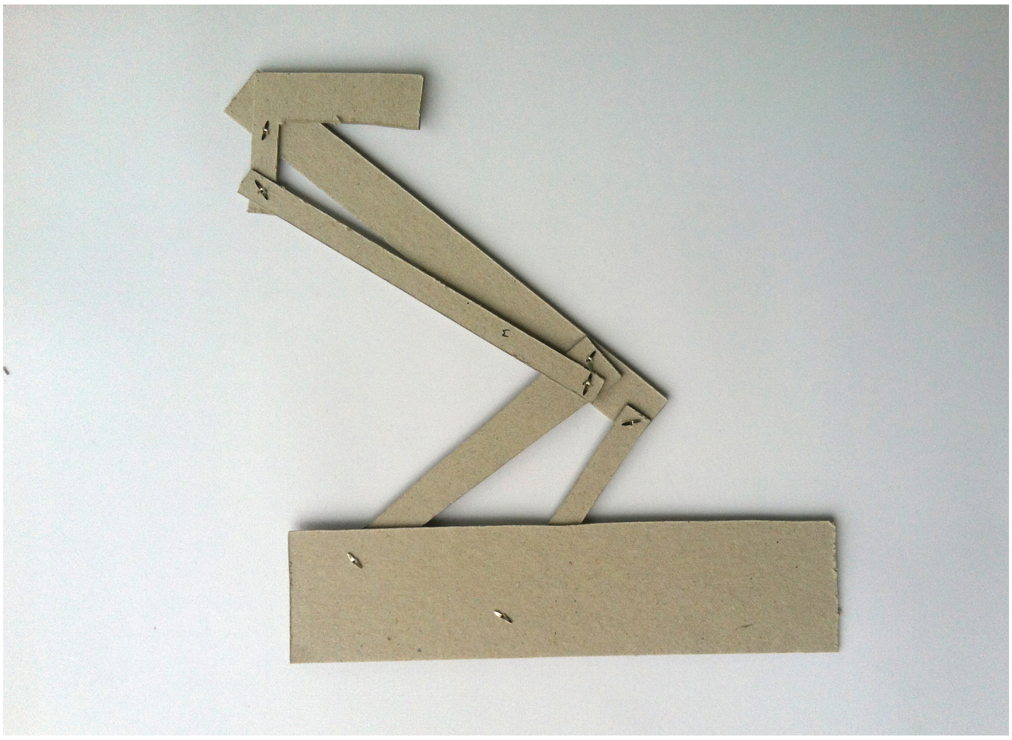
Understanding the crane knee

The easiest part was to understand how the knee interacted with the load-bearing beams and balance beams and after a few models where I focused on that aspect only, that functionality was pretty much understood. But the problematic part was to understand the tandem beam, where it needed to be connected, and how the position of the connections related to how it was supposed to move. After a few modeling tries it was approximately known how everything needed to relate to each other. Then foam models with two knees were made to be sure that everything behaved as expected.

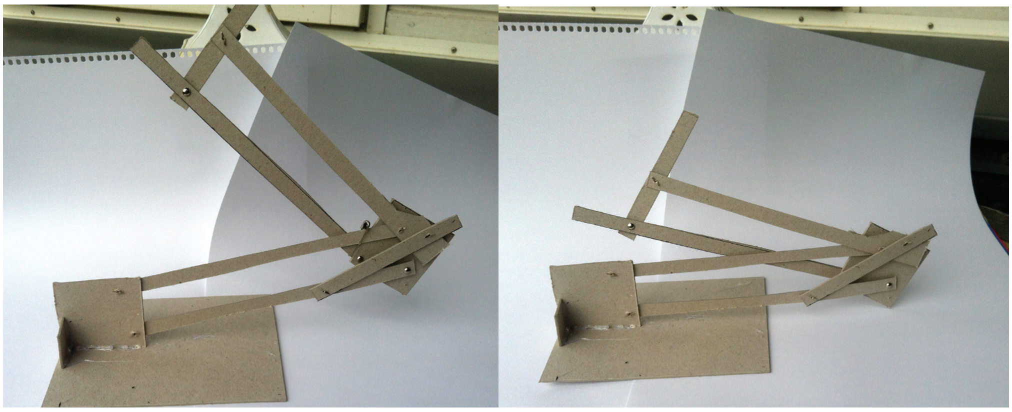
Next step was to test the mechanism in CAD. Simple CAD models (see screen-shots on the next page) were built and the positions of the connections between the main beams and the tandem beam were tested out. Finding the correct position where to connect this, was not as straight forward as initially though. To find the length of the tandem beam was easy, as it needed to adhere to the pythagoren theorem when the crane was laying down flat. But the exact po-



Testing two knees, with no tandem beam



Alternative mechanism



Testing one knee with a tandem beam

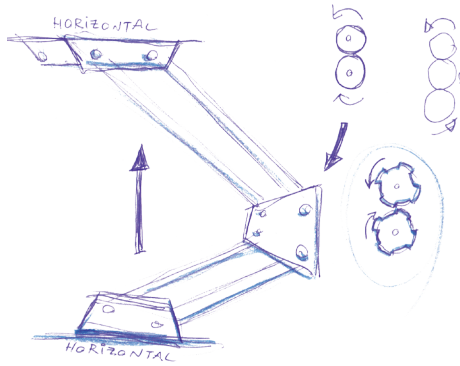
sition where the tandem beams connected to the other beams were found by trial and error.

The final CAD model was then devised and designed as to fit the pod-car, be able to extend to over 5,2 meters (height required by regulations for objects over roads) and be able to lay as flat as possible on top. In order for the crane to be as flat as possible, the knees were found to need to be of a specific design where the connectors for the balance beams was in front of the connectors for the load bearing beams (on the knees). The final crane CAD model can be seen here below (See part dimensions in Appendix F).

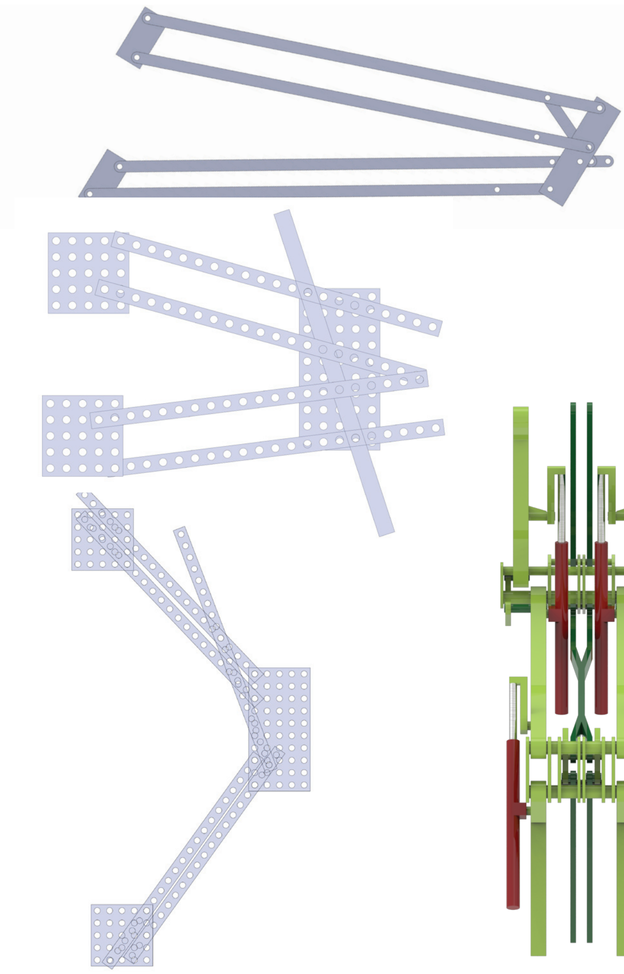
Foam model made concurrently with the 3D model

MATERIALS

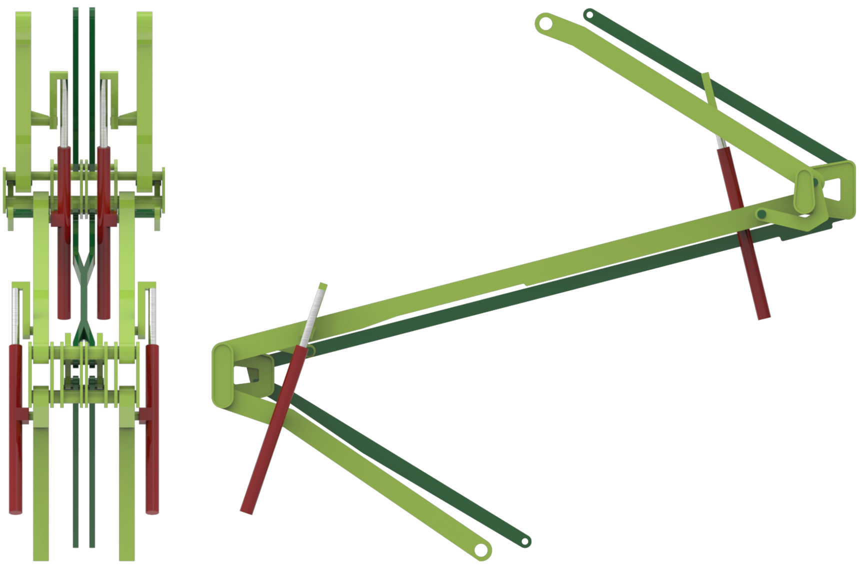
Because of the strength needed, the crane mechanism is a steel structure.



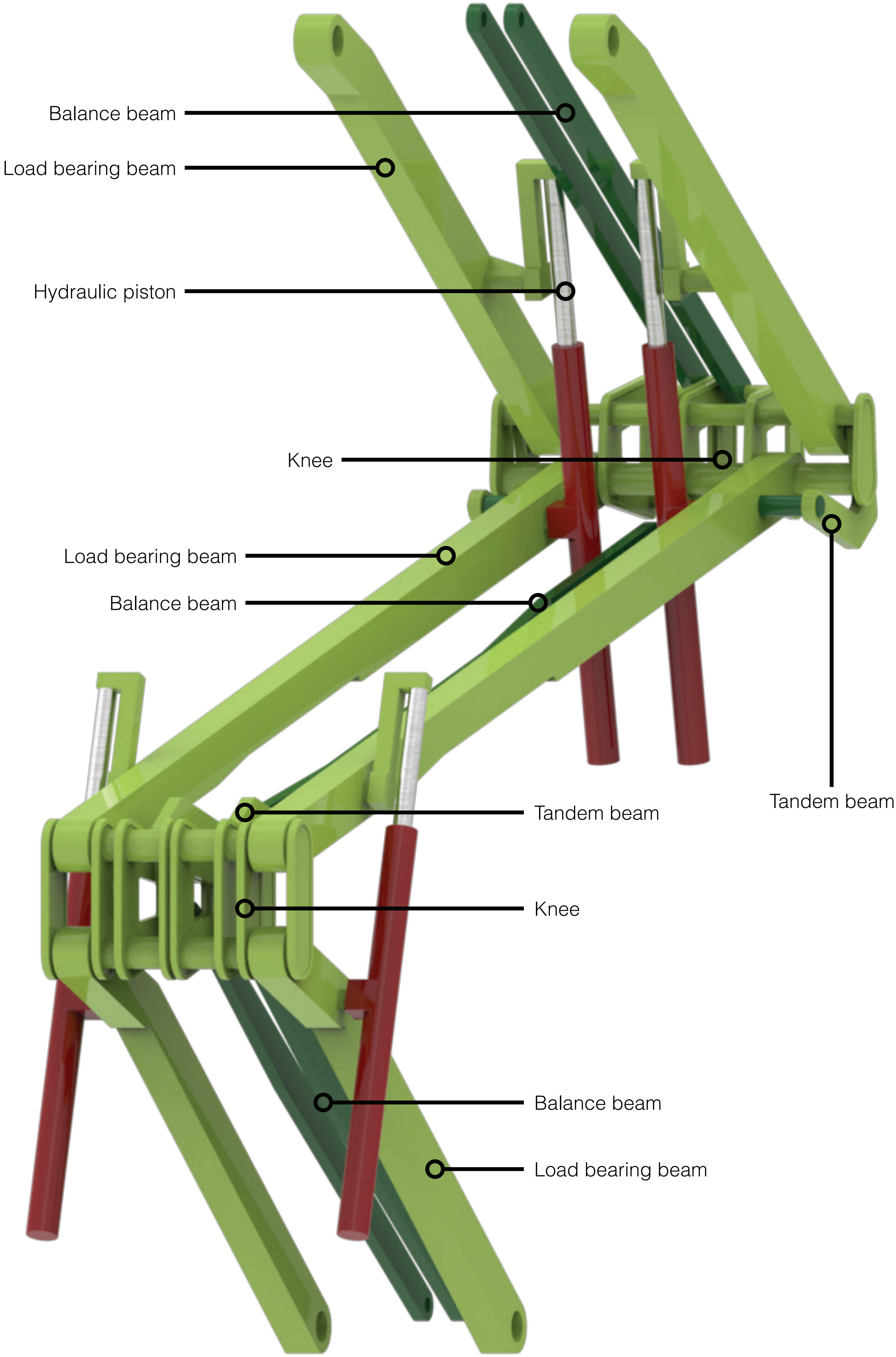
Early knee idea with cogs instead of tandem beams



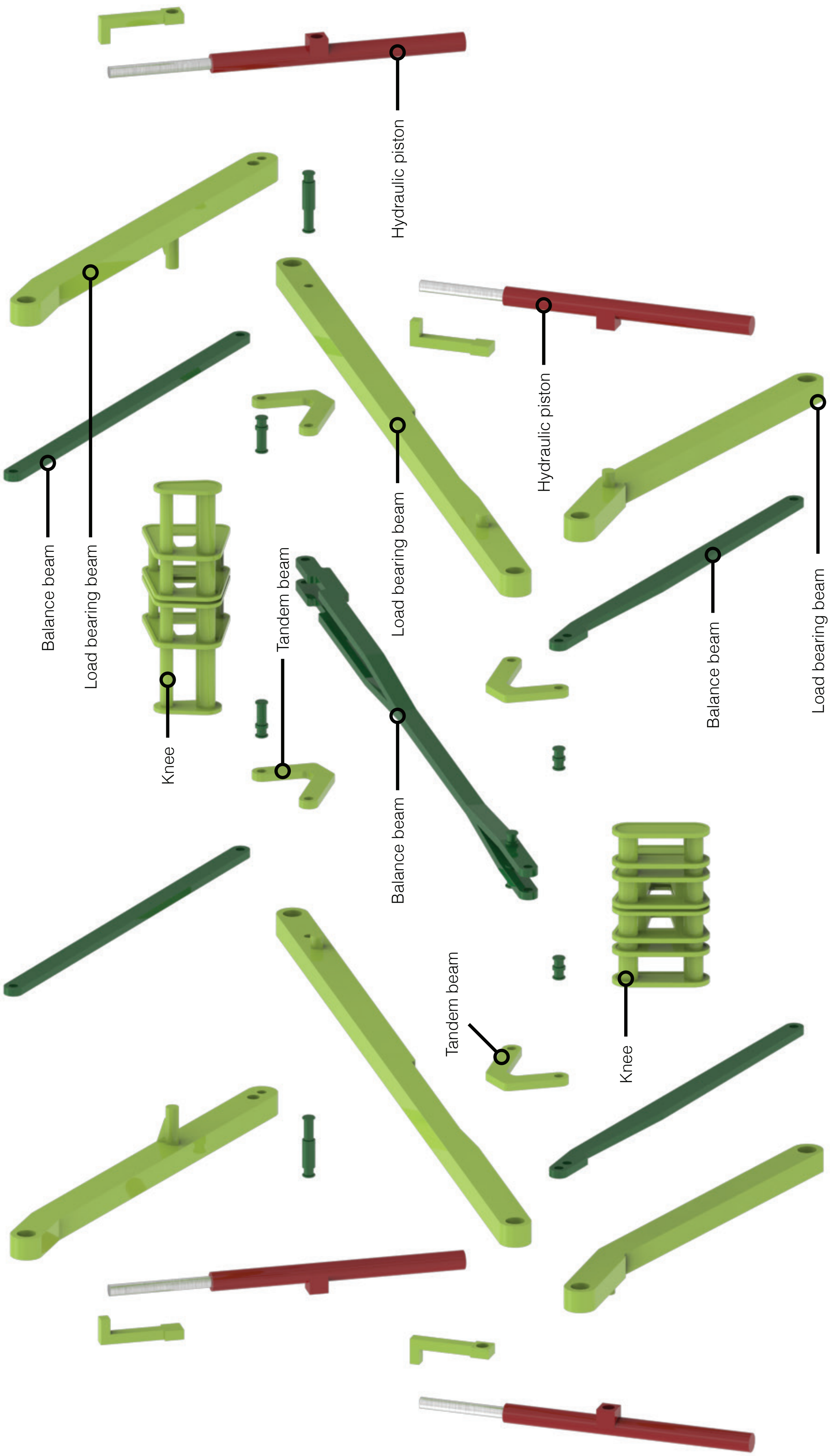
Testing knee mechanism in CAD



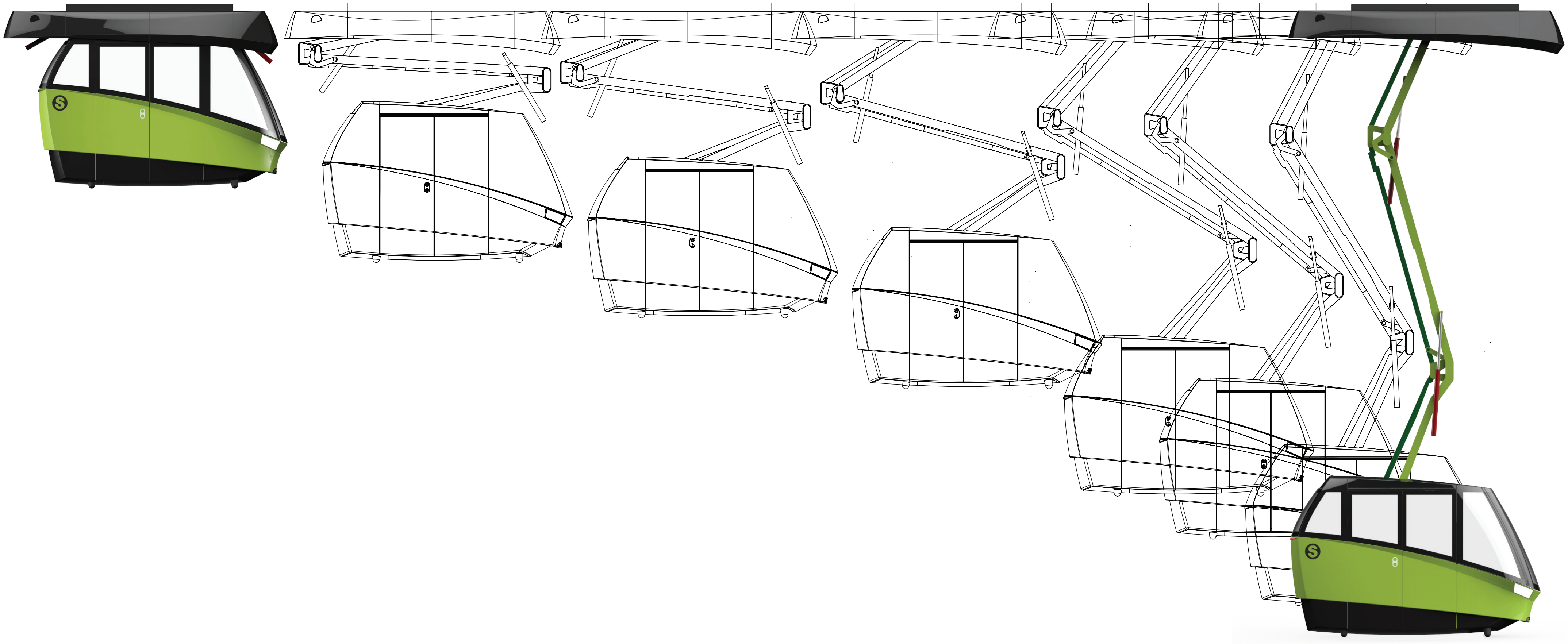
Final crane 3d model



Final crane 3d model



Final crane - exploded view. Small connectors are not labeled



Crane mechanism movement

DETAILING

This section shows selected aspects of the final proposal and how they are devised and detailed.

POD-CAR INTERIOR VOLUME - 1ST ITERATION

In order to push forward, decisions on the interior volume are made. As the pod-car is suspended and both the frame structure of the car itself, as well as the track infrastructure have to hold certain weight, the lower the weight of the pod-car, the less material is needed for both the frame and the infrastructure. So to keep the weight low, the size of the pod-car has to be as small as possible without being unusable.

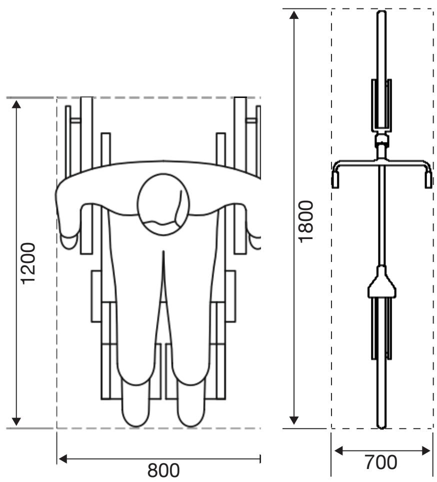
This has an effect on the interior volume as it is imperative that it is not bigger than needed, as this would push the weight up.

DEFINING THE NEEDED VOLUME

The objects that define the volume are a wheelchair, bicycle and a passenger. All other objects are smaller and don't have a defining effect on the volume.

It is decided that a the pod-car should be able to carry one wheelchair or one bicycle. This has the effect that the width needed for the wheelchair is large enough for two seats side by side to be used. The length of the bicycle has the effect that when no bicycle or wheelchair is in the pod-car, 2 rows of standard seats can be used. This leads to several defining area usage configurations (see illustration on the next page). For all configurations to work, flip-up seats need to be utilized. Because of the low speed of the pod-car and the disappearing risk of collisions, seatbelt are not necessary, as well as means to hold the bicycle / wheelchair. Another consideration to make is that the wheelchair needs certain space to maneuver, but this can be alleviated by the usage of large doors.

From considering these constraints, we get an area of 2200x1000 which includes the usage for folding seats and small



room on each side of the wheelchair. Seat dimensions from an average bus are used. From this we can make assumptions about several different area configurations.

