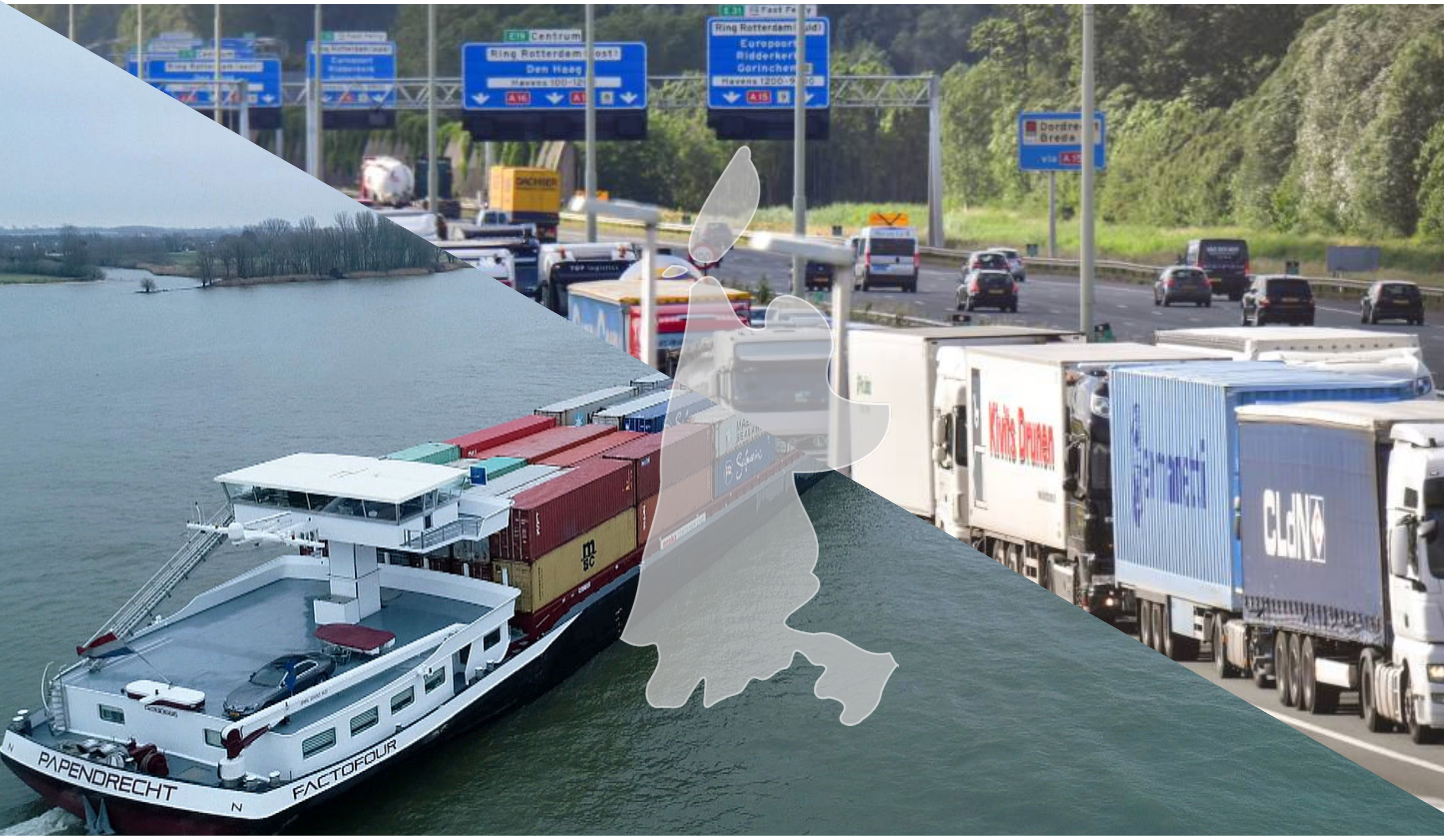
North Holland Corridor



Bron: (Bouw Bedrijf Puremerend, 2020) (Een vandaag, 2020) (Wel ingelichte kringen, 2020)

Team NWC2:

Ahmed Ibrahim
Nanne van Schravendijk
Avni Tayanç
Rick Brouwer Popkens

Consultants:

Sjoerd Sjoerdsma *NWC P.M*

THIS PAGE WAS INTENTIONALLY LEFT BLANK

Summary

North West Connect is looking for the implementation of a modal shift, in order to reduce the number of road transport kilometers in Noord-Holland. A modal shift deliberates on a more sustainable transport and results in less congestion on the roads across North Holland. North West Connect requested young professionals of the Amsterdam University of Applied Sciences to research the possibilities for a modal shift implementation in North Holland. The focus is diverted to the transportation of containers with the use of Inland Waterway Transport. The North Holland Corridor will be transporting TEU between Amsterdam and Alkmaar. As Amsterdam has excellent connections via land and sea to other destinations and Alkmaar opens new connections.