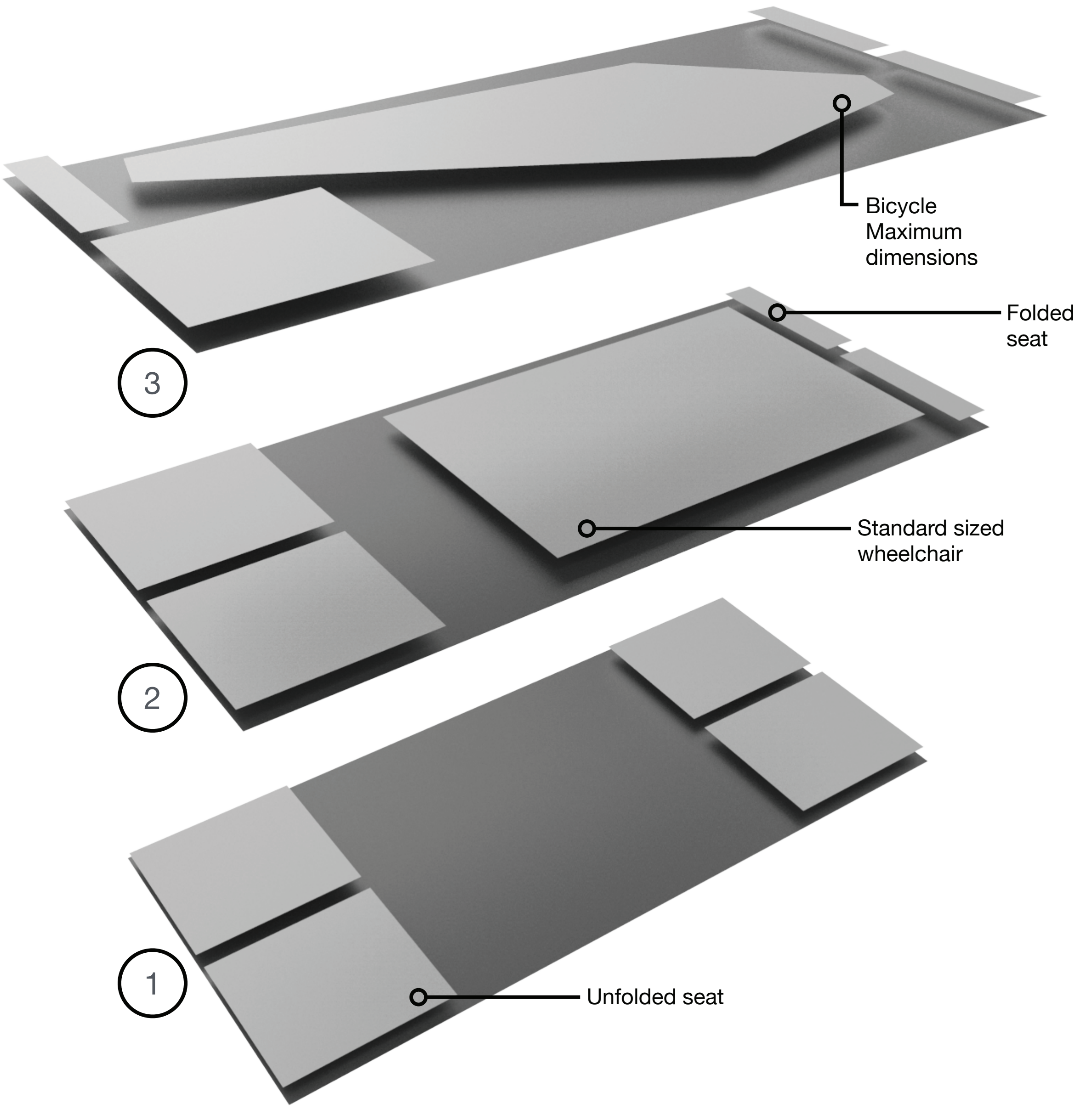
AREA CONFIGURATIONS

The three defining configurations are shown on the illustration here below. Bottom configuration (1) has all seats folded down. In this configuration four passengers can be seated. The next configuration (2) shows the space when the pod-car accommodates a wheelchair. In this configuration two other passengers besides the user of the wheelchair can be seated. The third and final configuration shows the layout when a bicycle is accommodated. In this configuration one passenger can be seated. The maximum dimensions of a normal bicycle are used so if the dimensions are smaller, or the bicycle is made stand differently, there should be a way for a second passenger to be seated, or a second bicycle to be transported.

HEIGHT

As the height of the pod-car is critical and needs to be as low as possible, because the taller the pod-car, the higher the track infrastructure needs to be, the interior height is decided to be similar to the interior height of a typical minivan or around 1450mm. This means that entering and exiting the vehicle, passengers need to bend their bodies quite a bit.

Looking at minivans, this was assumed that should not pose a problem as moving around in the pod-car is not expected.



DETAILING

POD-CAR INTERIOR VOLUME - 2ND ITERATION

Interior space - frame model

For the second iteration of defining the interior space, a rough frame model was built to test the interior volume that was the result from the first iteration.

FLOOR DIMENSIONS

The floor dimensions from the 1st iteration (length and width) proofed to be comfortable when sitting, as well as the size was just right for a bicycle and a wheelchair (frame was used with the maximum dimensions for the wheelchair as a real wheelchair was unavailable when testing). No changes where therefore necessary for the floor dimensions but the results proofed that the dimensions could not be smaller, without hampering the usability of the space.

HEIGHT

The height from the first iteration proofed to be to low when testing. 1450mm was too uncom-

1600mm final height

Testing passenger space. Final height (red string) is shown on the lowest image.

Maneuvering a bicycle into the pod-car and testing needed doorway width.

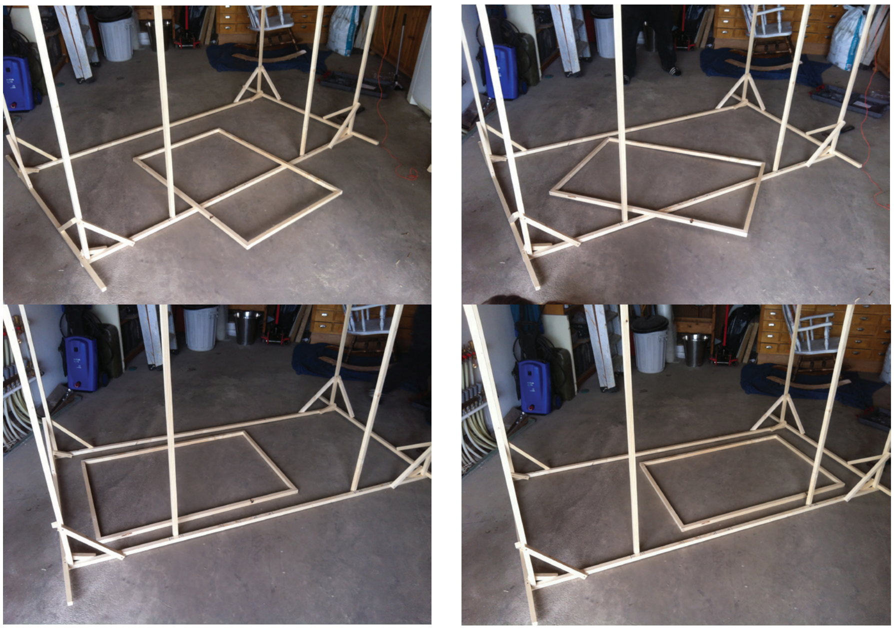
fortable when getting in and out of the pod-car, and also when seated within the pod-car, it felt too low, to the point of being claustrophobic.

By testing different heights, the conclusion was to use 1600mm, which made it easier to enter and exit the pod-car, as well as the feeling of sitting inside with that height felt satisfactory.

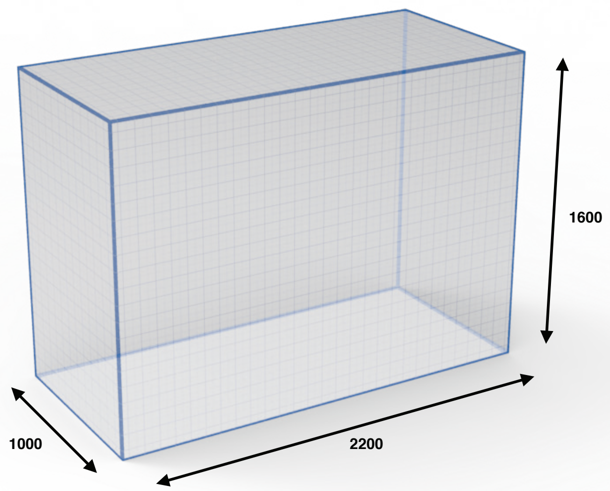
Bicycle clearance when maneuvering a bicycle through pod-car doorway.

ENTRYWAY DIMENSIONS

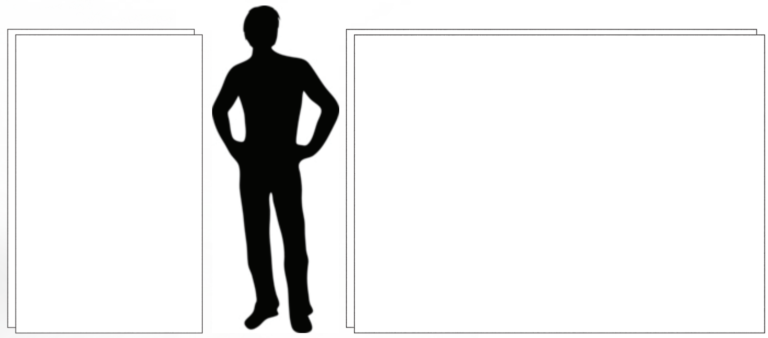
The dimensions of the doorway were also tested out and by trial and error, the width of the doorway was found out to be satisfactory at 1300mm. This width was enough to fit and maneuver both a bicycle and a wheelchair through the doorway without a hassle and set them up inside the pod-car. No great problems were seen regarding the wheelchair. On the images it might seem that there would be difficulty fitting a wheelchair, but what fools the eye is that the frame is absolute maximum dimensions of a wheelchair with a person in it. So the frame width for example, does not represent the wheels of the wheelchair, but also hands of the person. The length is as well maximum size possible.



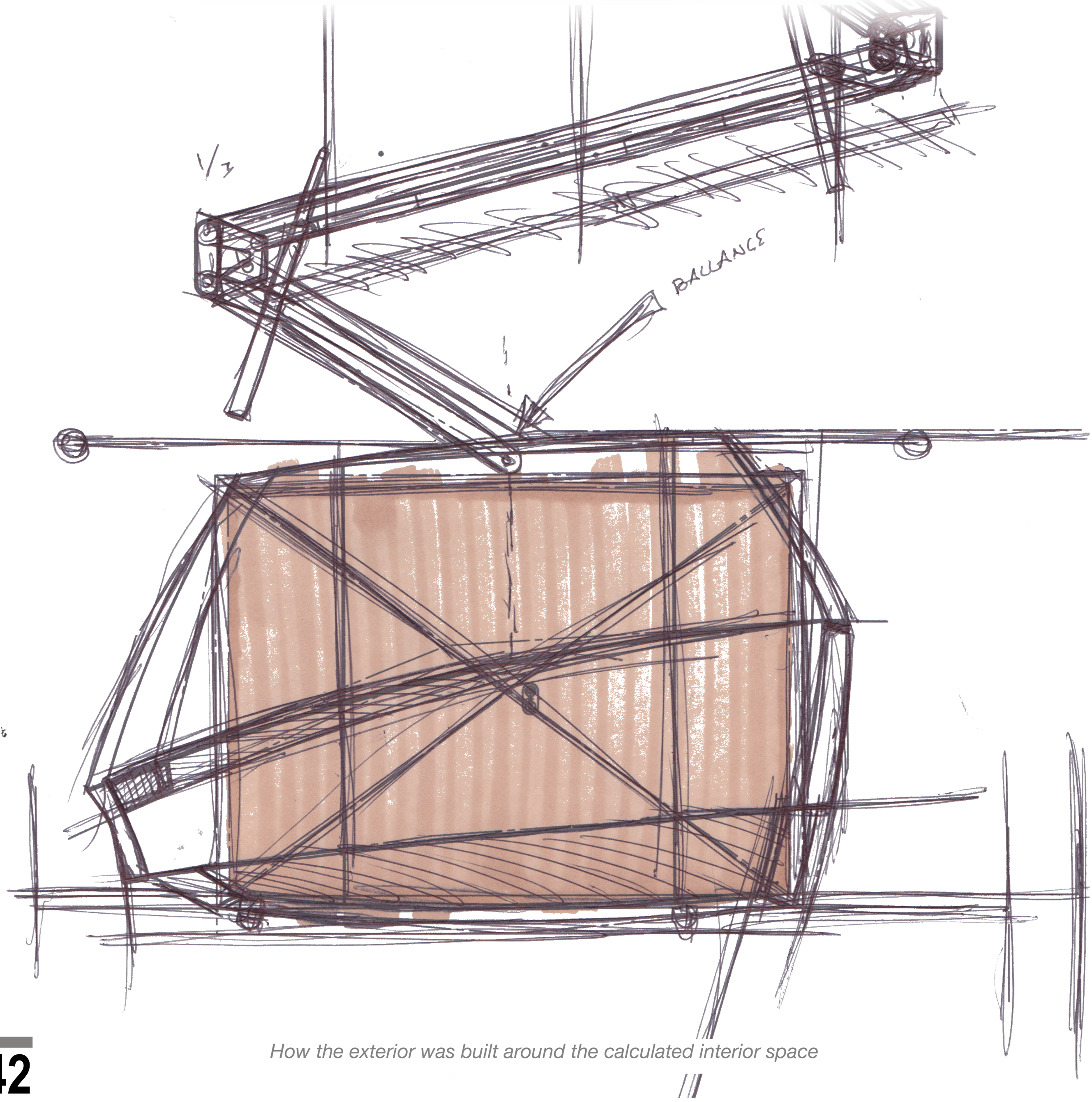
Maneuvering a wheelchair sized frame into the pod-car.



Final interior dimensions



Front and side views of the volume in comparison to a 1800mm tall person



How the exterior was built around the calculated interior space

DETAILING

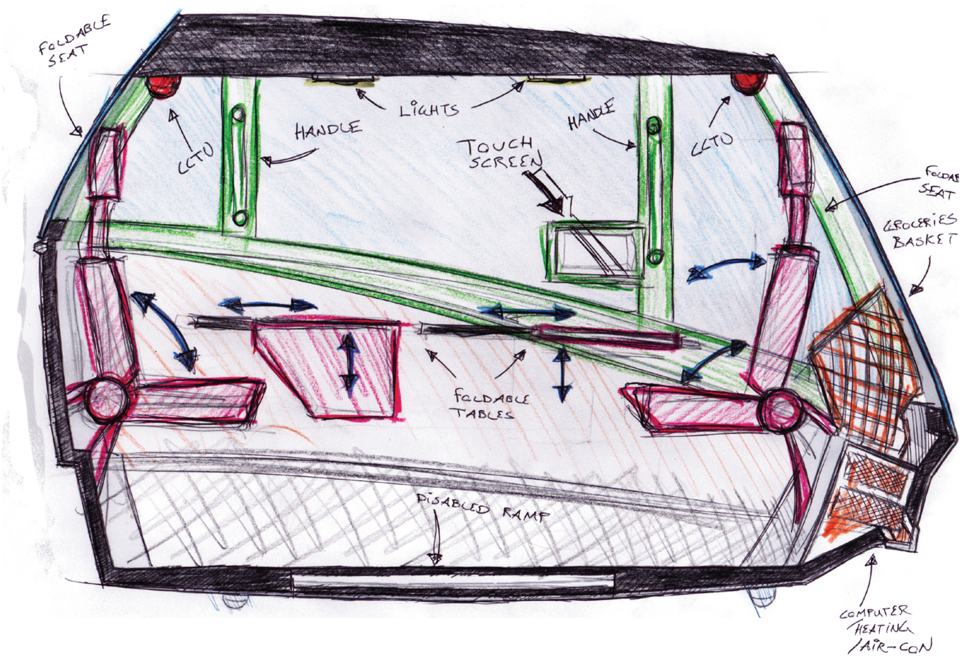
INTERIOR

The interior of the pod-car is defined by the volume calculated in the interior volume sections. It is large enough for 4 collapsible seats, 2 in each end, front and back. The seats are collapsible in order to fit a wheelchair or baby carriage (2 seats need to be collapsed) or a bicycle (three need to be collapsed, although it depends on the size of the bicycle).

Other notable features of the interior are handles on each side of the door, to facilitate easier disabled access, two touch screen interfaces for choosing destination and interact with the system, non-slip rubber flooring, lights in the headliner, as well as four CCTV cameras, one in each corner. In the front, there is a basket for groceries or other belongings. folding worktables are are on one side of the pod-car. By the entrance, a check-in mechanism is located, as well as an open-close door button and extend/retract disabled-ramp button. Manual lowering and door opening handle is close to the door on the inside, as well as a n emergency hammer and an emergency radio.

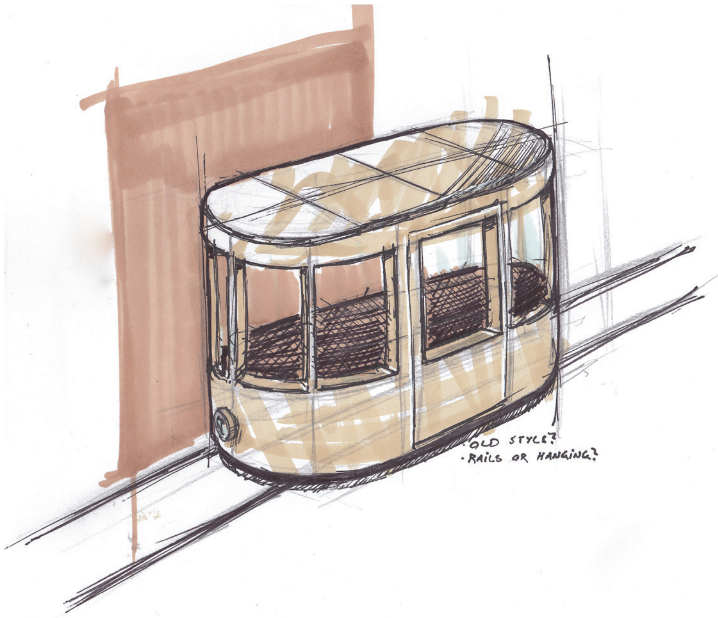
Interior panels are vacuum formed from gray and black grained ABS.

Here below a rough sketch (section view) of the interior can be seen, this was not developed further. Colors are not representative of the final vision.



DETAILING

EXTERIOR DESIGN



No specific direction was taken right away with the aesthetic exterior design. At first there wasn't even a decision if the system would be elevated or on-ground. But later, after the decision to make the system elevated and suspended with the crane, it was decided to go for a car metaphor as almost all the current designs of pod-cars tend to be similar shape with no apparent front or back section. It was wanted to give the pod-car some familiarity for the users and pedestrians, and therefore try do give the pod-car some features commonly found on cars, like headlights and tail lights and an obvious front side. This decision was also influenced by the fact that the pod-cars use car parking spaces as stops (see visual-

Fig. 12.

Fig. 13.

Fig. 14.

Fig 15.

ization in product report). Another thing that was attempted was to give it an eighties/ninetees look (see inspiration images of cars). The reason for inspiration was that I wanted the pod-car to fit the city of Reykjavík, which is in many aspects quite old-fashioned, mainly if looking at the old part of town.

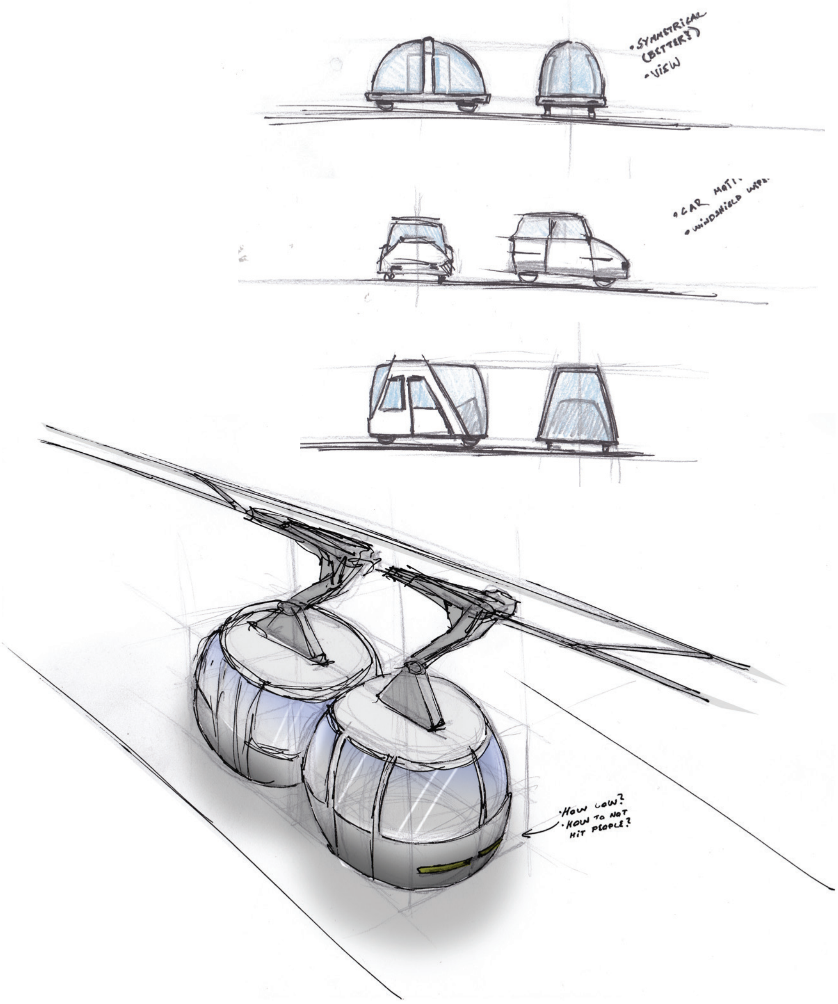
The colors selected were black and green. Black to give it a bit of a modern look, as well as to camouflage how tall the pod-car

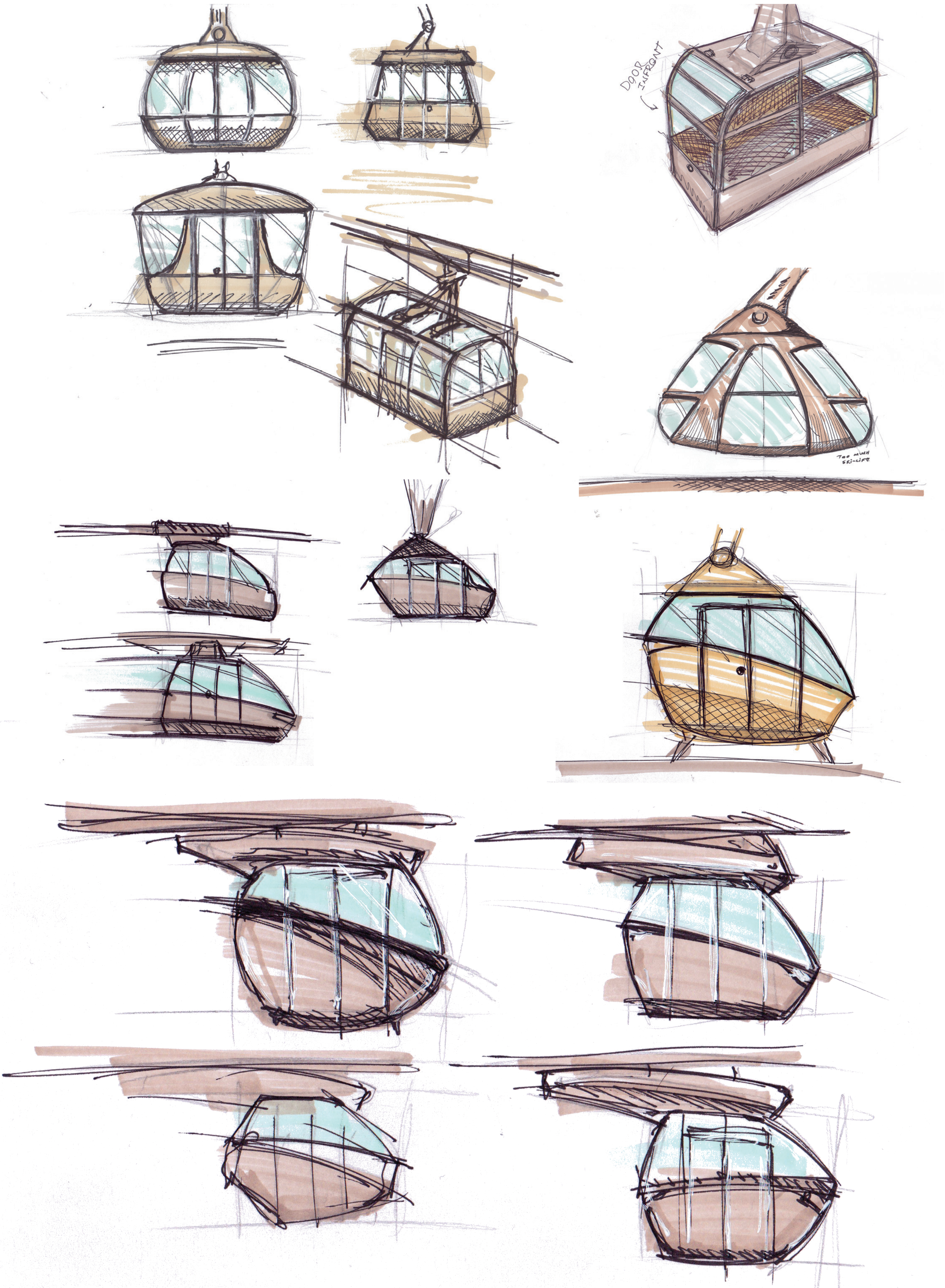
is, and green because that is the old color of the public buses in Reykjavík (the current modern color is orange) and I found it fitting to use this color because of the retro shape that I was trying to achieve.