This advisory report covers the following question: “*By which infrastructural and logistical transport solutions can our team of Off-Road runners organise an infrastructural logistic joint corridor in Noord-Holland in the upcoming year?”*

To answer the main question, the research team researched the following criteria: Financial, Infrastructure, future proof and environmental aspects. Also, the current vision of the industry is considered in this report. Within the infrastructure of the logistic model, it is assumed that the new container terminal in Alkmaar is expected to be build.

Concluded from the research is that the project is feasible to execute, but a change in mindset is required within the industry for the successful execution of this project.
The calculated scenario of a class III ship (type Dortmunder) can lead up to a savings of 54.55 euro and a CO_2 emission reduction of 32.89% per transported container. For a class IV (type Europa ship) savings can lead up to 71.99 euro and a CO_2 emission reduction of 46.32% per transported container. With these savings the maximum last mile range for the Dortmunder is six kilometer and, for the Europa ship the maximum last mile range is eight kilometers.
The project covers the Future Proof aspects, with the implementation of Physical Internet in the logistic process. By applying the technique of Physical Internet, the logistic process for transportation will be made less complicated to manage and gives a better tracking overview where goods are located within the process. The feasibility of this project demands the industry willing to shift to a sustainable alternative. In order to convince the industry of the use of a modal shift, Team Noord West Connect 2 has designed a logistic model. This model is illustrated in the schedule below (figure 1) and is based on a 14-hour workday, providing the optimal working schedule available. The schedule provides a two-weekly planning, which completes seven cycles in total.

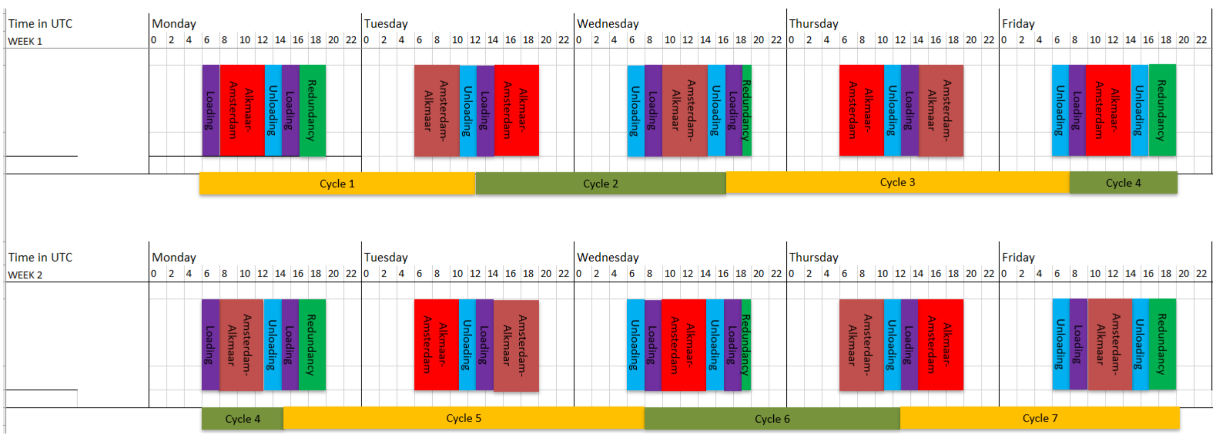


Figure 1: Schematic view of planning (Team NWC2, 2020)

Preface

This advisory report contains the layout of the North-Holland corridor. Young professionals from the minor Future Proof Airport Seaport Logistics from the Amsterdam University of Applied Sciences formed a project team that have worked on this project for Lean and Green Noord Holland.

This report contains a logistical model for the implementation of the North-Holland Corridor, a scheduled inland shipping service to stimulate modal shift in the region Noord Holland. This includes a shipping plan and a theoretical framework supporting the logistical model.