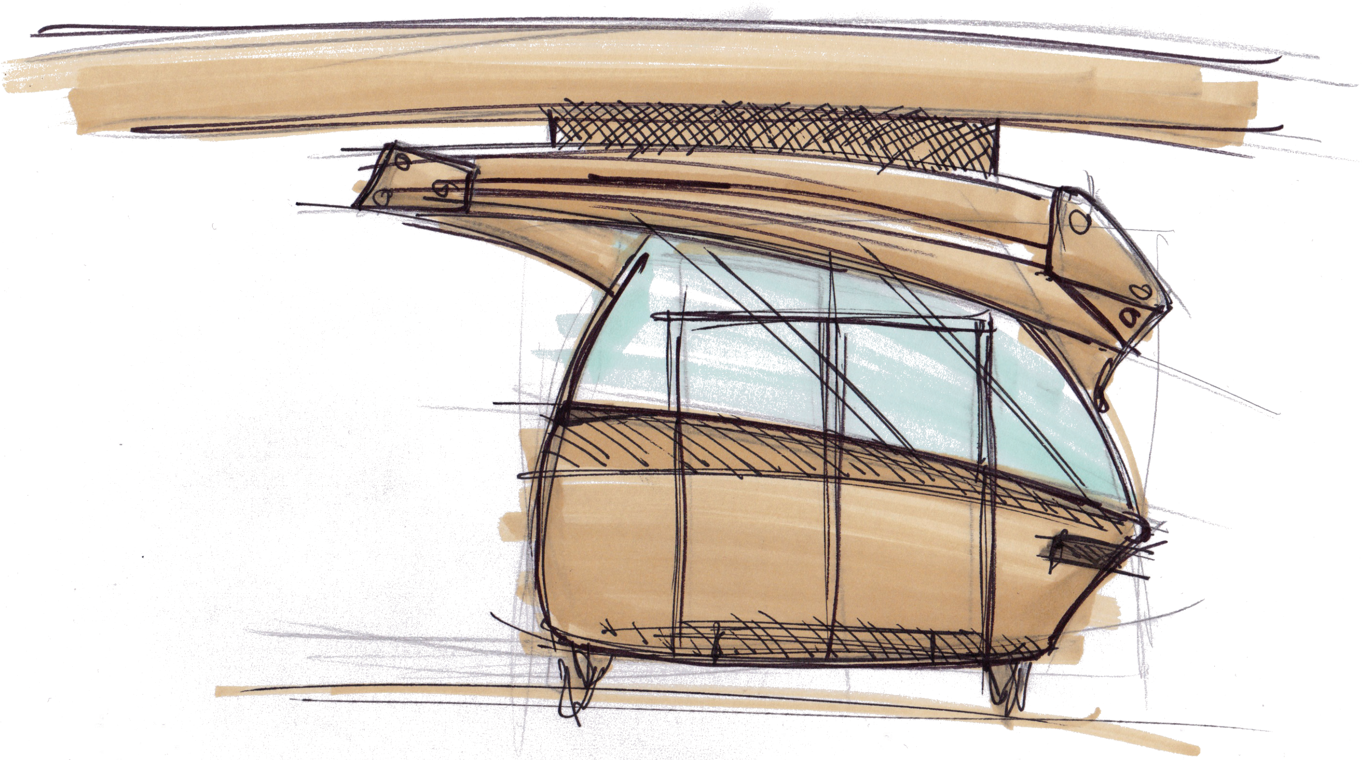
The crane cover was supposed to be like an extension of the pod-car when the pod-car was elevated to the rail. This looked fine on paper, but unfortunately the cover seems a bit out of place in the final design.

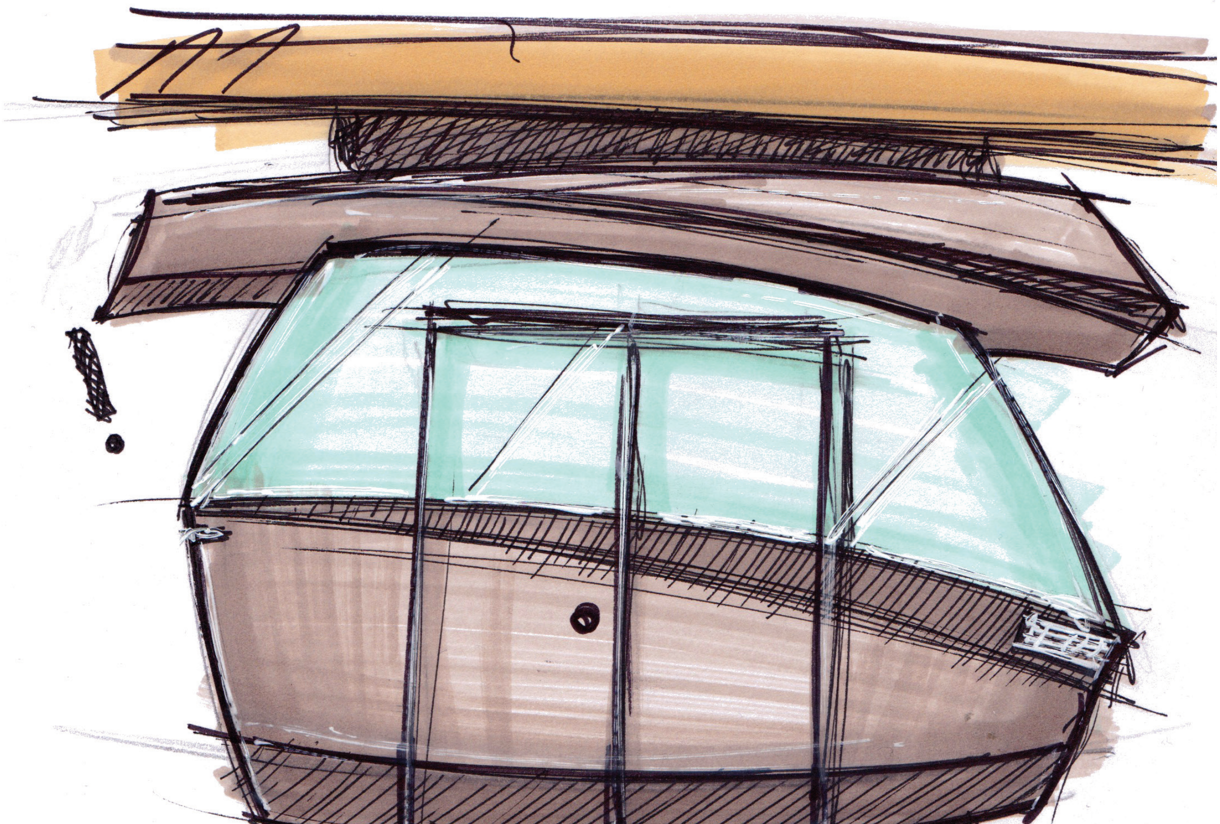
It is worth noting that the headlights were directed to the sides in later iterations, because no need is for headlights on the pod-car, so they serve as a mood/status light, as well as lighting for the passengers when on the ground.

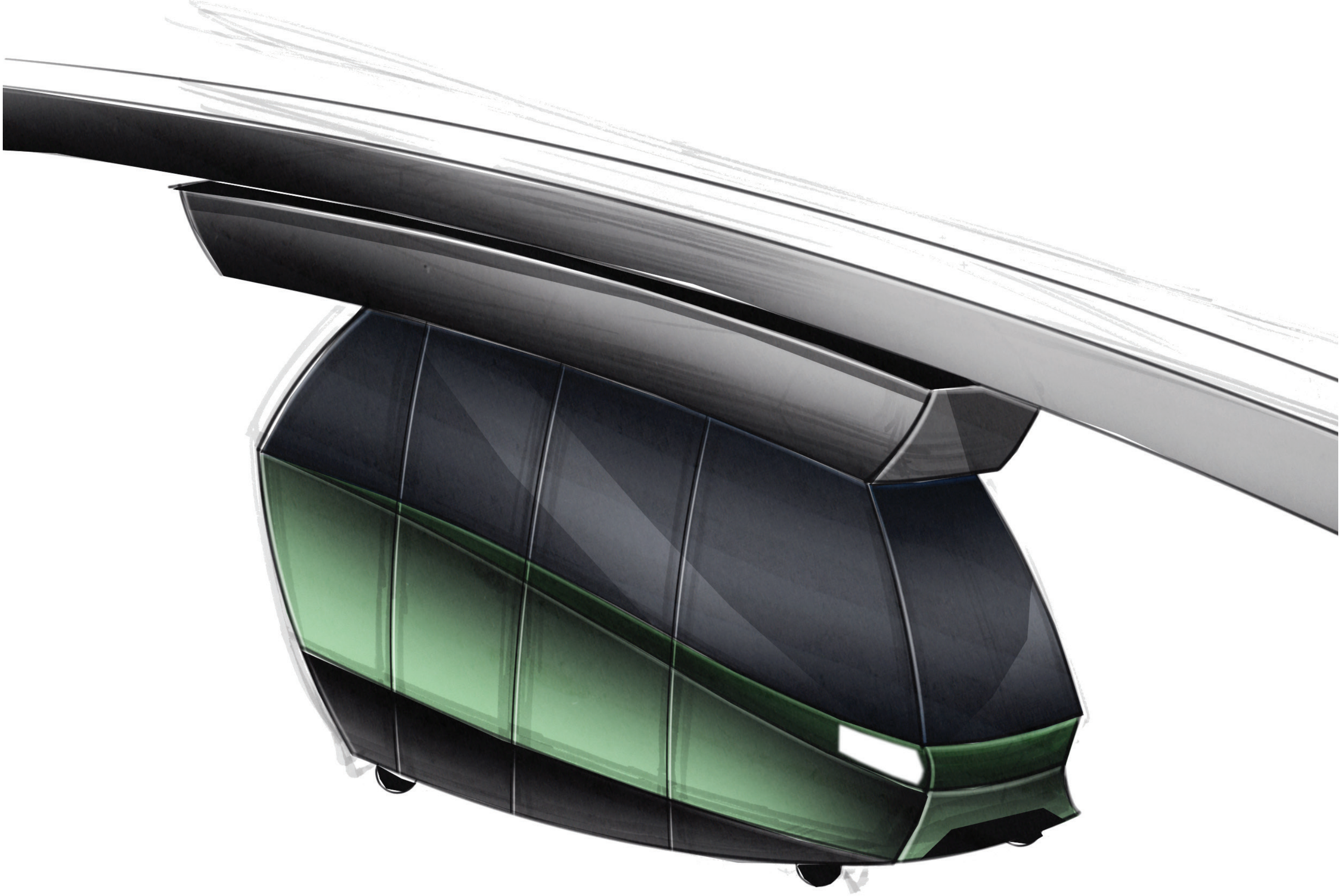
Here the development of the exterior can be seen, approximately chronologically organized, ending with the final 3d model.

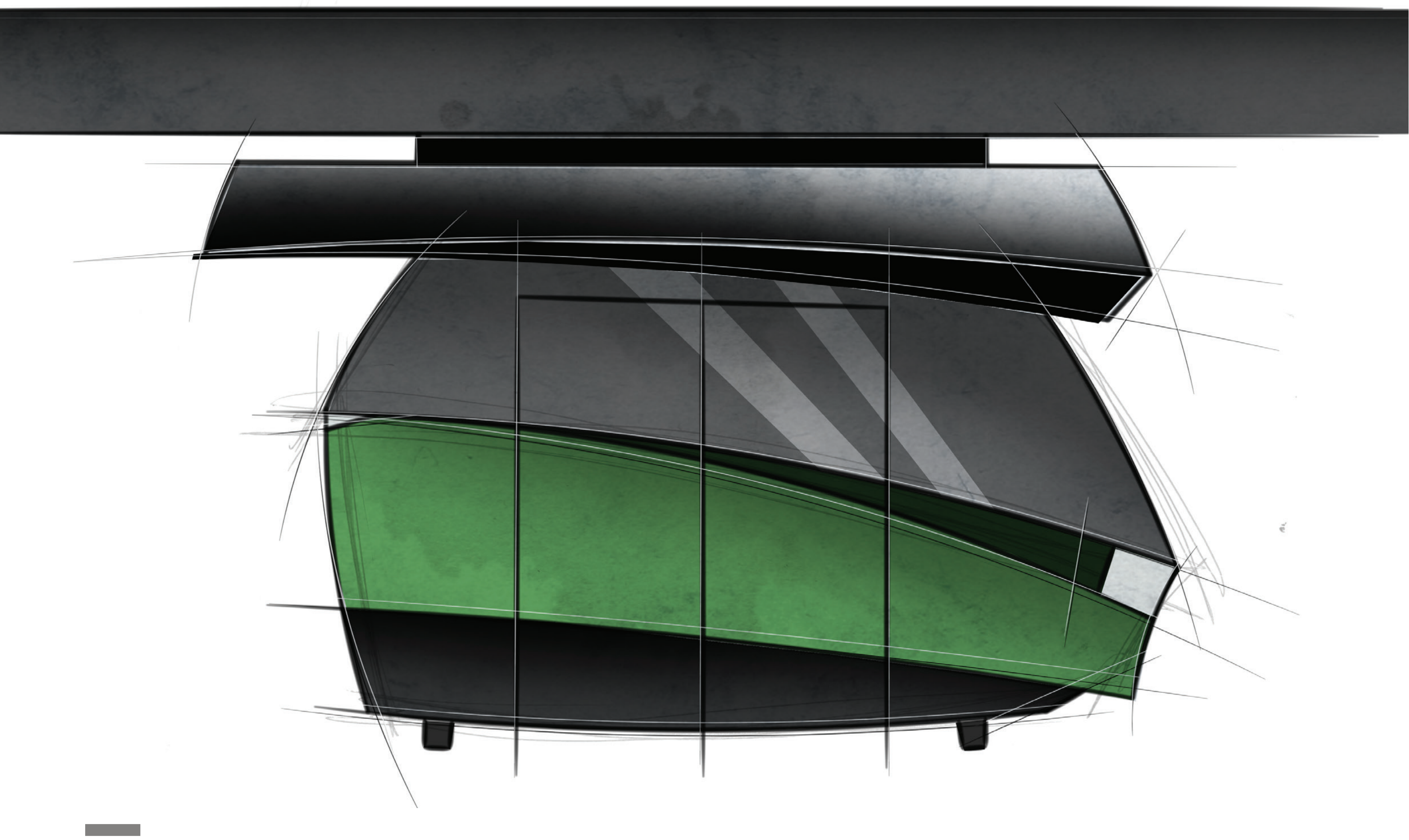


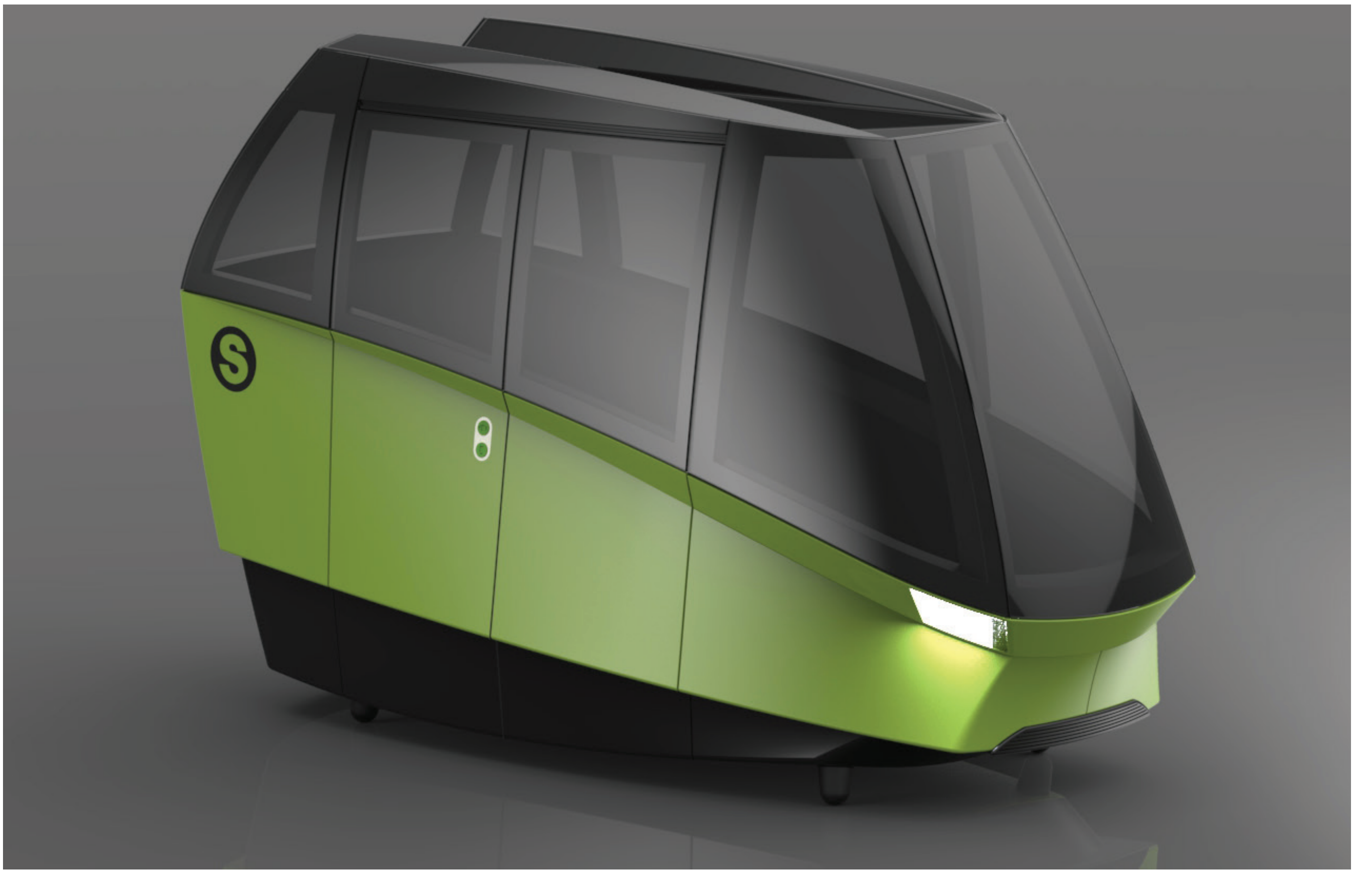

DOOR INFRONT
TOO MUCH SKI-LIFT











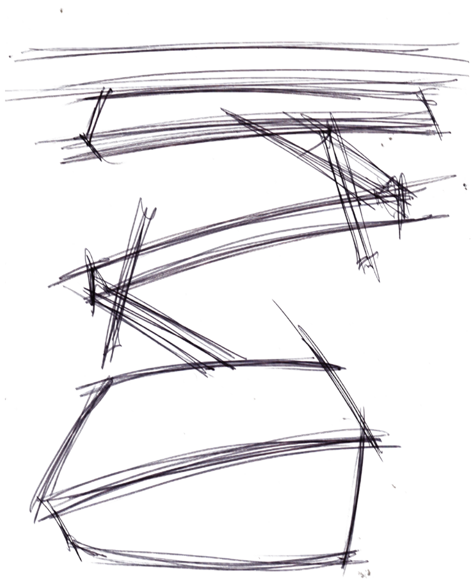
DETAILING

CRANE COVER DEVELOPMENT

The pod-car was first built in CAD from sketches, but with a tapered top to anticipate adding the cover afterwards, as well as a cut on the roof for the crane. When the crane had been developed, and the knowledge of how much space it would take on top of the pod-car, sketches were made and then a CAD model.

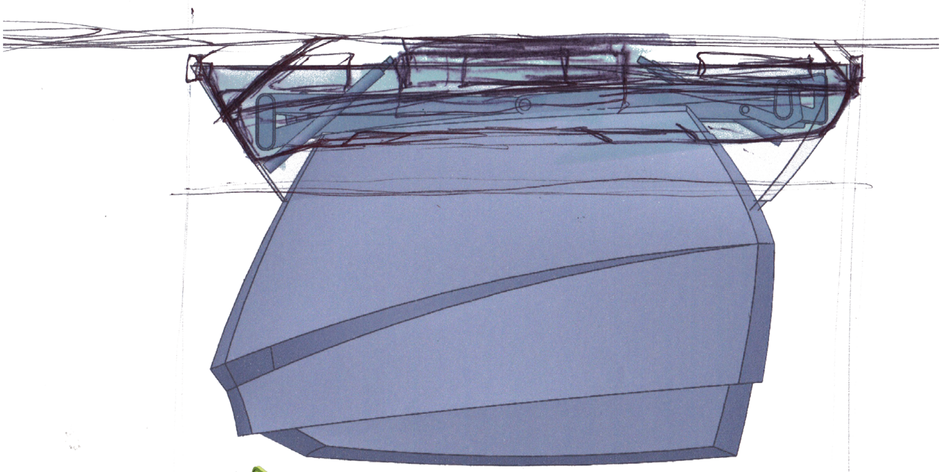
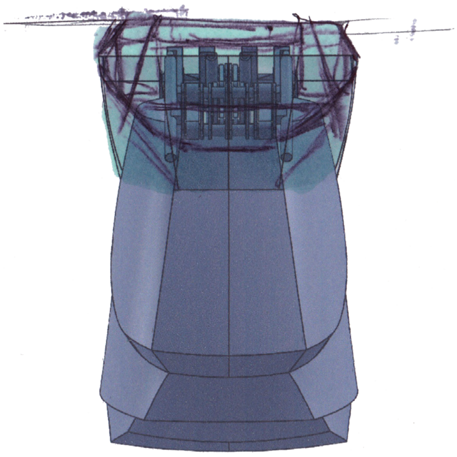
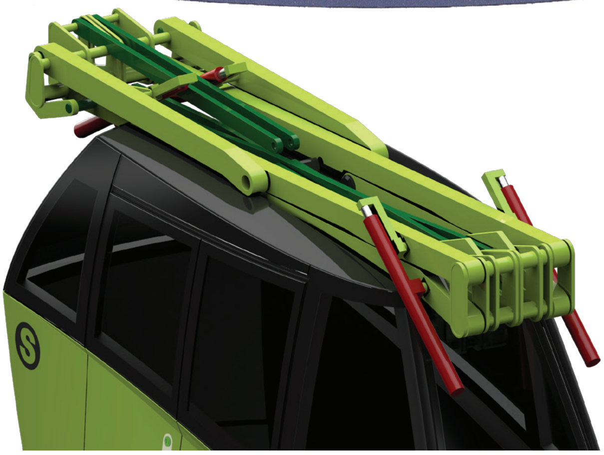
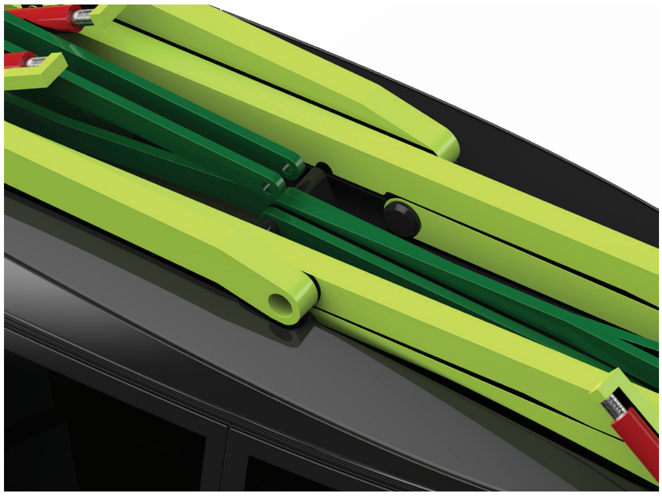
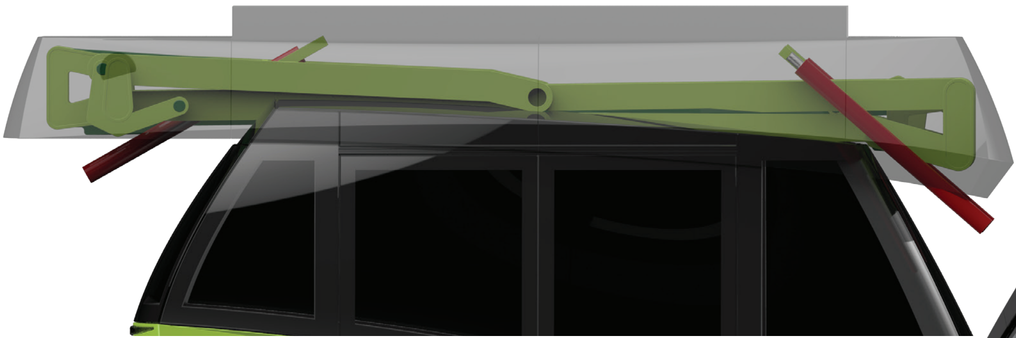
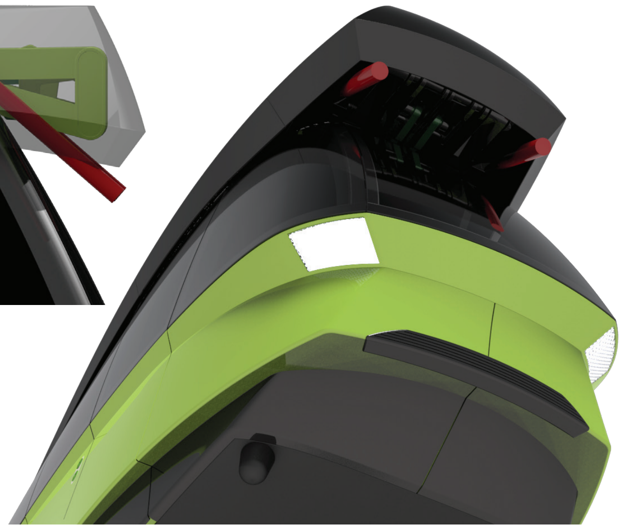
The desired results were that it would be tightly fit to the crane, and flush to the pod-car, to make it look like an extension of the it. This worked out on the sides (there is just a few cm clearance on each side) but the crane was longer and wider than anticipated. Therefore especially the back end did not look as desired. In the back, dimples for the crane knee can be seen, as cover got an undesired shape when I tried to put it completely around the knee.

Room for the technology (motor, pump, battery, etc) was estimated, at the time of development, and was then supposed to be finalized when the dimensions of the technology were better known. Unfortunately I didn't reach that point. But the space (plus an added space above the cover) in all probability allows for all the technology needed, as the dimensions of similar technology that was briefly researched are quite small, and the volume needed would probably be smaller than the volume that the end results of the cover can hold. This is of course an assumption.



The inside design and architecture of the cover were completely skipped because of time constraints. The material of the crane cover is aluminum.

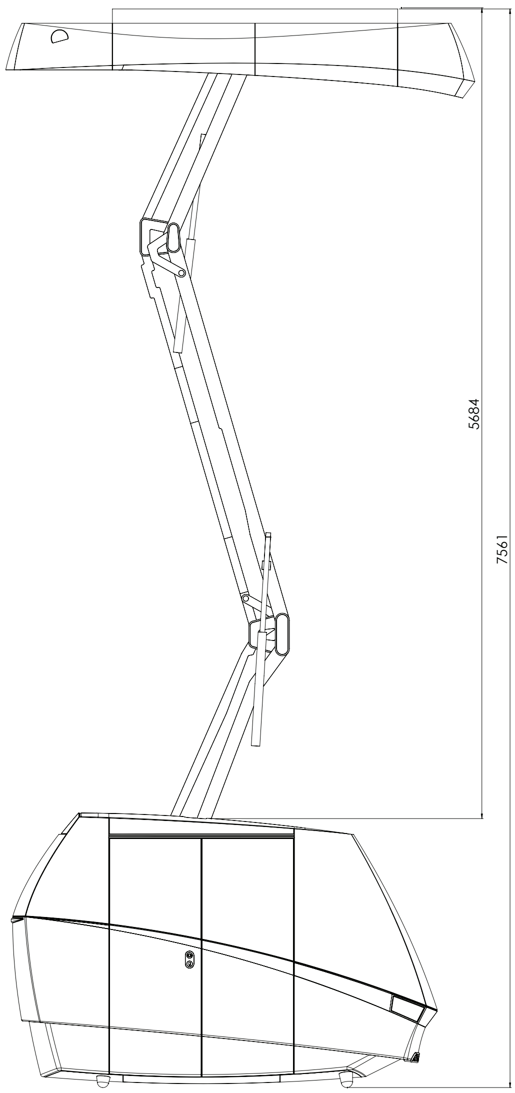
Here a couple of sketches of the cover development can be seen as well as the final results.

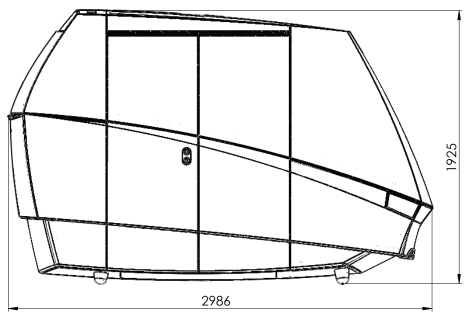







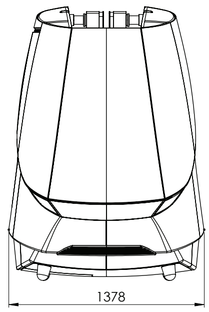
DETAILING

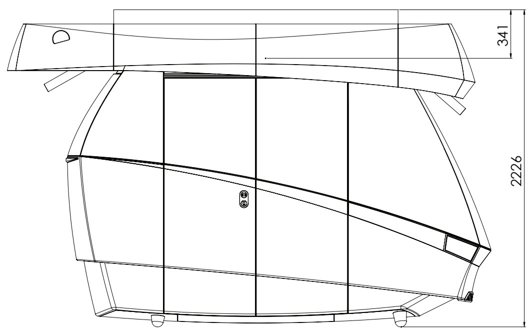
FINAL DIMENSIONS

The final maximum dimensions of the pod-car and crane are pictured below. The dimensions of the pod-car are driven by the interior volume needed. The dimensions of the crane (the height when extended) are driven by allowed minimum height of obstructions over roads (bridges, walkways, etc.). The dimensions of the crane cover are driven by the dimensions of the crane as well as estimated dimensions of the technology that are housed in it alongside the crane.









ESTIMATED POD-CAR & CRANE WEIGHT

To have some idea of the weight of the whole construction, mass estimates were taken, using SolidWorks. As the dimensions, and thicknesses of the different parts are based mainly on assumptions, this mass estimate is only a rough assessment of the possible mass of the pod-car and crane. Absolute worst case is assumed.

As there were problems shelling out the crane profiles/extrusions as well as the pod-car frame, the mass given by Solidworks assumes the parts are solid through. Therefore the mass given by CAD was divided by 3, to give a more realistic estimate.

Materials of the different parts are based on the material section.

Part	Material	Total weight (kg)
Exterior body panels (all parts)	Fiberglass	36
Rubber bottom and feet	General rubber	17
Interior panels (all parts)	ABS	26
Top frame	Aluminium Alloy	93
Bottom frame	Aluminium Alloy	88
Glass windows	Glass	180
Lights, rubber seals, fasteners	Various	10
Technology (est.)		50
	Total	500

Part	Material	Total weight (kg)
Crane (all parts)	Alloy Steel	305
Other (est.)	Various	50
		355

As no decision was made if the exterior panels use ABS or fiberglass, fiberglass is used in the calculations as it has greater mass density than ABS and as this is a worst-case-scenario weight estimate, that seemed fitting.

The calculations give us an estimate of 500kg. for the pod-car itself, and 355kg. for the crane.

Laden weight for the pod-car (based on four persons 120kg. each) is then 980kg.

Total unladen weight (including crane) is then 855kg. , laden weight then becomes 1335kg. (worst case scenario).

As these calculations are based on a lot of assumptions, they are only a rough guide of how much the whole assembly would weight. These estimates can change a great deal just by increasing thicknesses by millimeters.

DETAILING

TECHNOLOGY OVERVIEW

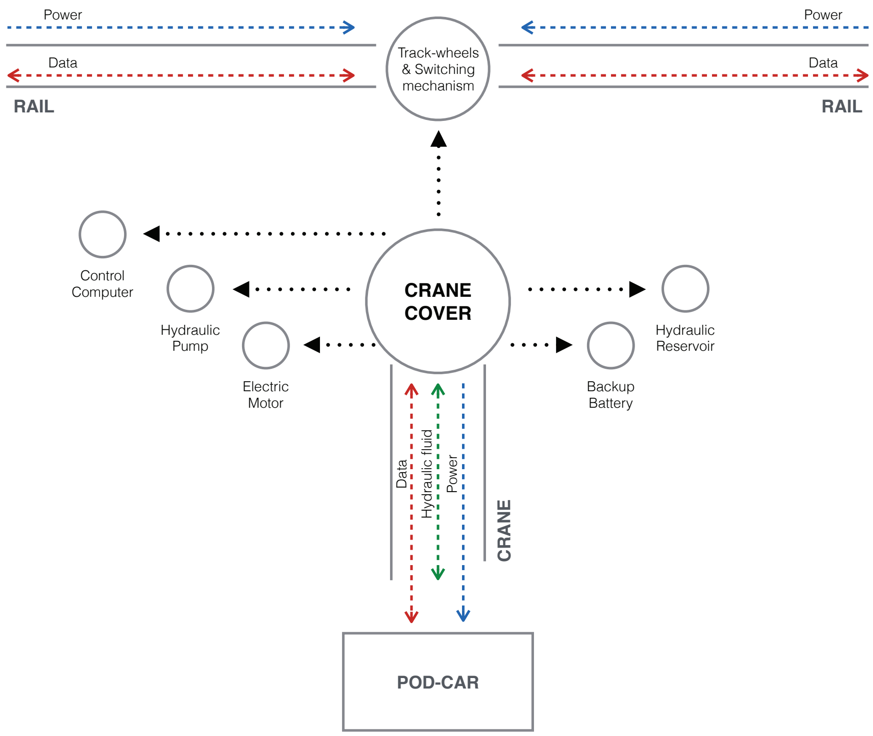
The technology needed was divided into two parts; what is absolutely necessary for the pod-car to drive and function on the system (housed in the crane cover), and secondly, the technology needed in the pod-car itself. I didn't go into very much detail with the technology as that was in my mind, out of scope, so this chapter is an overview of the possible technology.

VITAL SYSTEM TECHNOLOGY

The technology needed for the pod-car to drive and function can be seen on the diagram below. All main vital systems are housed in the crane cover.

Track-wheels & switching mechanism

The track-wheels are rubber covered, similar to normal tires to give dampening. The rail switching mechanism is usually on the track when it comes to rail systems, but a system with constant usage, a better idea was to have the switching mechanism on-board the pod-cars. This also means that if a switching mechanism would need maintenance, it would be easy to take the relevant pod-car into repairs, in contrast of having a whole section of the rail closing down for repairs.



Pistons
Four hydraulic pistons drive the crane mechanism. The number of pistons is a safety precaution as well, as if a piston stops functioning, the pod-car can keep on functioning and drive it self to repairs.

Power, hydraulic fluid and data-link connections
The track has a built-in power and data transfer mechanism that feeds the pod-car with power and communicates data to and from the central system control. The crane then mostly hides these wires that go through the crane steel beam extrusions. The pistons are connected to the hydraulic pump in the cover by hydraulic tubes that are mostly hidden as well. These connections all go outside of the beams over the crane “knees” (not visualized on the renders).

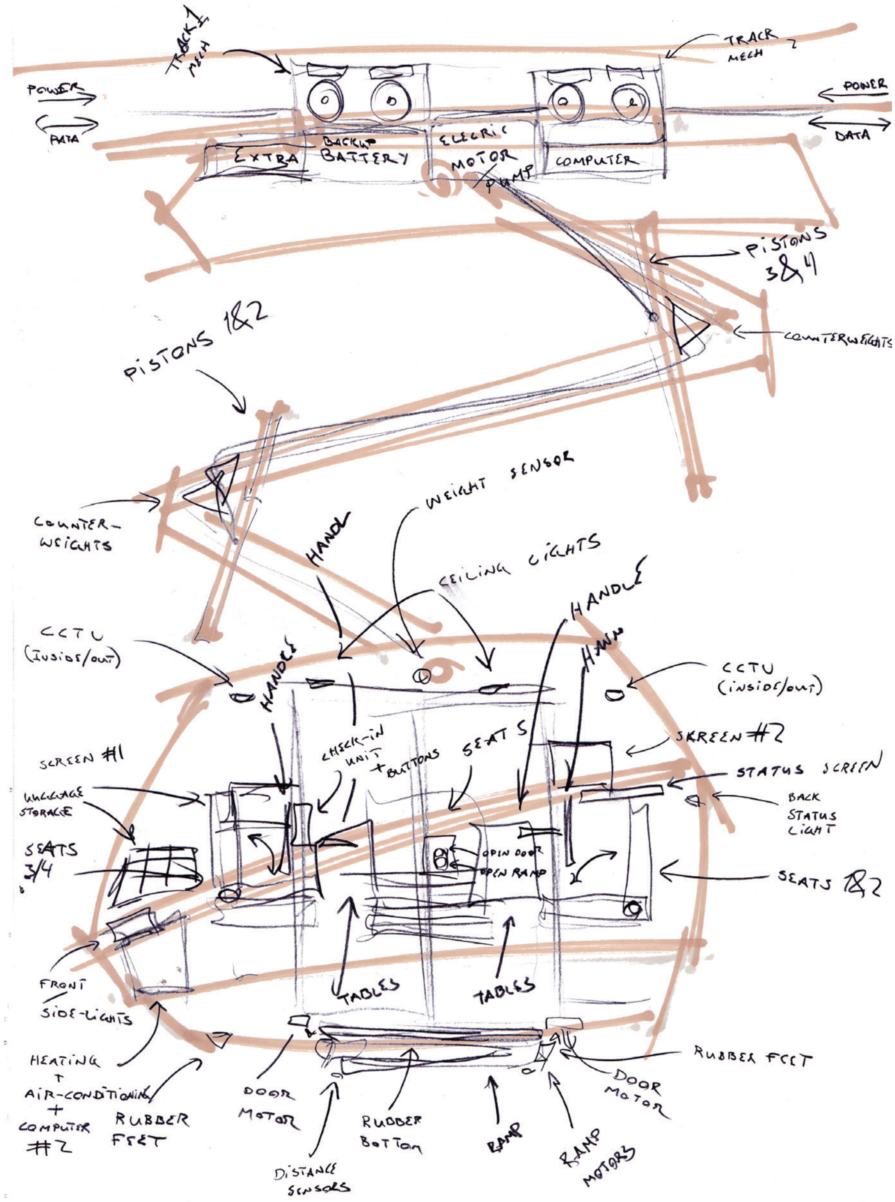
Control computer
A computer is also housed in the crane housing. It manages the control of the pod-car, and all communications with the central system control.

Hydraulic reservoir
The hydraulic system uses a reservoir to manage the hydraulic fluid.

Electric motor
An electric motor runs the pod-car (trackwheels/rail-switching), and hydraulic pumps. As the ULTra pod-cars employ a small 7kW electric motor with the average power use of 2kW (ULTra weighs 1400kg fully laden), it is assumed that this would be sufficient (Ultra Global PRT, 2011).

Backup battery
A backup battery is needed if power from the grid goes down so that the pod-car can maneuver to a safe point (for example if it is positioned over a road) and let the passengers out.

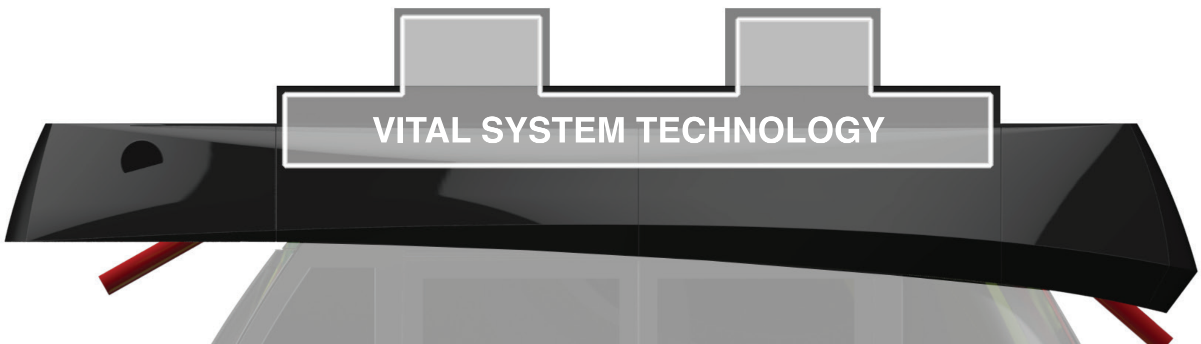
Hydraulic pump
A hydrolic pump is needed to drive the pistons.



POD-CAR TECHNOLOGY
The pod-car itself houses number of technology items.

Weight sensor
To make sure that only up to a certain weight is loaded on the pod-car, a weight sensor is needed. It is positioned where the crane meets the podcar.

Cctv cameras
CCTV cameras (four, one in each



corner) are used to monitor the pod-car. The video is archived for security reasons, in case of vandalism and for active and passive security (passive by being visible, and by that being a deterrent to criminals or vandalism). The cameras feature fisheye lenses and cover both the interior and exterior of the pod-car.

Status screen / light

Status screen shows (to the outside) if the pod-car is available or not. Three different statuses can be shown; (1) Nothing / No light, if it is unavailable or it is in transit, (2) “Available” / white light, if it is available, and “Taken/CODE” / amber light if it has been ordered (CODE being a numerical code that the person that ordered the car, got on their smartphone app/website or by the automatic phone system.

Emergency button / Intercom

For security and safety reasons, the pod-car has an emergency button and intercom system (which connects to 112/911).

Taillights & headlights

The pod-car features both taillights and headlights. The taillights are white instead of red, as to not confuse road traffic below, and are only used as an indicator of where a car is in darkness. The headlights function as status lights as well, but also as illumination to the sides for users/boarding passengers.

Touch screens

There are two touch screen interfaces in the pod-car for the passengers to select a destination or change a destination en-route.

Open door/ramp buttons

Both the interior and exterior has open door / extend ramp buttons. On the exterior they are located on the doors but in the interior they are located next to the entry. Emergency lowering and door opening lever is also in the pod-car.

Check-in

The interior features a check-in mechanism for a payment card. This is similar to the “blue-dot” system in Denmark.

Door / ramp motors

Both the doors and the ramp use small electric motors to drive the mechanism.

Ground clearance sensors

The underside of the pod-car features a series of distance sensors similar to what is used on cars. If obstructions are sensed when the pod-car is lowering, the pod-car stops and makes a sound to alert about the obstruction. It tries to lower again after an interval. After a few tries it lifts the pod-car and leaves.

Horn/Speaker

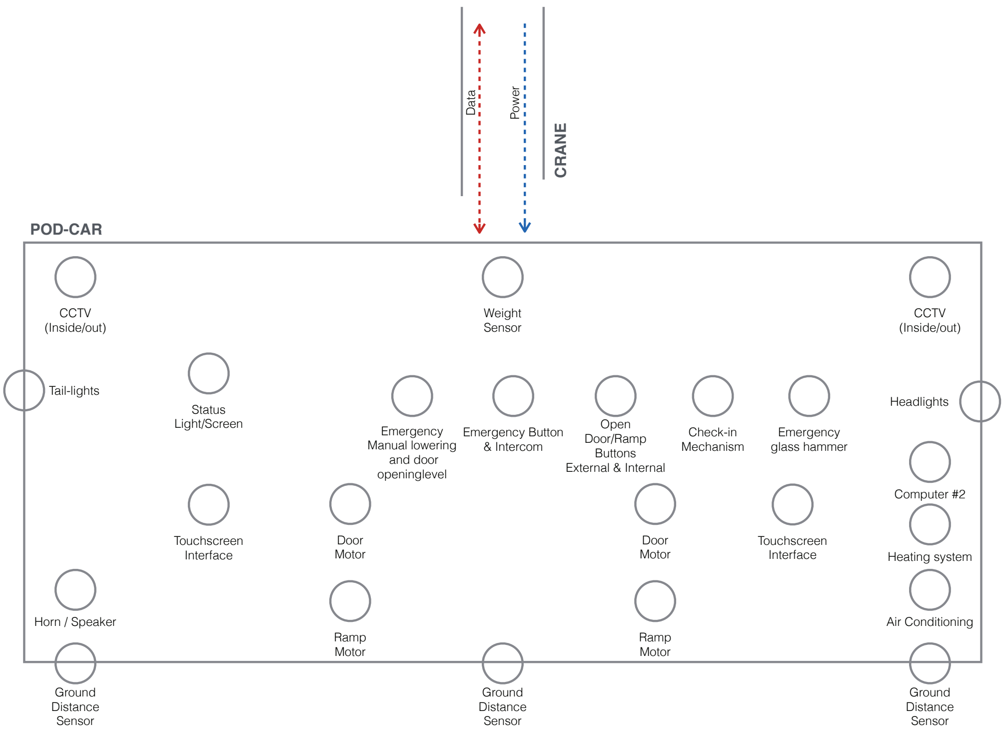
A speaker or horn is located in the front that is used to sound an alarm if the weight is to much when boarding (weight sensor), and if there are any obstructions when lowering (ground clearance sensor).

Computer

A second computer is located in the front of the pod-car and drives the touch screen interfaces and other electronics within the pod-car. It also communicates with the computer in the Cover section (Selected destination, etc.)

Heating & Air-con

Heating and air conditioning units are located in the front of the pod-car.



M

POD-CAR MAIN MATERIALS & EXPLODED VIEW

The main materials used in the pod-car are aluminum alloy (for the frame/chassis, glass (for the windows), ABS for the interior panels, rubber for the bottom, floor and feet and fiberglass or ABS panels for the outer panels. The frame is divided into a top part (window part) and lower part (which is covered with fiberglass panels).

Lightness was the main factor in choosing these materials. Early on it was considered to use Plexiglas for the windows, but because of the fact that they scratch easily, it was decided to use glass. A simplified exploded view of the pod-car can be seen on the next page and outline views of the frame can be seen in Appendix D.

The lower chassis frame is sealed with thin welded aluminum sheets (as is common in automobile chassis in space frame fashion).

It is also worth noting that the glass windows are frame-less, using bonding (glued in place).

The door panels are complete aluminum construction rather than having ABS or fiberglass panels like the rest of the pod-car.