The young professionals would like to thank Sjoerd Sjoerdsma as project sponsor during the minor. Furthermore, the professional coaches: Patrick Oudijk, Jolanda Visser and Thierry Verduijn from the Amsterdam University of Applied Sciences supported and assisted the team during this project. Lastly, the team also thanks Kees Modderman from Bureau Voorlichting Binnenvaart and Jaap Schuurman from Stad Alkmaar Logistics, for their detailed information that have deliberated on the outcome of this project.

Amsterdam, December 28th, 2020

Ahmed Ibrahim
Avni Tayanç
Nanne van Schravendijk
Rick Brouwer Popkens

Abbreviation list

Abbreviation	Meaning
AI	Artificial intelligence
BVB	Bureau Voorlichting Binnenvaart
CO_2	Carbon Dioxide
SOx	Sulphur oxide
NOx	Nitrogen oxide
PMx	Particulate matter
IoT	Internet of Things
TEU	Twenty Foot Equivalent Unit
PI	Physical Internet
ZES	Zero Emission Services
IWT	Inland Waterway Transport
HP	Horsepower
kg	Kilograms
NSC	North Sea Canal
GHG	Greenhouse Gasses
LNG	Liquified Natural Gas
KW(H)	Kilowatt (per hour)
NH	Noord-Holland

Table of Contents

1. Introduction

The North West Connect program has been set with various stakeholders in order to achieve a main goal, the reduction of the transport kilometers on the road by changing the way of transportation (modal shift) to more Inland Waterway Transport (IWT). The desired impact from the program is to improve the quality of living by reducing emissions with a more efficient supply chain and to increase the regional competitiveness and accessibility of the region. It is therefore essential to setup, present and analyze an appropriate model in order to strive for the mentioned objectives. Although Noord West Connect has identified multiple shippers who want to shift from the current road transport to rail or Inland Waterway Transport, there is no appropriate service offered on the intermodal transport market.

1.1 Main Question

This advisory report answers the following main question: *"By which infrastructural and logistical transport solutions can our team of Off-Road runners organise an infrastructural logistic joint corridor in Noord-Holland in the upcoming year?"* In order to reach this goal a research shall be conducted based on the preliminary examination phase, the feasibility phase and as last the implementation phase as stated in the minor study plan of team Noord West Connect 2. This research will only focus on the possibilities and the theoretical layout of the North-Holland corridor. No companies are actively approached to physically join the North-Holland corridor. In this report multiple assumptions are made based on confidential information provided by professionals in the nautical and logistic sector.

1.2 Structure

The structure of the report is as follows. In the starting chapter 2 an analysis is conducted containing the identification of the most suitable trajectory. Along the chosen route, locks and bridges are pointed out that may act as a constraint relevant for the classification of ships and the docking facilities necessary to accommodate a ship. Followed up by chapter 3, the entire logistical model is pointed out covering the final trajectory that is being sailed with, suitable ships that can be utilized along this trajectory including potential constraints, the type of goods expected to be distributed with the focus on container handling, the choses docks for the loading- and unloading phase and finally a forecast of how the ships are being planned to be distributed including time slots and frequencies. Chapter 4 discusses the relevant financial factors when realizing a modal shift, a calculation tool has been developed in order to get an overview of how beneficial Inland Waterway Transport compared to trucks are and the money saved within this process. Current hubs and routes that are made available including the connection with the use of trains, trucks and ships are being covered within the chapter 5. Followed up by chapter 6 sustainability within the North-Holland corridor, the main topics covered in this chapter starts with an analysis comparing the number of Carbon Dioxide is being produced by both trucks and ships and a given percentage of much is saved, current alternatives to marine fuel and future developments in order to strive for an emission-free operation and finally the various number of benefits achieved when operating sustainable within the NH-corridor. Chapter 7 focusses on the futureproof aspects that links this minor and this project with each other. At last is the importance of Physical Internet discussed. Chapter 8 provides insights in the industry vision, their logistical problems and potential partners for the North-Holland corridor are discussed. This report will be wrapped up in the last two chapters 9 and 10, followed up by a conclusion with the most relevant information from the research and a recommendation for the company NWC whether the transition to a modal shift is worth it.