The thicknesses of the panels, and glass are all estimated:

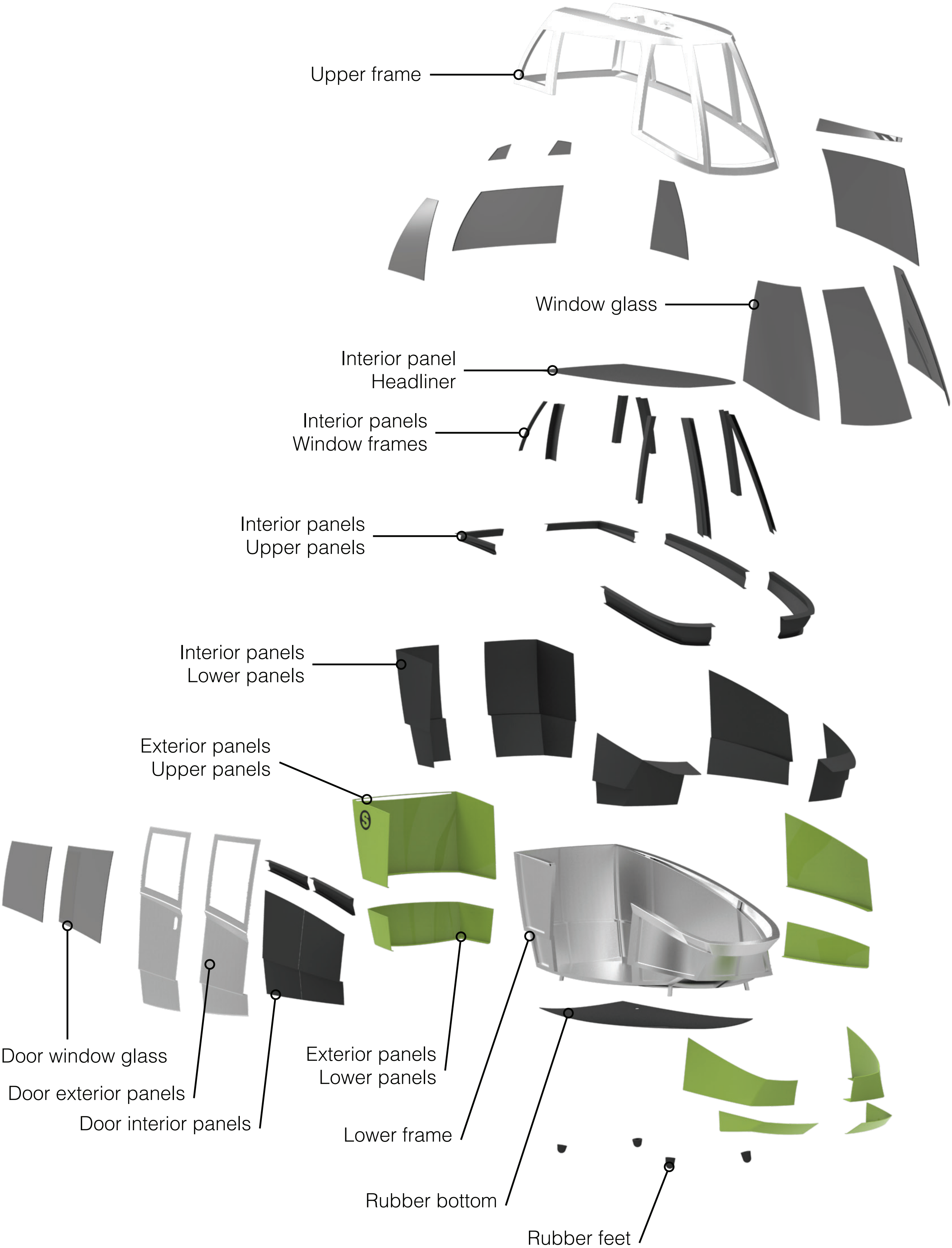
- Glass: 6mm.
- Exterior panels: 7mm
- Interior panels: 3mm

The frame is based on welded aluminum profiles:

- Top frame extrusions: 50mm (thickness not determined)
- Bottom frame extrusions: 40mm (thickness not determined)

All fasteners, screws, rubber seals, etc. are not considered. Also missing from the exploded view is the frame inside the door.

This was not detailed further.



Upper frame
Window glass
Interior panel
Headliner
Interior panels
Window frames
Interior panels
Upper panels
Interior panels
Lower panels
Exterior panels
Upper panels
Door window glass
Door exterior panels
Door interior panels
Exterior panels
Lower panels
Lower frame
Rubber bottom
Rubber feet

DETAILING

RAIL INFRASTRUCTURE

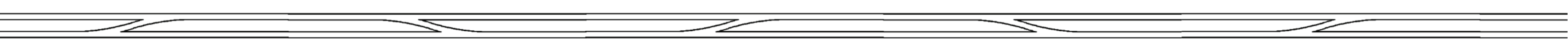
The infrastructure uses a loop network topology, as described briefly in the pre-phase. It has two track lanes, one that functions as a “go” rail (for traffic) and one as a “stop” rail. In order for this to function, frequent merges and diverges need to be between the two rails.

It is envisioned that the “stop” rail merges completely with the “go” rail before network merge and diverge network points (crossroads), and then diverges after the point, as otherwise it would be impossible for the network merge/diverge points to function.

The pod-cars also need to only be able to stop for a short time on the “stop” rail, to not block other cars that might be stopping at a similar spot, and are not behind a diverge to the “go” rail. 3 minutes is mentioned in the product report.

Switching is on-board, rather than on the track infrastructure. Many types of vechicle based track switching mechanisms exist, and an example can be seen in Appendix E.

This was not detailed further. The actual design of the infrastructure was not considered (sizes, widths, arrangement and so on), nor which type of loop network topology is used, but an example of how it could look can be seen in the product report.



“Stop” and “go rails - Frequent merges and diverges

DETAILING

SYSTEM CONTROL

Not much time could be spent on the system control in the end, but there are off-the-shelf solutions available (for example FROG network and vehicle controls - www.frog.nl). No decision was made on the manner of positioning of pod-cars (for example GPS). To give an idea of what is expected of the system control, some of the things the system has to manage can be seen here below, order is random and is not a complete list.

Route selection / calculation	Empty pod-car management and route planning
Manage distance between pod-cars	Complete vehicle management and overview
Pod-car demand control	Fare/payment management
Pod-car speed management	System load management
“go” and “stop” rail selection / track switching	Self-learning demand calculation
Error and emergency detection	Manual demand override
Network merge and diverge points control	

DETAILING

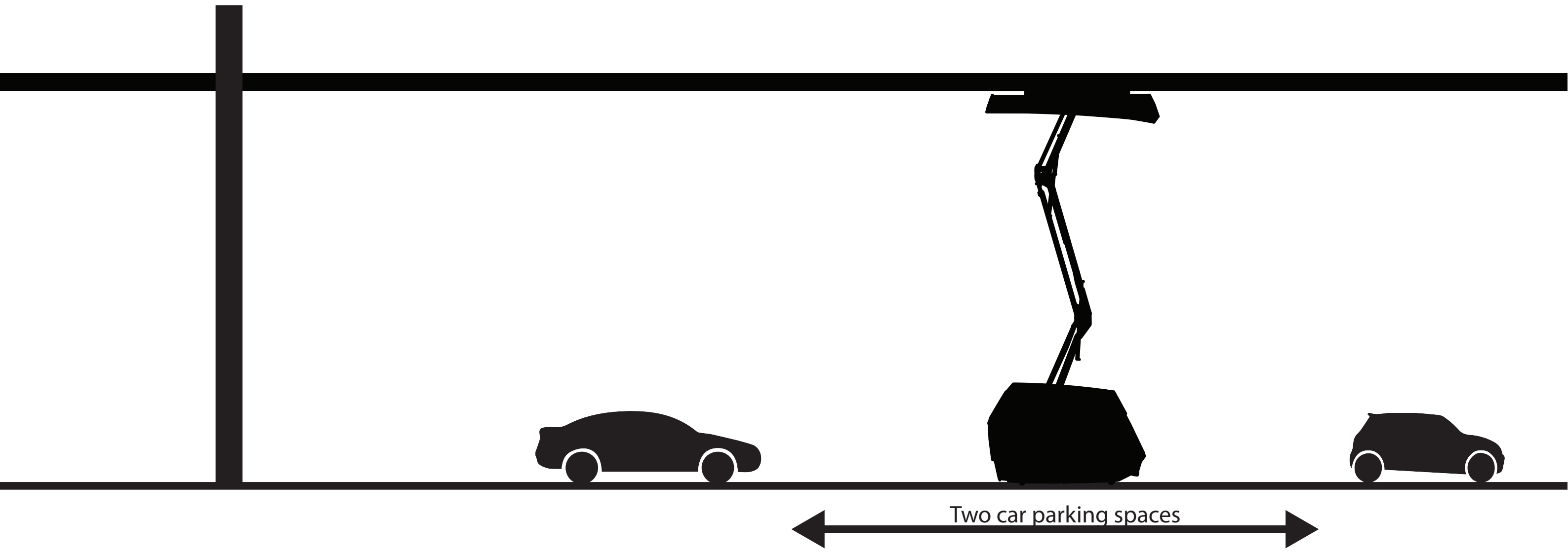
STOPS / STATIONS

Even though the system uses no typical large stations, where people can board and disembark the pod-cars, a part of the concept became that car parking spaces could be specially marked for the use of pod-cars to stop and descend onto.

This has the side-effect that if people start using the system in numbers, and stop using their cars and eventually (hopefully) sell their cars, more and more car parking spaces will be available to be used by the system. Because of the small size of the pod-car, hypothetically it could only need one car parking space, but realistically two in a row should be used for safety concerns.

Most streets in Reykjavík have parking spaces on the streets, in either of two configurations (see diagram on the next page). The rail itself would need to be strategically put up to allow for this method to be used for stopping.

This, like other things relating to the pod-car system would need a regulation change, and some



kind of new traffic symbol, to express the fact that a specific parking spot is taken for pod-cars. An idea for this could be to use a diagonal painted pattern on the ground, similar to the hazard pattern often used to mark spots that are under construction. Instead of black and yellow colors, the colors would be black and green. Both because there isn't anything using this kind of markings connected to traffic or traffic laws in Iceland, and also because of the color of the cars. This way, people have an easy way to connect the colored parking spaces to the pod-car system. The bright green color is also highly visible and is quite visible in snow and icy conditions. If visibility is a problem even with these markings, a sign (in the same lines as disabled parking signs) could be used as well.

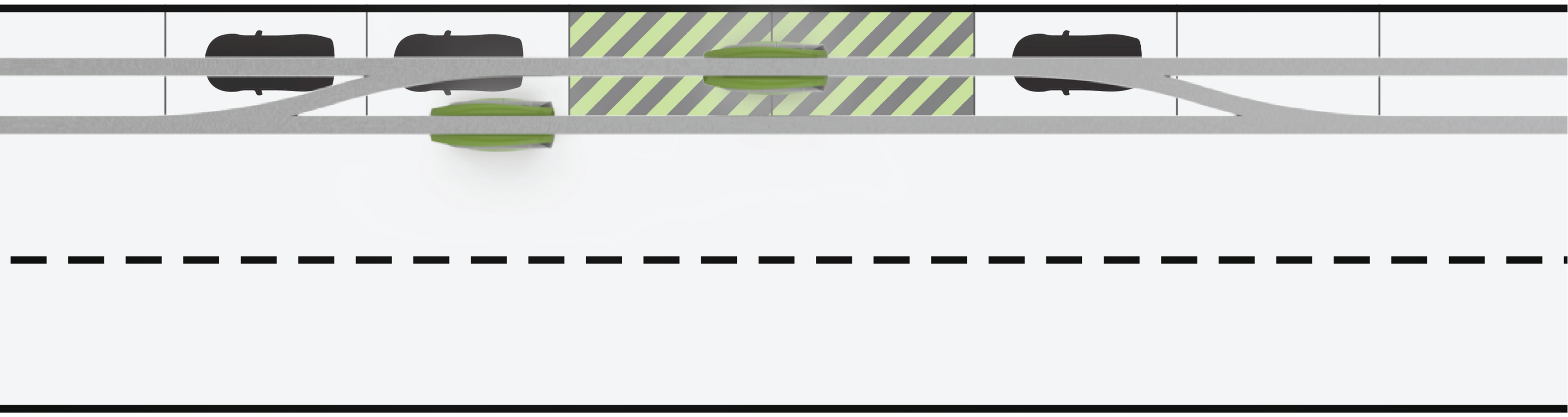
Parking spaces vary greatly in size, but obviously fit an automobile, so in relation to the dimensions of the pod-car (around 3 meters long and 1,4 meters wide) two parking spaces would be a good size to use because a lot of buffer safety space would be around the car.

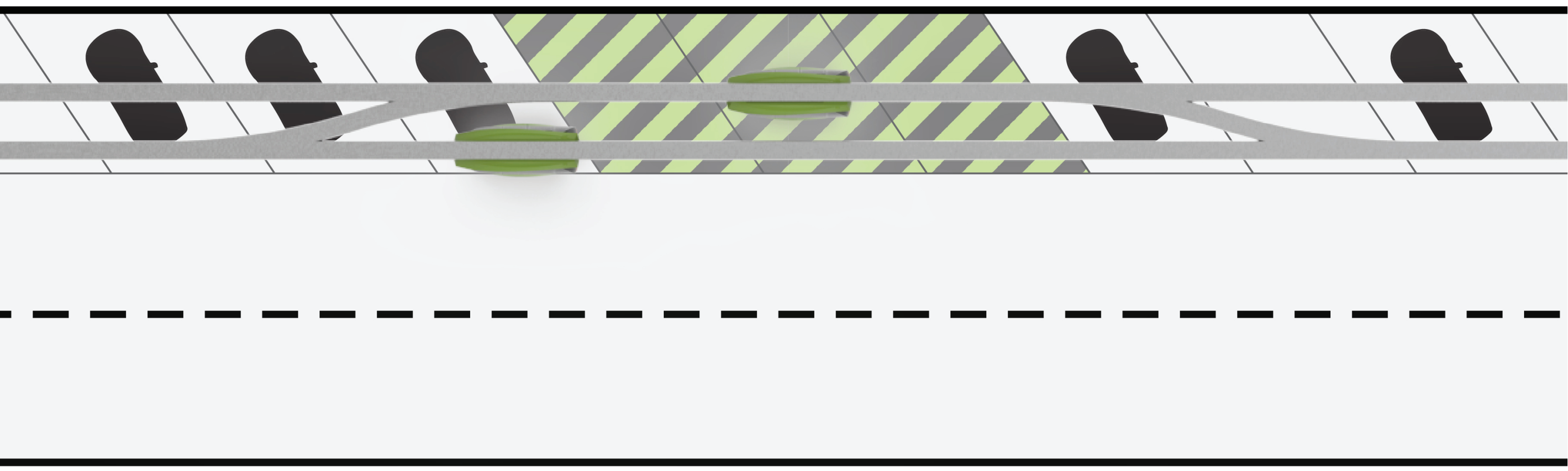
As can be seen on the illustrations here at the bottom, the main rail would then be partially over the road itself, and the stop rail over the middle of the the parking lane.

In streets where diagonal parking is used, the pod-car parking takes approximately 3 parking spaces (Illustrations are not in scale).

Where no parking spaces are available (in streets with no parking spaces), other space has to be reserved for the pod-cars. This would be decided on a street to street basis.

In the product report a visualization of a pod-car parked in its reserved parking space can be seen.

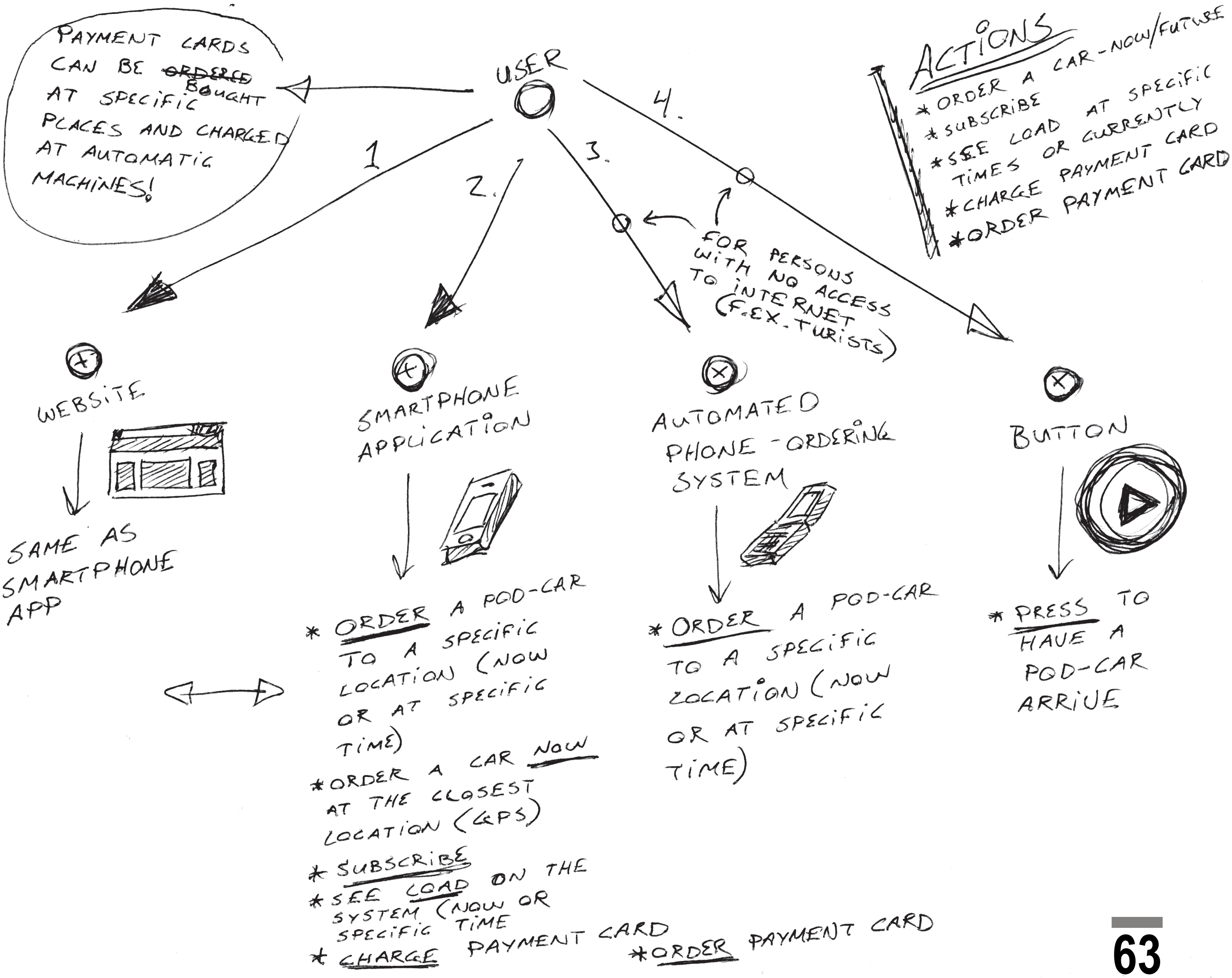




DETAILING

I USER INTERFACE

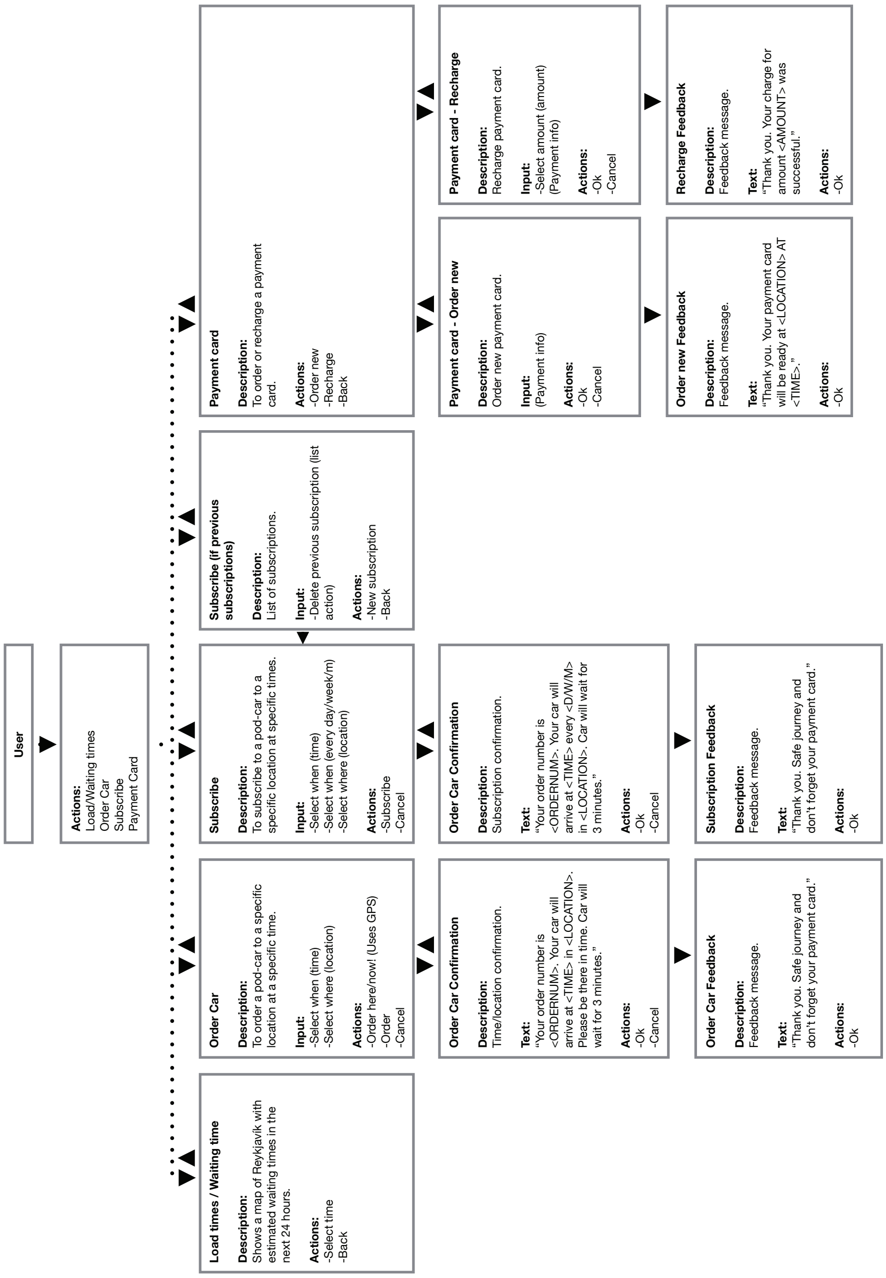
To interact with the system, for example to order a pod-car, there are 4 different channels that can be used. These are a website, smartphone app, automatic phone ordering system and specific locations where it is possible to press a button to get a pod-car to arrive at that location (similar to pressing an elevator button). These different channels are described on the next page.



WEBSITE & SMARTPHONE APPLICATION

The website and smartphone are the main channels for interacting with the system. With both you can order a pod-car to a specific location, either right away or at specific time. In either case, the system gives you an order number/code which you can use to identify your pod-car. For the smartphone app, the possibility is for the app to recoqnize the location of the user with GPS. Other actions you can do with the website and app are: Subscribe to get a car at specific location at specific times, view load on the system (estimated minutes until arrival of a car in different zones), order a payment card, and charge (top-up) a payment card. Other actions need to be available as well, for example registering for the system in the first place, etc. For simplicity sake, these are not described.

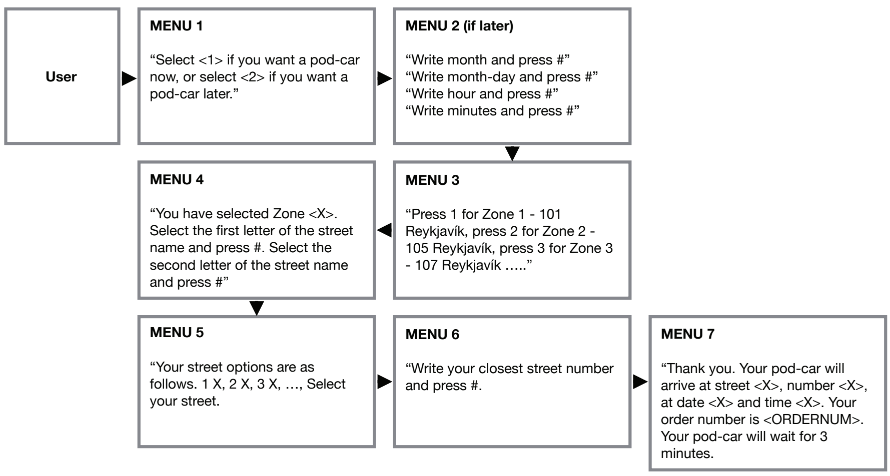
Here to the side is a simplified flow diagram for the workings of these actions on the app and website and on the next pages there are example screen-shots of the app. All error message feedbacks are omitted on the flow diagram for simplicity sake.



Website and smart-phone - Flow diagram

PHONE-ORDERING SYSTEM

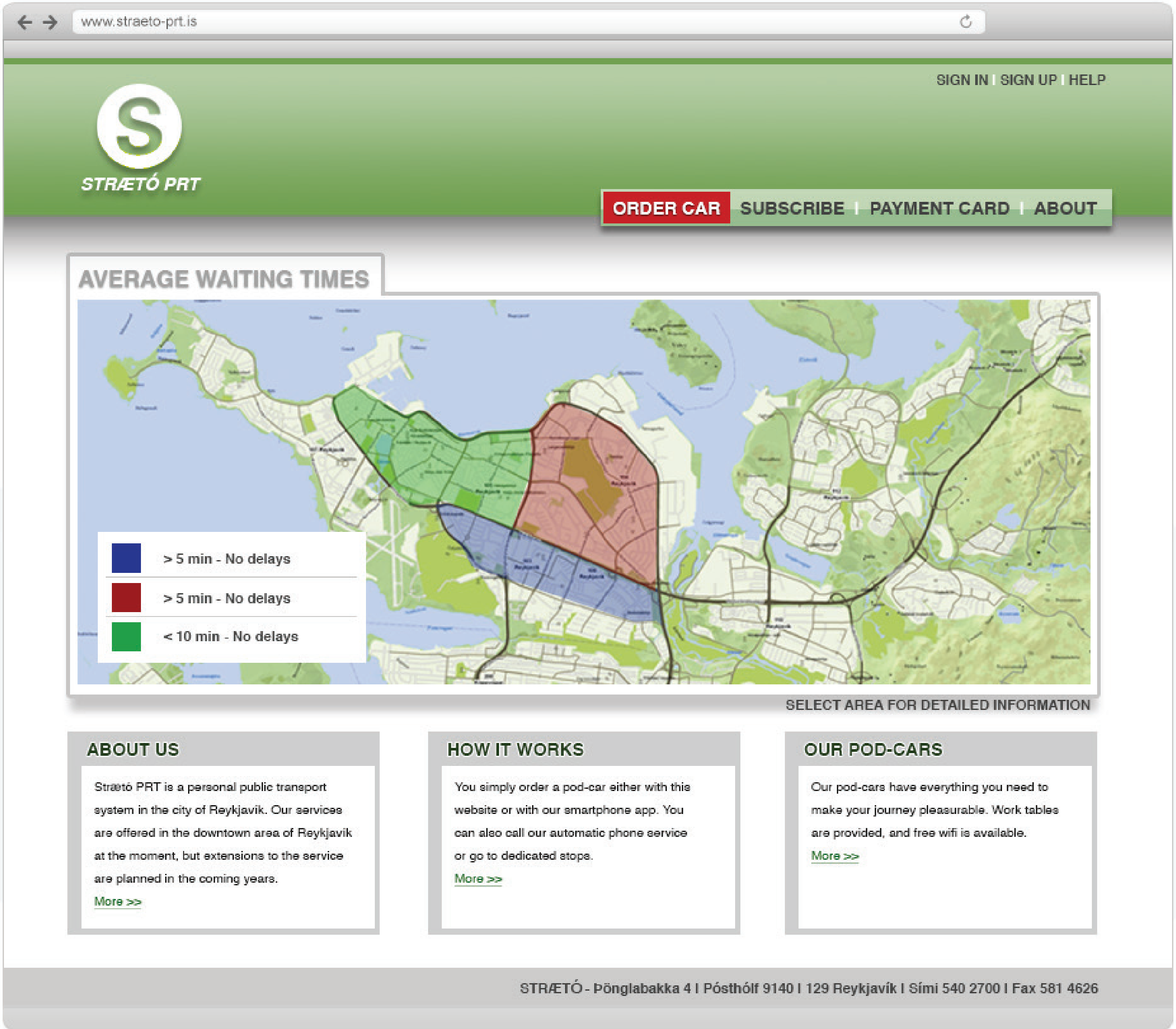
The phone-ordering system is an automatic phone system which the user can call and be led though the process of ordering a pod-car (See diagram). The system gives an order number which can be used to indentify the pod-car.



Phone ordering system - Flow diagram

POD-CAR STOP (BUTTON)

In selected areas, for example



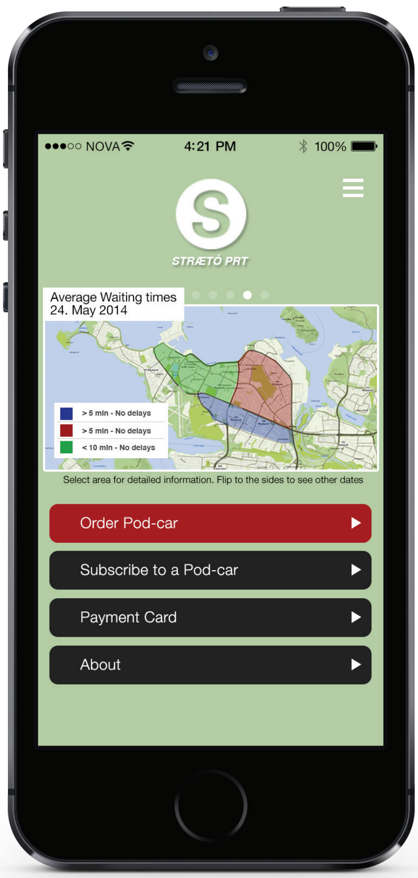
where tourists are expected to be, there should be an actual button to call a pod-car. This makes sure that even that you don't have an internet access or a phone, you can still use the system.

ON-BOARD TOUCH SYSTEM

In the pod-car itself, two touch screens are located that are used to select destination, change destination, see estimated time of arrival or stop the pod-car as soon as possible. This was not illustrated or visualized.

PAYMENT CARD

Payment cards can be bought in selected locations, for example at the offices of Strætó, bus stops and grocery stores. Both normal cards can be bought that can be recharged, as well as temporary cards that are directed at tourists and other temporary users.



DETAILING

SCALING THE SOLUTION

The usage of the proposed system can be envisioned as not only being a public transport system but also as a system for delivering products and services.

Private Companies

Private companies could have their own pod-cars (either rented or owned by the companies themselves) that are tailored to their needs. Examples of this could be restaurants (food delivery), express mail services, various transportation and product delivery services (groceries, clothing, furniture). These pod-cars could carry the branding of the individual companies. (See examples in the product report).

The municipality

The municipality of Reykjavík could have separate pod-cars for other uses than public transport. Example of this could be specialized garbage and recycling collection pod-cars.

Pod-car size

A possibility could be to have larger pod-cars for uses such as transferring larger goods.

Combining pod-cars

An idea could be to have the pod-cars function as trains between towns. They would then attach together to form a train (to reduce drag and in this way safe energy), use increased speed, and function as a normal train (non-private cars).

Many other uses could be envisioned, and here I have just touched the surface of the secondary usages of this kind of PRT system.

EVALUATION

In this section, a conclusion to the project can be found, as well as a discussion and reflection on both the process and the product. Amongst other, aspects that are missing, as well as should/could have been done differently are discussed.

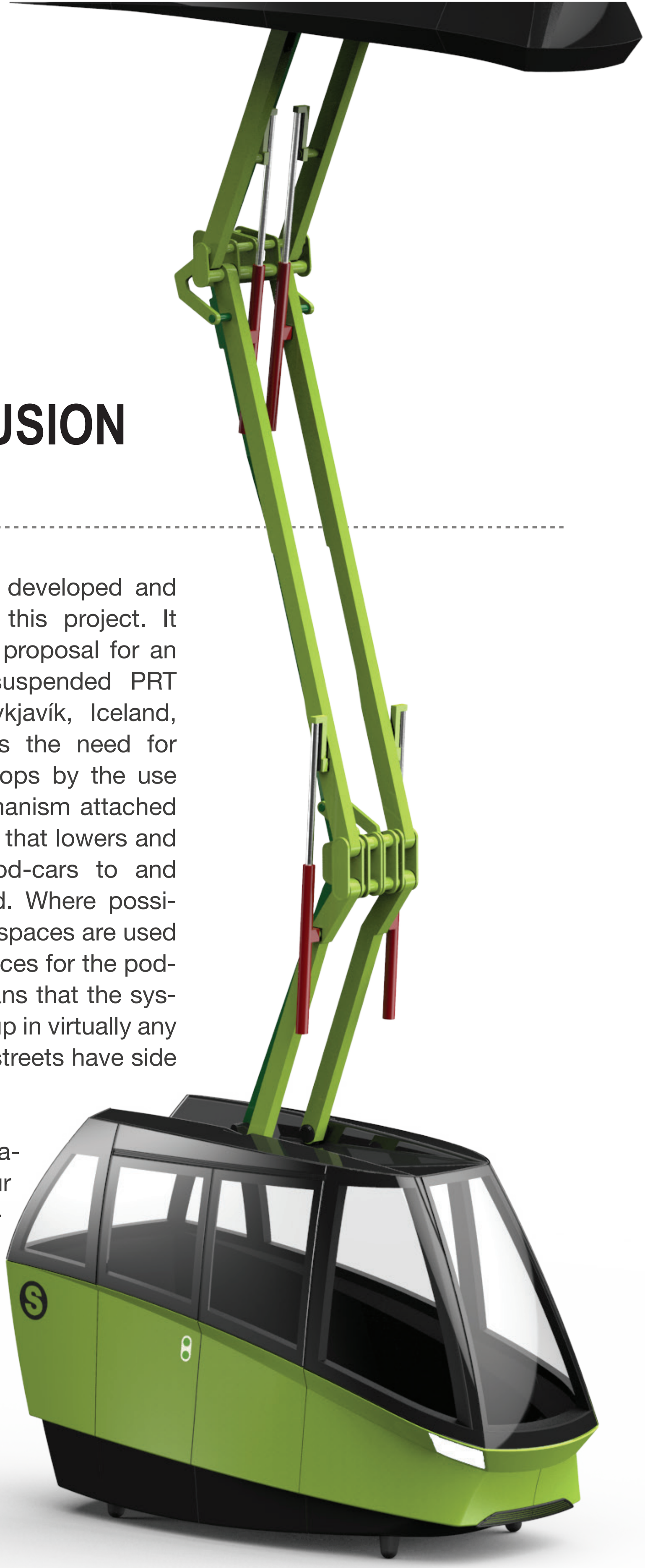
EVALUATION

CONCLUSION

C

Járngerður was developed and detailed during this project. It is a conceptual proposal for an elevated and suspended PRT system for Reykjavík, Iceland, which eliminates the need for large stations/stops by the use of a crane mechanism attached to the pod-cars, that lowers and elevates the pod-cars to and from the ground. Where possible, car parking spaces are used as “landing” spaces for the pod-cars, which means that the system can be put up in virtually any street, as most streets have side parking.

With the presentation of Járngerður in the accompanying product report, the problem statement is considered to be fulfilled.



REFLECTIONS ON THE PROCESS

I think the main problem with the process of doing this project was that I wanted to do too much, and I didn't limit myself enough. This meant that the whole project became a bit too unfocused, which can mostly be seen in the detailing part of the report, where I jump from one thing to the other, and a lot of details are superficial because of this fact. This was then amplified because of the time pressure I had in the end.

The confusion about the focus was also connected to the fact that I felt like I needed to explain every detail broadly because people generally don't know this kind of system.

Another thing that was detrimental for the process was that I got stuck on what I was trying to achieve. I started with a very general idea of a PRT system, which I discovered with the help of my supervisor around the time of the 1st midterm presentation, that wasn't good enough. I wasn't proposing anything new, or adding any kind of value to the PRT systems and designs already available. This realization, although absolutely necessary, got me seriously stuck. As much as I tried, I could not come up with a concept that would work. I had already had the idea of having a system where the pod-cars could stop anywhere, but early on I had written that off as I didn't have a solution to the problem of people embarking and disembarking the pod-cars without some kind of an elevator. The crane idea kind of appeared out of thin air, as can be seen in the concept chapter. Then the time left wasn't really enough to finish everything I had wanted, so hence the project became less detailed than I would have wanted (that again, goes back to the problem of me wanting to do too much and not limiting myself).

It is very obvious to me now that doing a project in a group has some important positive aspects. I wanted to do a project by myself to have a project, which was completely mine, and I could take all decisions by myself. This is because doing the group projects on the first semester as well as the second semester; the groups that I was a part of had a lot of problems. There were a lot of arguments and group politics, that I just didn't want to have happen again and instead I wanted to be able to focus on doing a project how I wanted to have it. Make it completely my own.

Now it is quite obvious to me that having a group-mate or mates matters in many important ways. First, it is important to be able to discuss things, as to not get stuck, as in my case. Basically, more persons in a group means more ideas, discussions and less possibility to get hung up on something, which maybe doesn't really matter when looking at the big picture. Another thing is of course that when you are alone, you can't achieve as much. You can't delegate work to others. And that relates to my project of wanting to do too much. I found out I just couldn't achieve everything in the end that I wanted, all by myself.

My time management was absolutely excellent before the point when I got stuck. After getting stuck, I lost the overview of what was needed, and when I got moving again I just had to press forward and work as fast as possible as to finish in time.

The design brief is not well enough thought out. Could be much better.

I was going to skip the focus group from the report, but added it to the report at the last minute to show that I did not only use my own hunches about the feelings and needs of potential users. In retrospect, I would have needed to do a survey, to get better input.

In retrospect, I would have needed to put a summary after each chapter, to tie everything better together. But that again was skipped because of time pressure.

One thing that needs mentioning was that it is very difficult doing a "hypothetical"/conceptual project, in the sense that not having a client. Having a client that can tell you exactly what is needed is easier than having to asses the possible need completely yourself. This of course can be amended with research, etc. but it just makes the process more difficult.

On that note, a lot of my documentation got lost because of computer problems (there is a "take backups constantly" lesson in there). Some things I had done early on I had to redo in haste. An example of this was the analysis of current PRT systems which I had done early on, but had to redo from scratch and only do in a very basic manner.

The CAD work took much more time than anticipated. Because I chose to go the route of doing rather complex surfaces as a part of the pod-car design, the work was much more difficult than I thought. SolidWorks is not the perfect tool for doing surfacing (as opposed to working with more simple solids), but I had to use it, because Rhino 3D, my other tool of choice, does not support assemblies and moving parts, which I needed because of the movement of the crane. Visualization of the project was not nearly as nice as I envisioned, again because of time constraints.

In the end, I think the concept was quite interesting, but the way I got to that concept was not correct in the sense that, because of the time pressure, I had to choose quickly, instead of exploring more what value I could add, how I could innovate, or extend the idea of a PRT system. I think doing a project like this, having the project more focused in the beginning is absolutely necessary.

In the whole, I learned a lot from this project, even though neither the results nor the process was perfect. The crane was a fun challenge, as I had not done something that mechanically complex before.

REFLECTIONS ON THE PRODUCT

As said in the process reflections, the detailing was quite superficial in the end. A lot of questions are left unanswered concerning both the system as a whole, as well as the pod-cars themselves.

Following are some aspects that I didn't manage to cover or should have been detailed more comprehensively (in no particular order, and large and small issues are mixed together).

Doors and disabled access

I didn't touch upon how the doors and the disabled ramp work. The ramp was to mechanically come out of the side/bottom, and the door was supposed to slide mechanically to the sides like on trains. Visualization of how this would look is in the product report, but it is photoshopped and faked, and wasn't modelled or worked out mechanically.

The number of pod-cars needed

I didn't cover how many pod-cars would be needed to be useful. This should need some calculations in relation to expected usage, how extensive the train network would be, and so on.

Where the pod-cars are stored when not in use, or being repaired

I didn't work out where and how the pod-cars would be stored when not in use. I thought about it, and had an idea of how it should be, but didn't have time to add it to the reports. The idea was to store them in some kind of underground matrix, where you could stack them (on rails) to safe space.

Interior

In order to get to the finish line, I decided to skip the interior completely. For me personally, that is kind of sad, as I wanted to show how it would look and feel on the inside, and give the whole thing a bit more of a human touch, make it more real.

The crane mechanism

The crane mechanism is superficially worked out, but would it work in real life? What about windy conditions? Or cold conditions (ice, frost, etc.)? Would it be too dangerous? I tried doing FEA on the crane, but I couldn't make it work for an assembly, only single parts. That did not give me any useful results as the crane has way too many parts. The thicknesses for the beams used had starting points in the thicknesses used by the cranes I saw when visiting the crane rental (but reduced because the pod-car crane has double/mirrored crane mechanism as opposed to the cranes looked at).

The crane cover

The crane cover, and everything relating to it is not worked out. For example how everything connects on the inside, how exactly big it would need to be to include all the technology needed (although I think it's safe to assume I'm not far off size wise as all the technology needed in there would not need to be large. The motor needed is tiny, the emergency battery would also need to be quite small. The hydraulics I saw on the cranes at the rental were really small volume wise. Again, this should have had been worked out, but didn't get covered. Another thing that I didn't work out (but thought about) was how the whole mechanism would work when at grade, when the rail is not level. Obviously there would need to be some kind of hydraulic mechanism to compensate and keep everything level to the ground.

Doors can't open when elevated

By accident in modeling, the door ended up partially covered by the crane cover, when elevated, and would not be able to open (as how they were envisioned working, was that they go out, and then to the sides). This would not be allowed, as obviously you would need to be able to open the pod-car when elevated, for example for emergency reasons.

Stations

I thought about the possibility of having real large stations in addition to the car-parking idea, where it might be needed because of high-traffic points/stops, for example at bus stops, at the airport, etc. But I didn't add it to the project in the end.

Hydraulic tubes and wires

The tubes and wires in the crane are not modeled nor worked on (how large and how they would connect, where they would be (hidden, etc.)

Available / taken lights

The available / taken status lights mentioned in the report can not be seen on the visualizations, simply because in my haste, it got forgotten.

Heating and air-con

In the front of the pod-car, there is reserved space for the heating element and air-con, as well as for a navigation computer. These things, and the exact volume needed were not worked on.

Interface of the pod-car screen system.

I only did work on the interfaces (and flow) for the website and app. The interface of the pod-car touch screen system and what actions you should exactly be able to do on it were not worked on.

The poles with buttons (to call a pod-car without a phone/website)

How they would be designed and so on was not devised.

Insulation

How the pod-cars need to be insulated was not worked out further than looking at cars. Cars use a thin layer of some insulating material (work as noise insulation as well), It seemed to sometimes be some kind of glasswool, but sometimes what appeared to be felt or some kind of soft fiber. I didn't go further with this, neither research nor making it a part of the project.

The rail infrastructure

Most of this didn't get time to be explored (strength in relation to the number/weight of cars needed to be supported, installation, actual rail workings, etc).

Bumpers on the pod-car cover

There are no bumpers (front nor back) on the pod-car crane cover, which would obviously need, as they might touch at some points where many are picking up users in the same spot, also because of storage of the pod-car, if they are kept close to each other, they will obviously touch.

Power of motor needed

The power needed for the pod-car and crane to function is missing (how powerful an electric motor). I did that very superficially. This applies for the other technology also.

Payment system

I didn't focus on how the payment system would work, further than just saying it would work similarly as the Danish rejsekort.

Strength of the pod-car chassis

I didn't cover this at all.

Suspension for the rail mechanism

I didn't cover this at all.

How does the system know the position of each car?

Is GPS accurate or not? Probably not, but what other means would then be used. I didn't cover this.

Total energy needed for the whole system

I didn't cover this. This would have to be calculated from the power needed by each car and how many cars would be in use at each given time.

Stress analysis for infrastructure

I didn't cover this.

Speed of the pod-cars

I didn't cover this more than mentioning the average speed of PRT systems.

Does ice/snow accumulation need considering (on rail or pod-car)

I didn't cover this.

Turn radius of the system

I completely skipped focusing on this. The pod-cars would have to facilitate turning, as well as the rail would have to be figured out (how much turn radius could be used. This is then connected to the speed of the pod-car/system which I didn't cover.

Performance of the system / Efficiency

I didn't cover the efficiency (how many passengers the system would/could carry (for example per hour) and what would be needed/acceptable in relation to foreseen usage.

Where the rail should be / need to be installed

I did put an example of this in the product report based on main roads / bus lines and where car traffic bottlenecks are, but didn't cover this in any detail.

Elevated track - Arguments

In retrospect, I think I didn't give good enough reason why the system should use an elevated, suspended rail.

Stations/stops

I didn't cover this in great enough detail or explore this part to its full extents. For example why large stations are a problem (needed better validation for this). I have an argument for this, but not a strong one.

Crane bearings and other crane details

I didn't cover the detailed workings of the crane, for example what kind of bearings it uses, etc. Generally the crane mechanism would need to be more detailed. But that is related to the lack of focus/extents of the project, not knowing how far down I wanted to dig into each detail.

Piston position

The piston location on the crane was assumed from the cranes at the crane rental. Should in reality be calculated based on where it the position would be most logical, strength- and stress-wise, etc.

Interior volume

How the interior volume was chosen was very subjective. Would in reality need much more testing. Also, testing the height of the pod-car after designing it around the interior would have been needed in reality, as in some parts of the pod-car, the volume is slightly less than found out with the frame model, for example the headroom in front and back.

Technology needed

The technology need is talked about very superficially. Would have needed to detail this and validate. But this is also related to the focus, I didn't know how far I should go into each detail.

Rubber feet and bottom

I didn't explain the reason for this at all, and some other aspects. I mention them in the product report, but not the reasoning. Sometimes the reasoning wasn't worth mentioning (for example, the pod-car obviously needs some cushions to "land" on, so rubber feet were an obvious choice. The rubber bottom was because sometimes the pod-car might land on an uneven ground where the bottom would touch the ground.

Construction and architecture of the pod-car

Very superficial, would need much more attention. Also the interior construction is missing as I didn't do the interior.

Green color usage on parking spaces

This could need some considering as green color is of course used in traffic (green traffic light), so maybe other color should have been considered.

Grid loop pattern

I didn't choose which one of the two grid loop patterns the system uses. I was going to make a choice but in the end the track infrastructure didn't get included in the project. Type B (illustration) is shown in the product report, but that type employs overhangs, which means that the pod-cars would obviously have to support descending and ascending at a grade (slanted) and from different heights. but as already stated, this wasn't thought out in the end.

Central Control System

I didn't cover this much because I ran out of time and there are systems like this that you can buy off the shelf that control every aspect of the train cars. So in a sense, it wasn't really interesting to detail.

Track switching mechanism

Solutions to this are quite common so I didn't detail this. I would have wanted to explain it a bit better, but in the end I didn't have time.

Weight estimation

The weight estimation is very basic. And in the end, it is quite useless, as the results of the estimation should then be used to calculate the strength of infrastructure (tracks and poles) needed, based on the number of pod-cars on the track at every given time. But because I didn't cover the strength and design of the infrastructure, this was quite reduntant.

Construction and materials

This was the last thing I struggled with finishing. It is very basic, but shows the main materials and basic construction (exploded view) of the pod-car. This should have been much more detailed.

General

Generally a lot of details are missing about the workings of the system, crane and pod-car. But I think my project is an ok overview of this kind of system. Again coming to the fact of lack of focus, I didn't choose my battles well enough, what exactly I wanted to achieve. I probably should have chosen more focused aspects to work on and leave others completely. But this is how it went in the end.

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All other images and illustrations are the work of the author of this report.

APPENDIX

APPENDIX A: FOCUS GROUP

Focus group was held with persons who have used the public transportation in Reykjavík, but don't on a daily basis (all being car owners) to get some input from individuals who didn't know PRT nor what the project is about beforehand.

Three discussion topics were used:

- Why don't you use Strætó more, and why do you think so few people use Strætó?
- What would need to change for you to take the bus more?
- Would you use public transport that is available at the time when you need it, and it was a private bus/car? And it would not stop on the way to your destination?

RESULTS

Why don't you use Strætó more, and why do you think so few people do?

Inefficient when it comes to time, takes way too long to go anywhere with buses.
Boring waiting for buses.

On a positive note, because it takes so long, you can sometimes get some work done.

When I was using strætó, it took 1,5 hours to take my daughter to school and come back home. By car, this would take 15 minutes.

Everywhere you go takes too much time. Sometimes it means you would rather take a taxi even though it would cost much more.

In many instances you have to change buses, which is annoying because it takes time, sometimes you have to wait for a long time for the next bus and sometimes the weather is terrible.

In some instances, I had to change bus 3 times. Extreme example, but that is what some people need to do if they live far and need to take the bus.

Seats are uncomfortable, not space to extend your legs.

My main problem is how much time it takes, and when you are both in school and work which are located far away from each other, it gets tedious, even impossible.

Annoying to sit besides strangers or against them. Basically lack of privacy.

Bus shelters are not good, in fact

usually terrible. There is a gap at ground level so the wind and snow can access them. The old type of shelters was much better.

In some cases at bus stops, there isn't even a shelter. Which is terrible when you miss the bus and have to wait in the windy weather for 20-30 minutes for the next one.

Sometimes on some bus lines on peak traffic times it can get very tight, too much people. Often you need to stand and sometimes completely up against other people.

People take the bus just if they absolutely have to. For example if they don't have a car which is rare in Iceland.

Sometimes it is ok to take the bus, but only if you don't have to change bus at all.

People only take the bus if they can't afford a car or the car is broken.

The car is always better because you don't have to wait for it in a shelter for 30 minutes. Also if you are going a short route then the trip is not going to take you forever like it would with the bus.

I would take the bus more often if the routes where logical and it didn't take so incredibly long to go anywhere.

It was more economical in my case to have a car than use the bus because I had both work and school to go to, and the routes where not favorable for me.