2. Infrastructure

The functions of well-functioning infrastructure are mandatory for the transportation of different goods. Especially at water trajectories where diversion is often not a possibility. This chapter focusses on the different water trajectories within Noord-Holland, the restriction by the bridges and the locks and as last the docking facilities in Amsterdam and Alkmaar.

2.1 Water trajectories

The optimal route to follow by boat from Amsterdam to Alkmaar and back is by following water trajectories:

- Noord-Zeekanaal
- Zaan
- Tapsloot
- Enge Strierop
- Weide Stierop
- Alkmaardermeer
- Noord Hollands Kanaal

Waterways are maintained by Rijkswaterstaat in the Netherlands, it is their responsibility together with the province of Noord-Holland and the local councils to make sure that these routes and their crossing bridges keep in decent condition.

2.2 Bridges and Locks

Along the route from Amsterdam to Alkmaar various bridges cross the route. These needs to be identified in order to come across potential constraints that may affect the type of ships that are being distributed within the North-Holland corridor. The following table provides all the constraints.

Noordsea Channel - Alkmaarmaardermeer - Alkmaar (Zaan route)				
	Movable		Fixed	
Bridge	Width	Depth	Width	Max Hight
Dr. J.M. den Uylbrug	17,7		26,6	7,1
Wilhelmina brug	12			
Beatrixbrug	12			
Prins Bernhardbrug	17,6			
Spoornbrug Zaandam	16		8,15	3,2
Prins Willem Alexanderbrug	14		14,21	3,1
Coenbrug	14		25	6,2
Julianabrug	16,5		17	4,5
Zaanbrug	12			
Prins Clausbrug	14,7		30,1	7,2
Prinses Amaliabrug	16,5			
Leeghwaterbrug Alkmaar	15,5		15,5	4,4
Lock	Width	Depth	Length	
Wilhelminasluis Zaandam*	14	4,7	156	
* Maximum size allowed: 86 m (length); 9,50 m (width)				

Figure 2: Restrictions by bridges and locks Zaan (Rijkswaterstaat, 2020)

It can be concluded that the lock at Zaandam determines that ships cannot be bigger than the length of 86 m and a with 9,5 m.

2.3 Docking Facilities

In Amsterdam the port of Amsterdam has all the docking facilities necessary for a ship. From the loading and unloading containers to dumping waste and refueling.

Facilities / Ports	Amsterdam	Alkmaar
Fuel and Lubricants	X	No Information Available
LNG	X	No Information Available
Drinkwater	X	No Information Available
Garbage	X	No Information Available
Garbage form shipment ex	X	No Information Available
Oil and Fat containing debry	X	No Information Available
Electrical connections	X	No Information Available
Container storage	X	No Information Available
Load and unload facilities	X	X
Dimensions Ships	No restrictions	No Information Available

Figure 3: facilities (Port of Amsterdam, 2020) (Sjoerdsma, 2020)

The port of Amsterdam is also big enough for turning large ships into the right direction for departure. The future Port of Alkmaar will have the loading and unloading facilities for containers, but it is unclear if the other facilities are available at the moment of writing this report. The port of Alkmaar will be suitable for turning a ship around in the right direction for departure.

3. The Logistical model

Setting up a (new) logistical model is not only about solving current problem(s) temporarily but coming with innovative solutions to gradually solve the problem(s) for the long-term. Our logistics model, the North-Holland corridor, comes with various challenges, ranging from finding a cost-saving trajectory between Amsterdam-Zaandam-Alkmaar, high investments, to finding stakeholders/companies that are willing to participate whilst providing of a cost-effective and future-proof solution.

Assumption, for the mentioned implications are being taken into consideration that may obstruct a successfully implementation of a modal shift and a joint corridor through North-Holland. The following chapter will discuss thoroughly the trajectory, docks, classification of ships, potential partnerships and the type of load cargo that will be distributed.

3.1 Route

To get from Amsterdam to Alkmaar and back ships a will have to follow a specific route.
When a ship will depart out of the port of Amsterdam it will at come across the following waterways:

1. Noord-Zeekanaal
2. Zaan
3. Tapsloot
4. Enge Strierop
5. Weide Stierop
6. Alkmaardermeer
7. Noord Hollands kanaal

The numbers matching the waterways are also shown in figure 4:

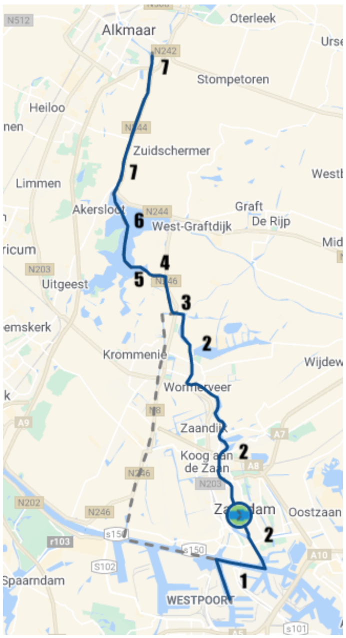


Figure 4: North Holland Corridor (Team NWC2, 2020)

In figure 4 an alternative route is provided. The route goes through the Nauwernasche Vaart and is more direct than the Zaan Route. In this waterway the Schermer lock is positioned. This lock has a very limited capacity. Ships cannot be longer than 27.00 meters and 5.70 meters wide. (Rijkswaterstaat, 2020). These relatively small sizes make this route unsuitable for industrial shipping. Lastly, there is a third route to get to Alkmaar out of Amsterdam. This route follows the complete Noord Hollands kanaal, which goes via Purmerend. This detour is much longer than the Zaan route and therefore automatically less interesting.

3.2 Docks

Chosen is for 2 transshipment terminals with the docking facilities for loading and unloading sea containers. The first one is the Port of Amsterdam. The port of Amsterdam is the second largest transshipment terminal of the Netherlands located at the west side of the city along the IJ-river and the Amsterdam-Rijn channel. The terminal of Amsterdam is chosen as hub for all the goods transported from the province to other parts of the country or other countries. This because Amsterdam has a good connection to the largest port of the Netherlands Rotterdam, but also good connections to the hinterland.
The second transshipment terminal is the future transshipment terminal of Alkmaar. Alkmaar is chosen because it is in the middle of the province and is the largest city in the vicinity and is the destination for phase one of the connection of the province by ship.
Zaandam is not chosen as Docking Hub because the port of Zaandam is adjacent to the Port of Amsterdam.

3.3 Ships classification

Now the trajectory including the constraints have been mentioned within paragraph 3.1. This paragraph's main focus is to know the type of ships are able to sail from Amsterdam to Alkmaar. Within this trajectory various bridges and lock are identified and mentioned in paragraph 2.2, including the dimensions of each. With the use of this information, criteria's can be created in order to select the most suitable ships to be distributed. The classification of the ships has been placed in Appendix 1 as reference.

Starting with the first criteria, the dimensions of bridges and locks as mentioned in chapter 2.2, the selections of ship classes mentioned in appendix 1 can get narrowed by applying the second criteria, drafts. This will be covered after applying the first criteria.

The lowest width on the bridge and lock within our trajectory is the Spoorbrug Zaandam (8,15 meters) and Wilhelminasluis Zaandam (14 meters) with a draft of 4,7 meters. However, as Spoorbrug Zaandam is divided into two sections, (a movable and a fixed area) the movable area of 16 meters can be used. Therefore, the mentioned width of 8,15 meters can be disregarded. As a result, all classes can be exploited when applying this criterion, with the exception of class VIb/VIc.

The sailing route that starts from the North Sea Canal (NSC) has several draft limitations that might impact the type of ships that can be used. The NSC draft including the lock can accommodate a maximum of 13,10 meters whereas the Zijkanaal G has a draft of 8 meters (Pantela, 2018)
(Overheid, 2020). Sailing after Zijkanaal G however (starting from the Zaan) the draft is limited to only 2,85 meters (as illustrated in figure 5). This limitation continues altogether until Alkmaar. Thereby, only ships of **class I-IIII** (the Spits, Kempenaar, Neokemp and Dortmunder) can be used if considering that the draft is a limitation.