Annoying to be dependent on a time schedule and not being able to just go somewhere without waiting or changing buses.

What would need to change for you to take the bus more?

The bus shelters, they are now terrible. But that is a result of having to wait for the bus. And if you miss the bus you have to stay there for 30 minutes. If it was 10 minutes, then it wouldn't matter as much.

Sometimes have to walk quite a distance to your bus shelter, which is annoying. Bus shelter position planning might be better

If you were fast between places, you didn't need to wait and you could just jump on the bus right away, then it would be different.

If you are lucky about bus stops, if it is not far you have to walk and it comes right away, then it would be ok.

If you didn't have to change buses, sometimes many times to get to some places.

On Sundays, the buses do not start going until almost at noon, that also has a great effect on my usage. Sometimes I need to go somewhere early on Sundays but I can't because there is no bus.

It's not allowed to take dogs on buses. So I can't take my dog on the bus.

Better payment system, here we have these ridiculous paper tickets (although you can also pay with coins) but a punchcard would be much better.

Something that would help me remember to take "continue ticket! (a ticket you have to take if you change buses). You have to remember to get one from the driver at the start of the first trip, and if you forget it you have to pay a second fare on the next bus.

The bus website is not good, if you need to organize a trip somewhere, especially for people that don't know the route system already.

It has to make me feel a bit less like I'm on a cattle wagon. Everything is so raw and annoying.

Interiors are raw and ugly and not comfortable.

It would be great if you could jump out and the bus is there right away. And also when you are late, that you don't have to wait a whole half an hour for the next bus.

The buses don't make it easy to take stuff with you, for example grocery bags. It is quite difficult to take a few grocery bags with you.

Also a problem is that when the bus is full during peak hours, it can be impossible to take a bike with you. You can only take baby carriage or a bike with you when the bus is not full.

PTR explained to the group and they asked if they would use such a system.

Yes I am quite sure I would.

Yes that would also make it easier traveling with my dog. And my bicycle. Or grocery bags.

I wouldn't have to wait at a bus stop in the wind and cold.

APPENDIX B: PRIMARY BRAINSTORM

To open up and explore if any issues could be brought to the surface, a divergent brainstorm is done with the help of the Lotus Blossom Technique.

As the main focus of this project is the Pod-Car itself, only the boxes "Users", "Exterior" and "Interior" is explained below.

THOUGHTS/ OUTCOME

Users

Child-safe
Are some considerations needed for the system to be child-safe? Do children need different seating?

Disabled & Elderly Access
What are the considerations needed for the disabled and elderly? Some mechanism to help them get on and off the pod-cars? What are the different help tools that they might need to bring on the pod car? Wheelchairs? Walker?

Distance/Time to next station
How far does a user need to walk to get to the next station? How long does it take and how does it compare to current public transport?

Able to change course when en route
How does the user change course when already en route?

Number of passengers?
How many passengers should each Pod-Car take?

Safety / Seatbelts
Are seatbelts needed? Any other safety considerations?

What kind of belongings?
What kind of luggage/belongings should be considered?

Keep passengers warm
How is the pod-car heated?

Pod-Car Interior

Materials
What materials are suitable for the interior? Are special considerations needed because of constant usage?

Construction
How is the Pod-Car constructed?

Facilitate work & play
What is needed to facilitate work and play? Tables? Power-outlets?

Styling

How should the styling of the interior be? Should it be based on functionality first and foremost?

Emergency stop & exit
How does emergency stop & exit work? Can the passenger contact a central service if there are problems?

Space for Luggage/Belongings
How much space is needed for belongings/cases/bags, etc.?

Loading / Unloading (Doors)
How do the doors work? Any special considerations for disabled people?

Seating
How do the seats need to be? Any special considerations?

Pod-Car Exterior

Power/Motor
What kind of motor is needed considering weight and speed of the pod-car? How much space does it need along with accessories? Where is it located in the pod-car?

Styling
How should the styling of the exterior be? What are the considerations needed to be taken for the styling? Are there Icelandic inspirations that can be used? Cultural influences?

Materials
What materials are suitable for the exterior? Weight considerations? Weather considerations?

What size?
What should the size be considering the number of passengers and belongings, disabled and the elderly?

Construction
How is the Pod-car constructed?

Lights needed?
Are lights needed?

Strength
How much weight should the pod-car need to hold and what can the usage of the pod-car be hindered to prevent too many passengers/too much weight?

Wheels or rail?
Will the pod-car have wheels or rails?

UNDERGROUND / ON ROAD / ABOVE GROUND?	HOW MUCH STRENGHT IS NEEDED?	WHAT MATERIALS ARE SUITABLE?	USABILITY	VIEW WAITING TIME	VIEW TRAVELING TIME	WEBSITE	SMS	APP (IPHONE/ ANDROID/ MICROSOFT)
HOW DOES IT GET POWER?	**INFRA-STRUCTURE**	WHERE IS THE MOST NEED? (PILOT AREA?)	STYLING	**USER INTERFACE**	SCHEDULE POD-CAR EVERY DAY / WEEK	IN POD-CAR	**CHANNELS**	AT STATIONS
HOW IS THE RAIL?	HOW DOES IT FIT WITH CURRENT INFRASTRUCTURE?	PLANNING INFRASTRUCTURE BUILD-UP	BE ABLE TO ORDER POD-CAR IN ADVANCE	PAYMENT	STUDENT / ELDERLY DISCOUNT	PHONECALL	PAYMENT METHODS	PENALTY PAYMENT IF NO-SHOW?
INTEGRATE WITH BUS STOPS?	DISTANCE BETWEEN STATIONS?	HOW MANY POD-CARS CAN STOP AT THE SAME TIME	INFRASTRUCTURE	USER INTERFACE	CHANNELS	WHAT CONTROLS THE SCHEDULING?	HOW MANY POD-CARS ARE NEEDED?	SPEED OF POD-CARS?
STOPPING WITHOUT OBSTR. OTHER P.CARS?	**POD-CAR STATIONS**	SAFETY AT STATIONS? (NOT INJURING USERS)	POD-CAR STATIONS	**PRT SYSTEM IN REYKJAVÍK**	SCHEDULING	WHERE ARE UNUSED POD-CARS STORED?	**SCHEDULING**	INTEGRATE SCHEDULING W/ OTHER MEANS
STYLING / MATERIALS	ARE STATIONS NEEDED AT ALL?	HOW TO RECOGNIZE YOUR POD-CAR?	USERS	POD-CAR INTERIOR	POD-CAR EXTERIOR	WHAT IS SAFE DISTANCE BETWEEN P.CARS?	TWO WAY OR ONE WAY?	DIFFERENT SIZES OF POD-CARS?
CHILD-SAFE	DISABLED AND ELDERLY ACCESS	DISTANCE/TIME TO NEXT STATION	MATERIALS	CONSTRUCTION	FACILITATE WORK & PLAY	POWER/MOTOR	STYLING	MATERIALS
ABLE TO CHANGE COURSE WHEN EN ROUTE	**USERS**	NUMBER OF PASSENGERS?	STYLING	**POD-CAR INTERIOR**	EMERGENCY STOP / EXIT	WHAT SIZE?	**POD-CAR EXTERIOR**	CONSTRUCTION
SAFETY/SEAT-BELTS?	WHAT KIND OF BELONGINGS?	KEEP PASSENGERS WARM	SPACE FOR LUGGAGE/ BELONG-INGS	LOADING/ UNLOADING (DOORS)	SEATING	LIGHTS NEEDED?	STRENGTH	WHEELS OR RAIL?

APPENDIX C: PRIMARY SKETCH WORKSHOP

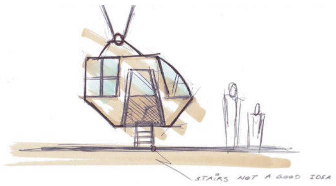
The first concept workshop was held without any constraints and with the least input or analysis behind it. This was a way to explore the topic without any predetermined influences or direction and to open up to the task at hand. All sketches are therefore fast and loose. No specific focus or was used and an holistic process was used instead of having a specific focal point.

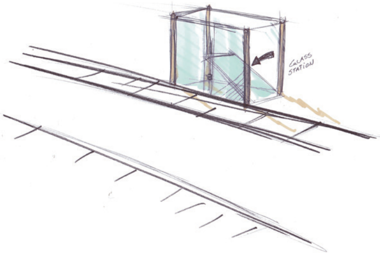
THOUGHS / OUTCOME

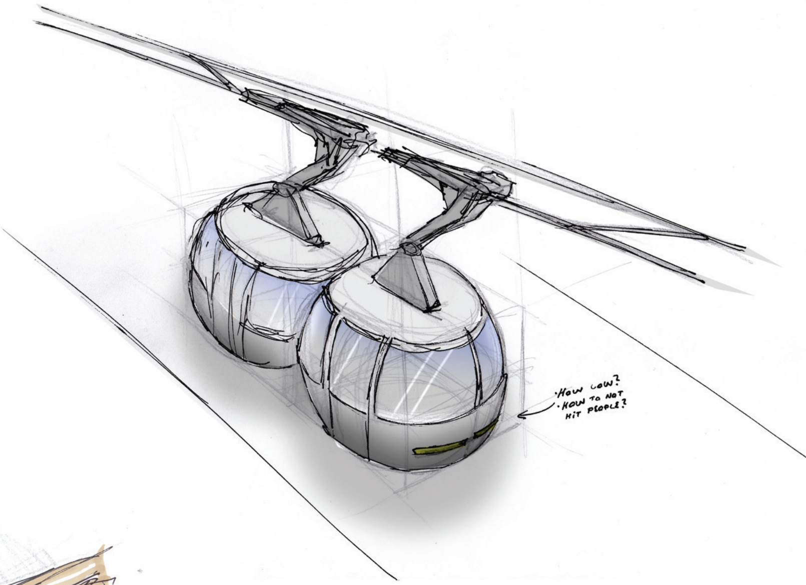
The main ideas that came from this workshop are presented on the next page. A more complete results from this workshop is shown in Appendix X.

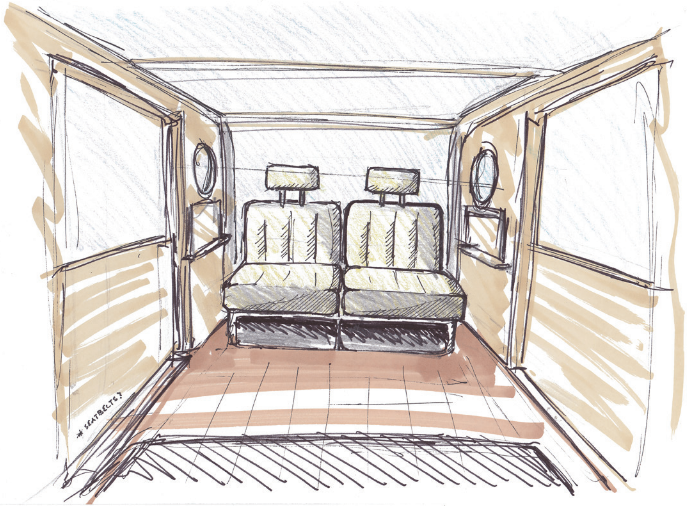
The workshop opened up many issues and questions. Some questions and thoughts were:

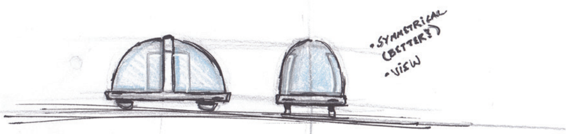
- Stairs are obviously not good idea from a accessibility standpoint.
- If the stations need to close between, they need to fit into the environment and not clutter it (glass used?)
- How does the rail switch work?
- Does more classic style fit better in Reykjavík than modern?
- Will the transit be on the ground, or suspended?
- If suspended, how does it move up to travel height when leaving a station?
- Is symmetrical transport better in some way?
- Is view (for the passengers) necessary or vital?
- Are seatbelts necessary?
- Can bike rack be included somehow?
- Tables/work area?
- What is the size of the podcar?
- How can pedestrian and user safety be guaranteed?

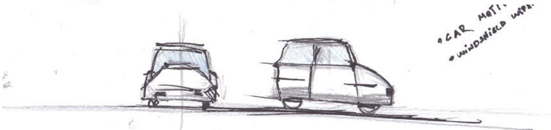

STAIRS NOT A GOOD IDEA


GLASS STATION

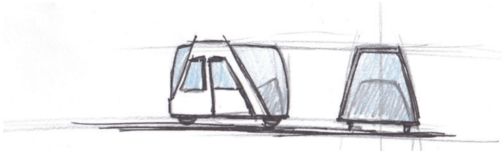

• HOW LOW?
• HOW TO NOT HIT PEOPLE?

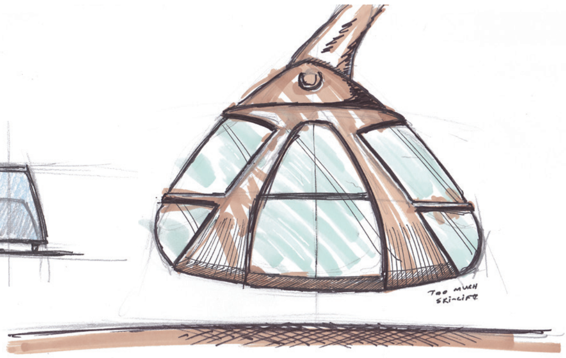

* SEATBELTS?

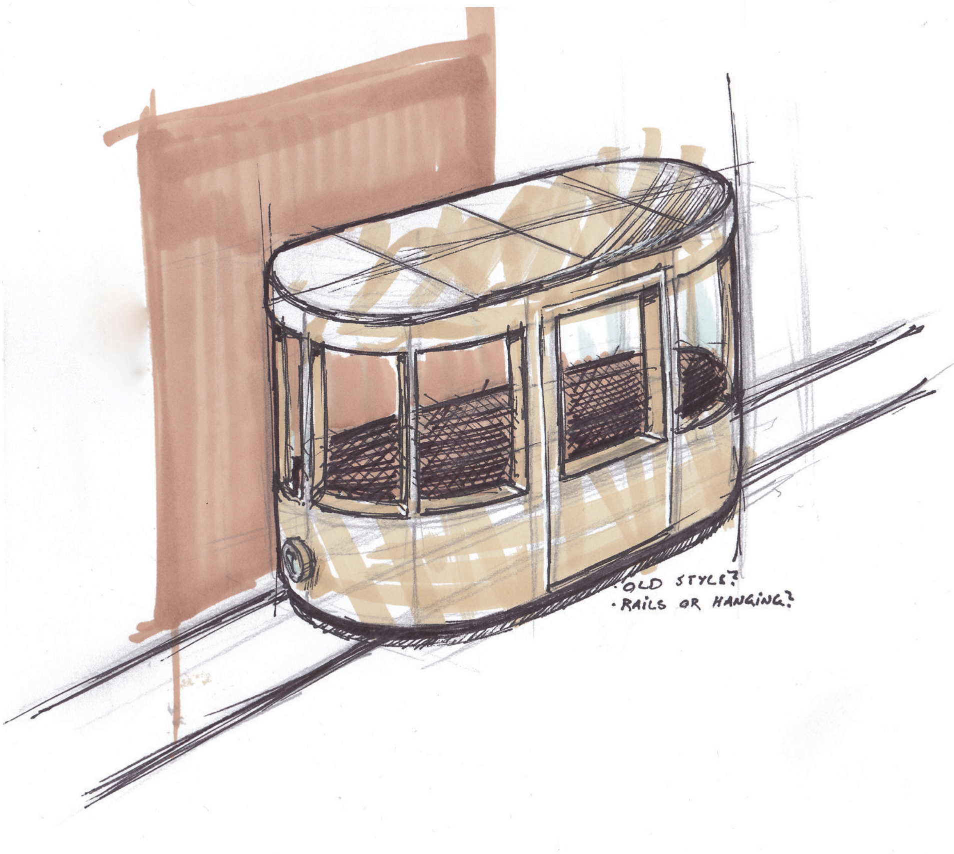

• SYMMETRICAL (BETTER?)
• VIEW

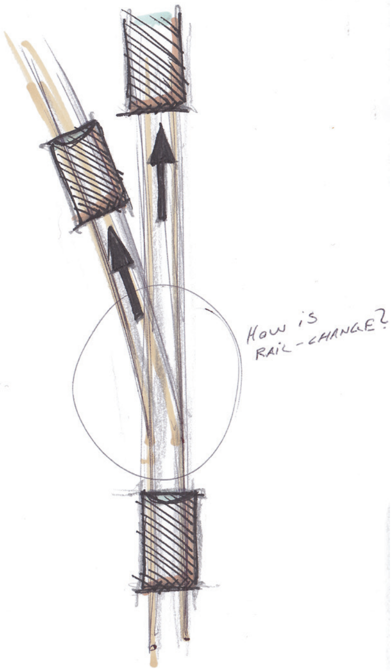



BIKERACK?

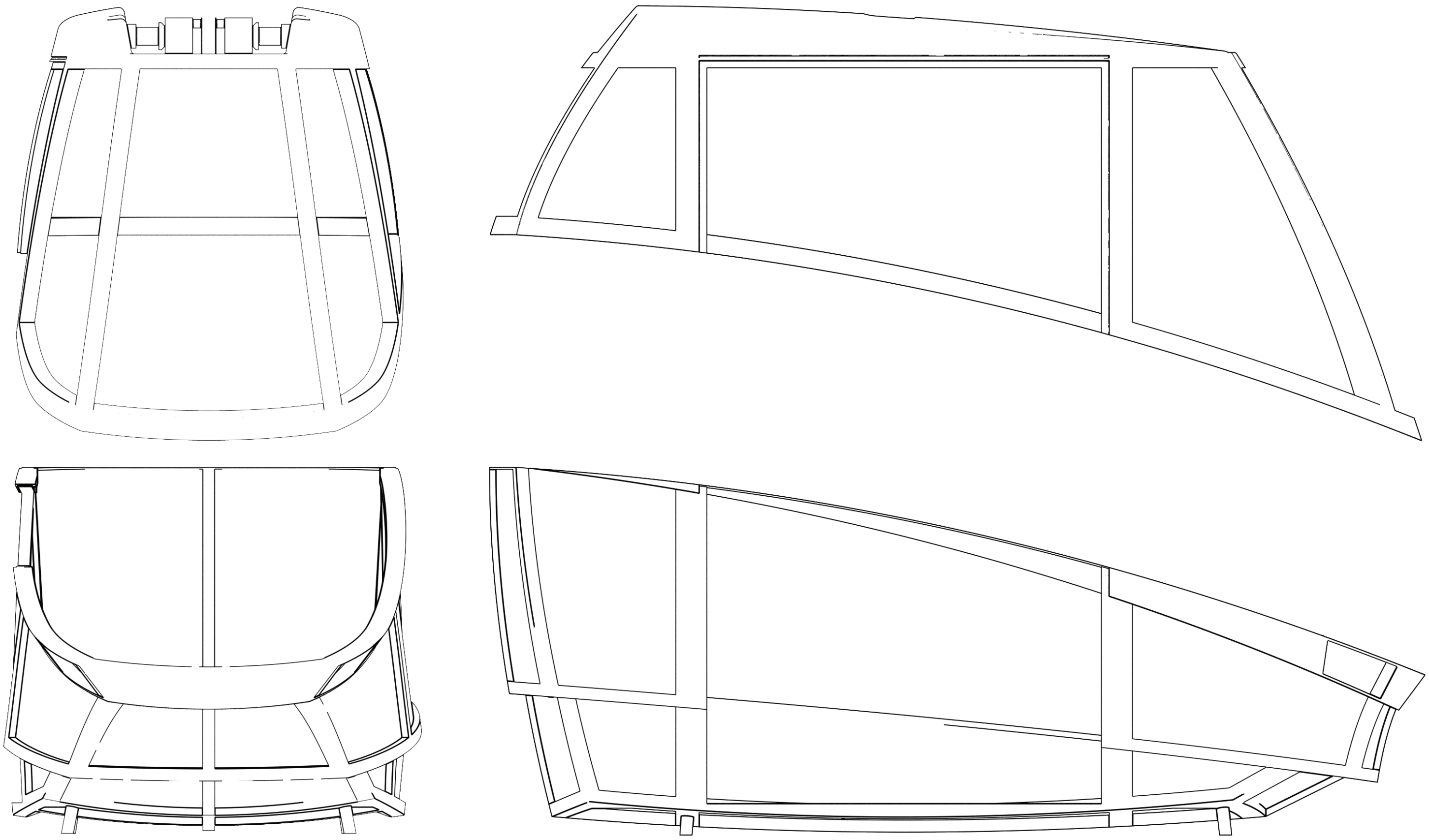


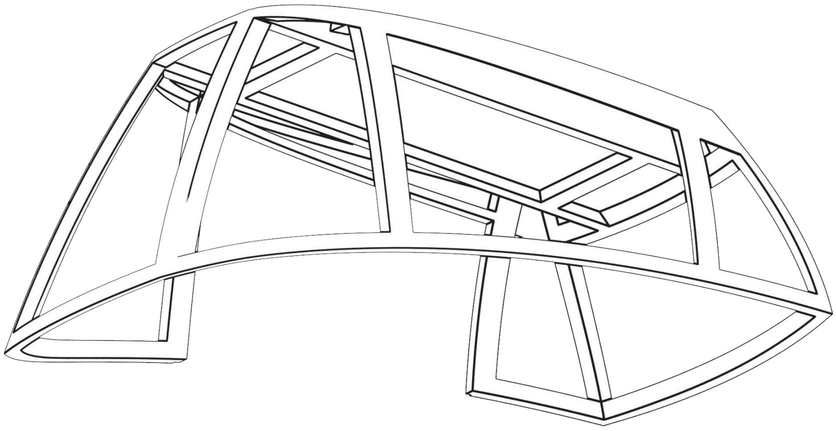


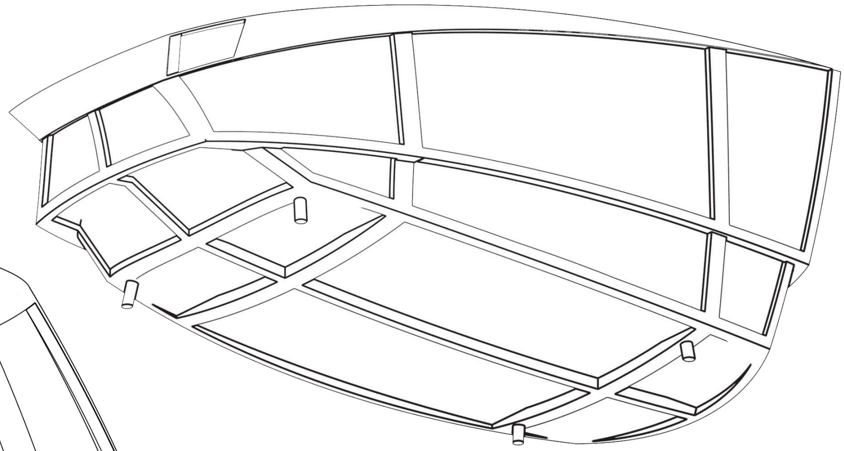

• OLD STYLE?
• RAILS OR HANGING?

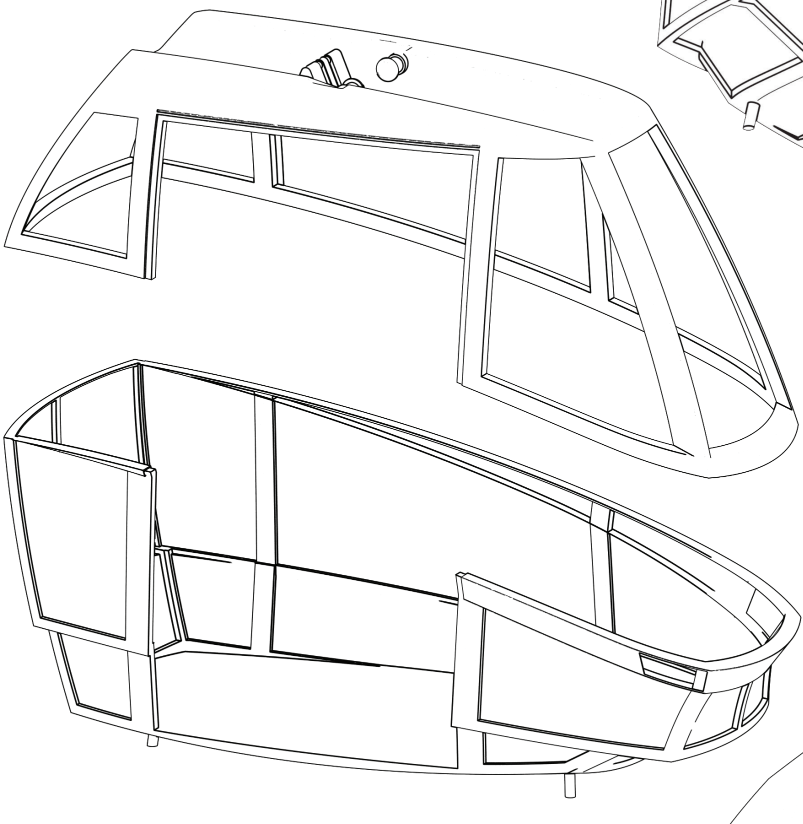

HOW IS RAIL-CHANGE?

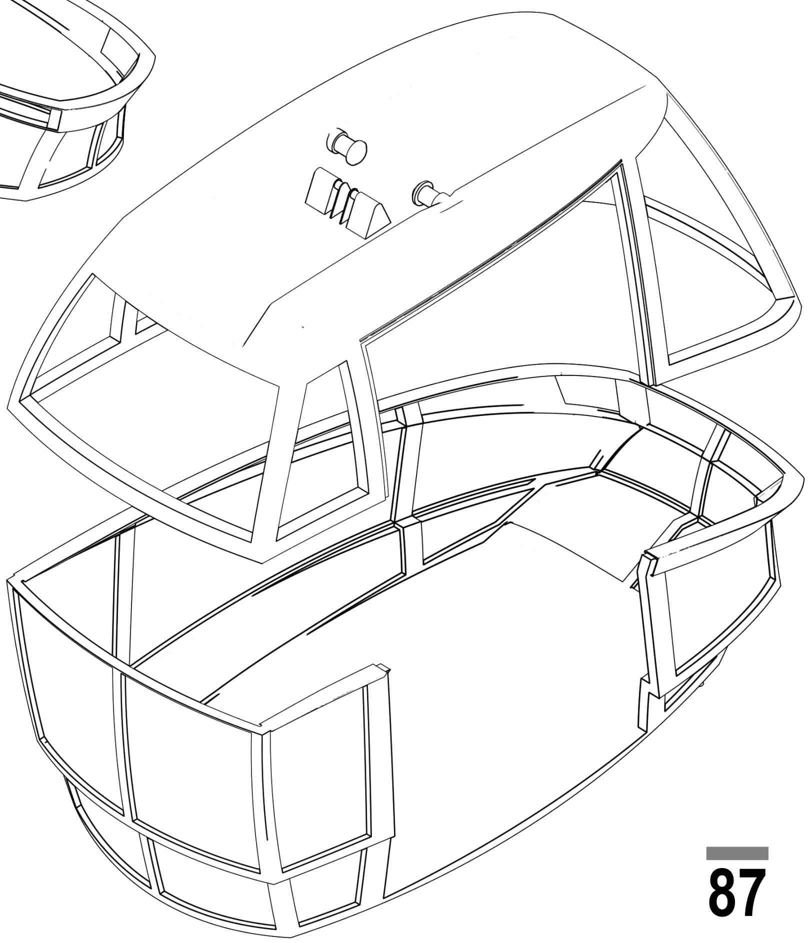
APPENDIX D: POD-CAR FRAME OUTLINE VIEWS











APPENDIX E: VEHICLE BASED TRACK SWITCHING (EXAMPLE)

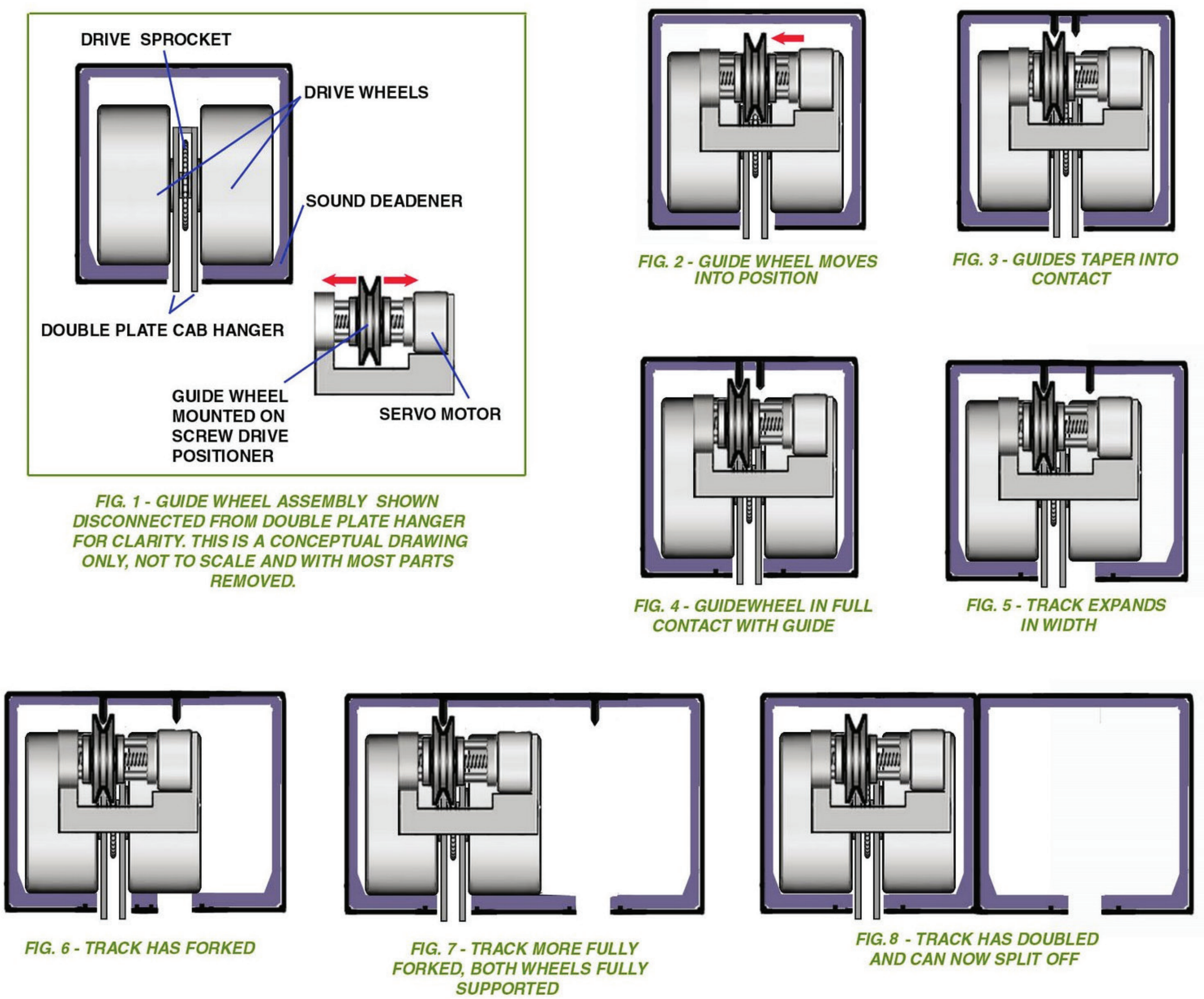
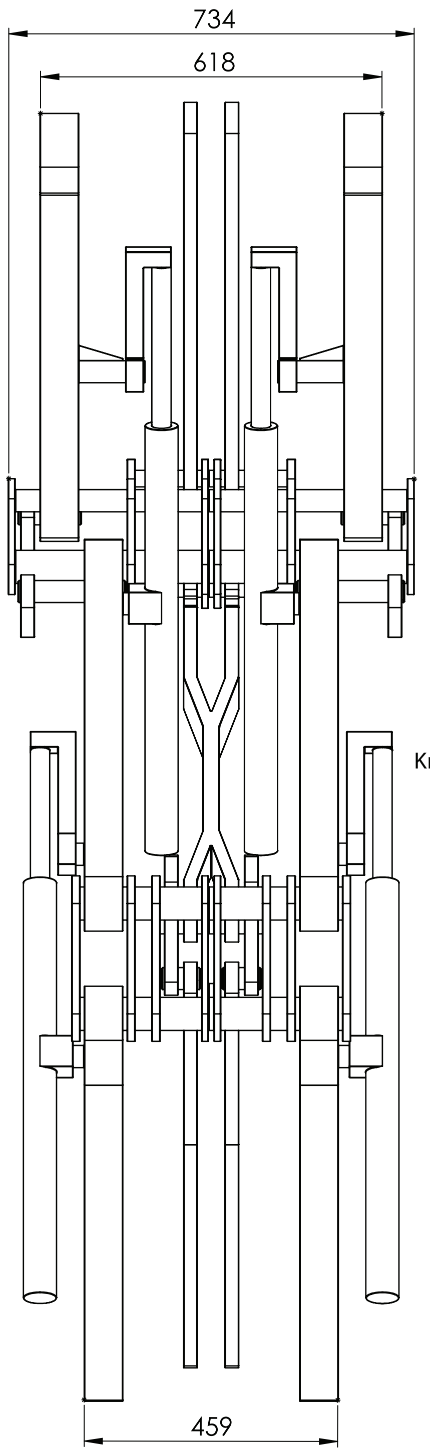
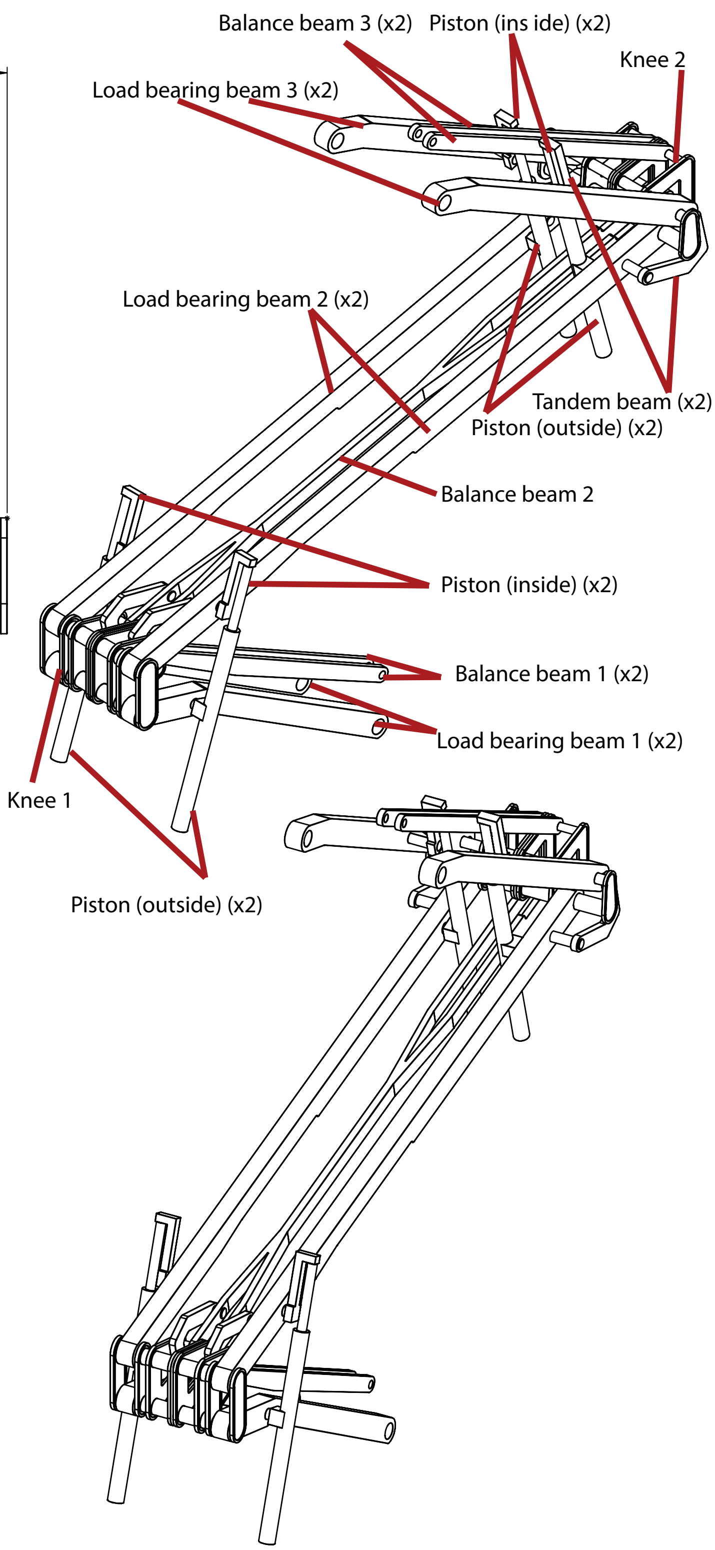


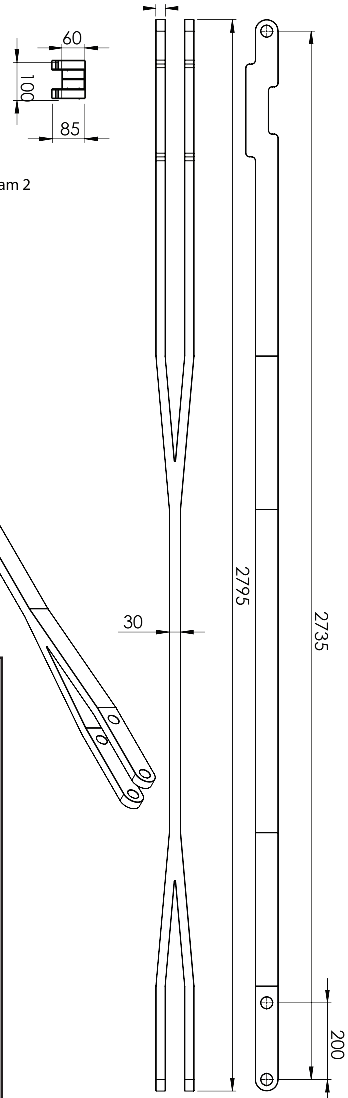
Fig. 14. On-board track switching mechanism

APPENDIX F: CRANE PARTS - DIMENSIONS

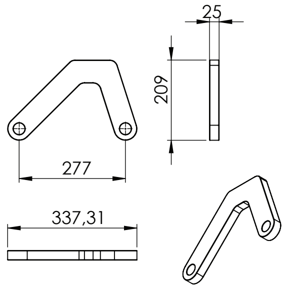




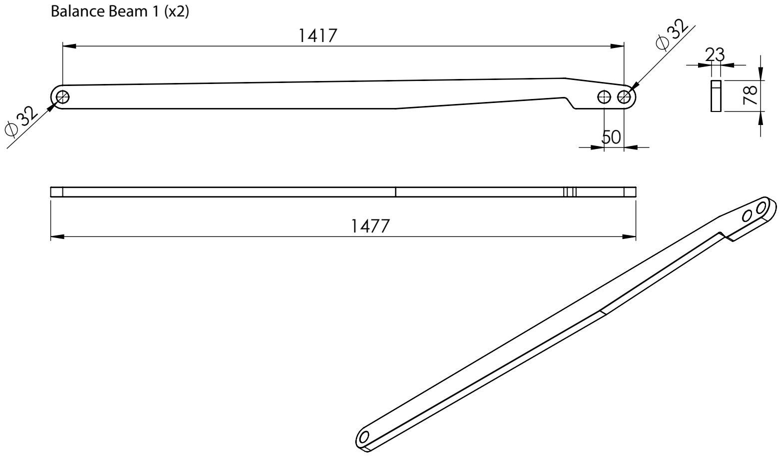
Balance Beam 2



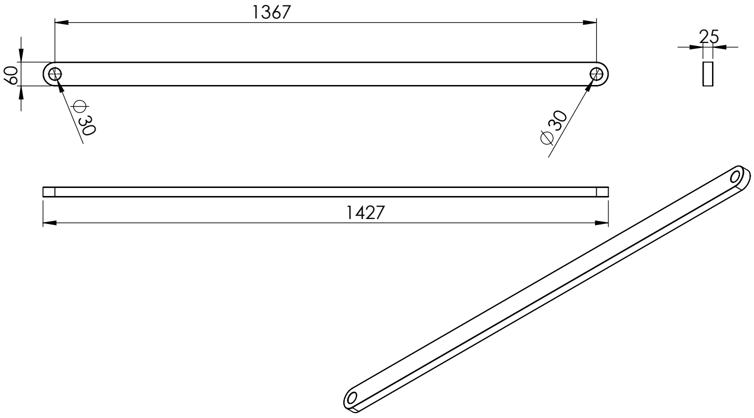
Tandem beam (x4)



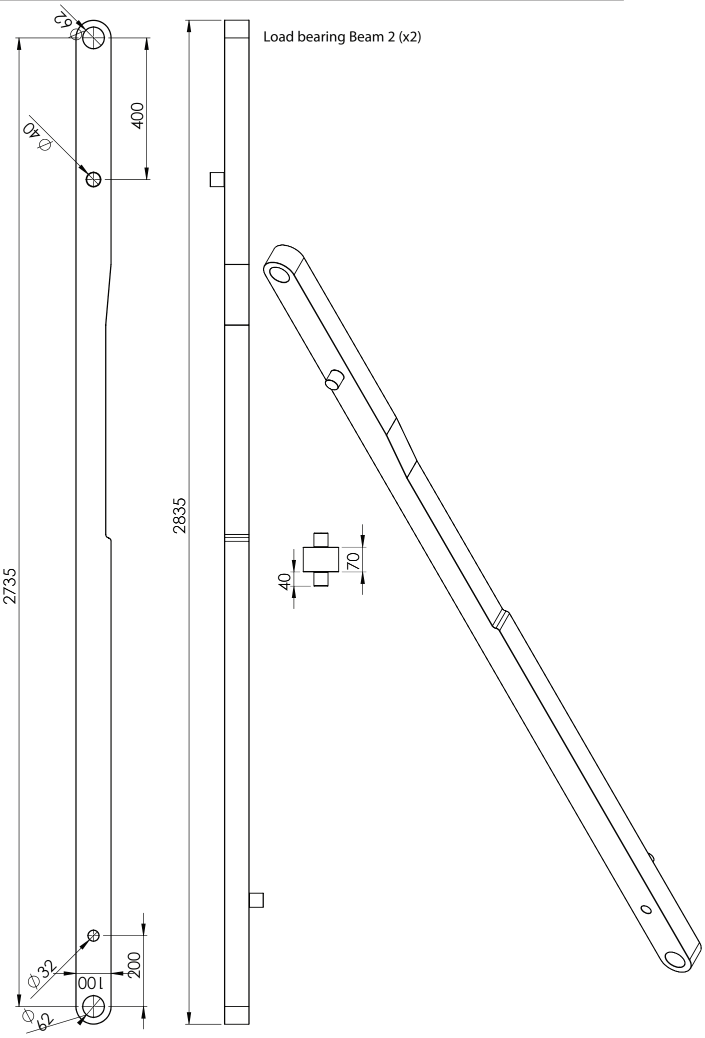
Balance Beam 1 (x2)



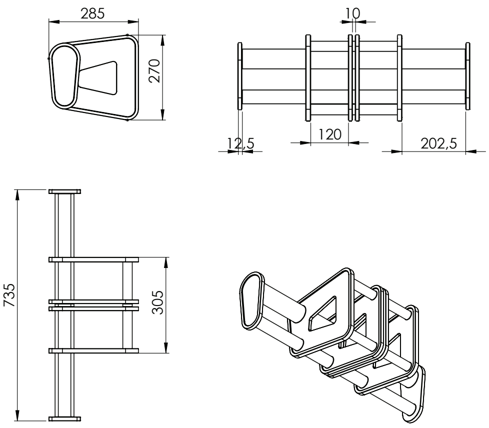
Balance Beam 3 (x2)



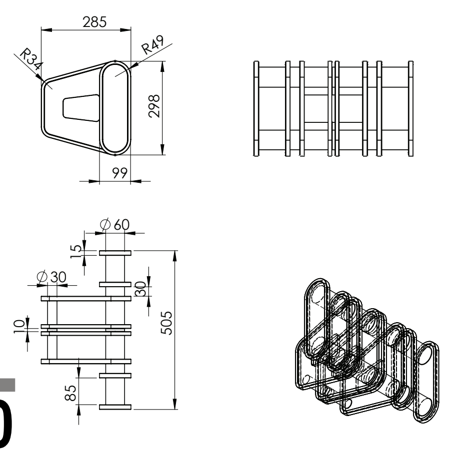
Load bearing Beam 2 (x2)



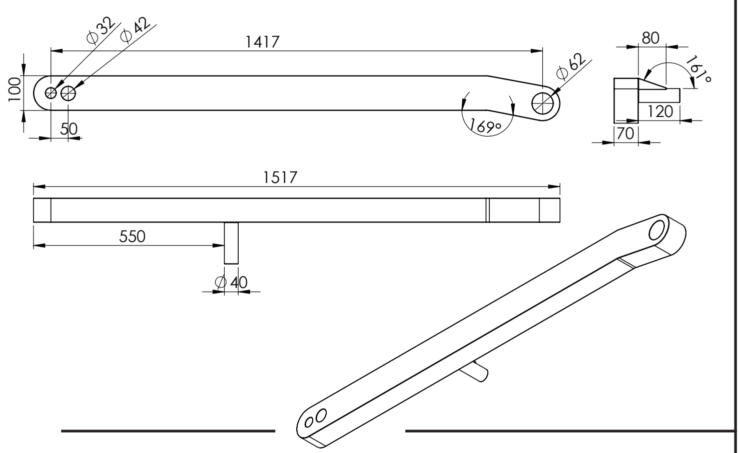
Knee 2



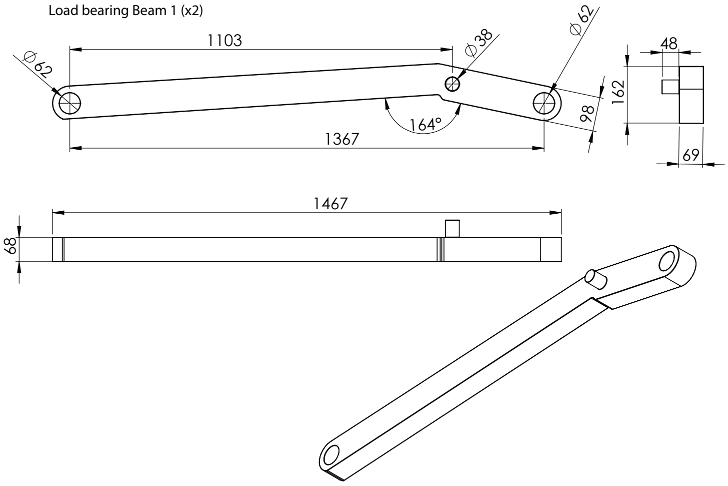
Knee 1



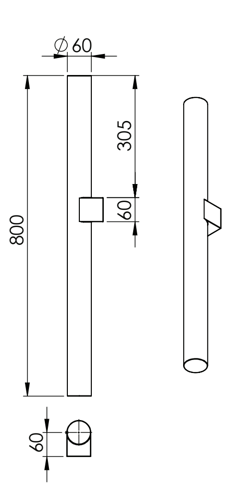
Load bearing Beam 3 (x2)



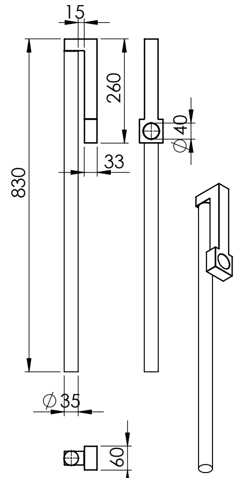
Load bearing Beam 1 (x2)



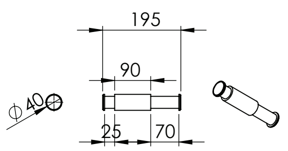
Piston (outside) (x4)



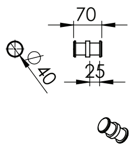
Piston (inside) (x4)



Tandem beam connector - Knee 2a (x2)



Tandem beam connector - Knee 1 (x2)



Tandem beam connector - Knee 2b (x2)