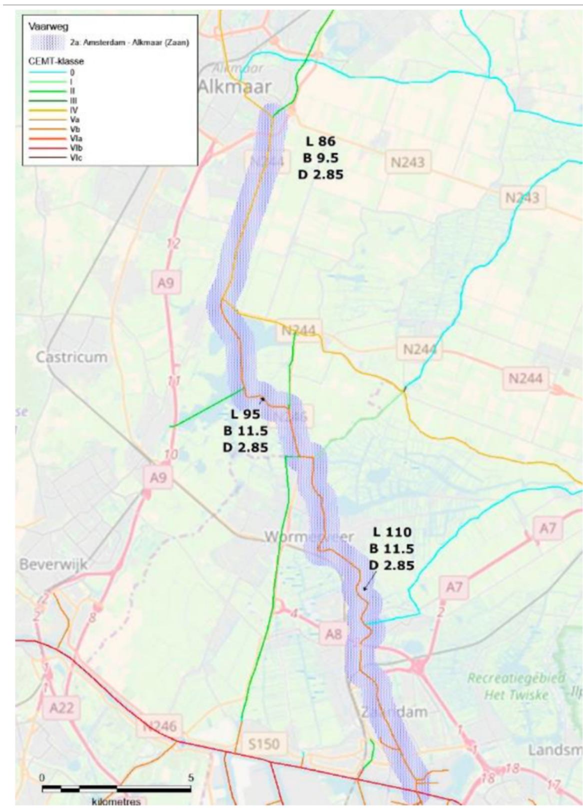


Figure 5: Trajectories draft limitation

From the interview that has been conducted with Kees Modderman, the logistical advisor of BVB, (Bureau Voorlichting Binnenvaart) concluded that the draft does not have to be considered as a limitation only when ships are operating at maximum payload, as ships are tending to sink more when the weight of shipments/payload are increased. Our assumptions are that the ships will operate at a capacity of 95%, that there is a balance between full and empty containers from Amsterdam-Alkmaar and vice versa, and the average tonnage within one container is 18, depending on the type of product loaded in the container. Therefore, the draft limitation will not affect the remaining classes I-Va.

3.4 Type of load

Various goods require different handling and facilities, for the sake of the NH-corridor, the main focus will be diverted to the shipments of container cargo with the potential of a transshipment terminal. The type of goods transported including the volume, will determine the trajectory, frequency and the type of ships suitable enough, to be distributed within the NH-corridor model.

The shipment of maritime and continental containers can help to increase the current declining share of the Inland Waterway Transport. The number of truck movements eliminated yearly on the road with the current terminal is 109.000. By developing a new transshipment terminal however in one of the following areas: Schiphol, Alkmaar, Amsterdam-Rijnkanaal or around the top of Noord-Holland, a potential of 171.000 yearly truck movements yearly on the road can be eliminated. (Pantela, 2018).

The trajectory Zaan-Alkmaar had a total volume of 889.436 tonnes of fodder goods divided through Koog aan de Zaan, Zaandam and Wormerveer (Pantela, 2018). Alkmaar is an important destination when it comes to construction materials and wood chips, a total volume of 340.561 tonnes has been transported from the Zaan. As Noord-Holland is the main province in The Netherlands with a large proportion for the transportation of fodder goods, continues volume growth is expected within Zaanstad-Alkmaar in the upcoming years.

Shippers currently face the problem that there is insufficient cargo on one’s own to transport the goods to the desired destination through Noord-Holland whilst being cost-effective. Freight can be bundled between shippers, to gradually solve this problem. This results in sufficient volume for the shippers to participate, and a cost-effective Inland Waterway Transport. As a result, there will be less traffic movements, a reduction of costs and environmental pollution for the shippers within the supply chain (Ministry of Infrastructure and Water Management , 2020).

3.5 Planning

To maximize the benefit of the modal shift, this planning will schedule the greatest number of trips possible in a week. For this situation, there will only be looked at weekdays. There are multiple options when it comes to how many hours are available in the day. The options are: 14 hours, 18 hours and 24 hours. For this planning the 14-hour option was chosen. This is to reduce the cost per day. For the other options more personnel have to be hired making the personnel costs higher.
With the 14 available workhours there are a total of 70 hours of potential time that can be used each week. The total time needed to sail retour is 10 hours. It takes about 4 hours to load and unload a ship. This has to be done twice each retour, so this is an additional 8 hours. Lastly an additional 2 hours has been added to compensate for any delays. This sums up to a total of 20 hours each retour (Modderman, 2020). This is schematically shown in the following chart.

Type	**Hours**
Time sailing retour	10
Time for two times loading and unloading	8
Time for potential delays	2
Total	**20**

Figure 6: Schematic view of required time (Team NWC2, 2020)

This means that with 70 hours available and 20 hours required for a retour, 3.5 retours can be completed each week. So, in this planning 7 retours will be planned over the course of two weeks. This planning if shown in the following figure, this figure is also illustrated in full size in appendix 2.

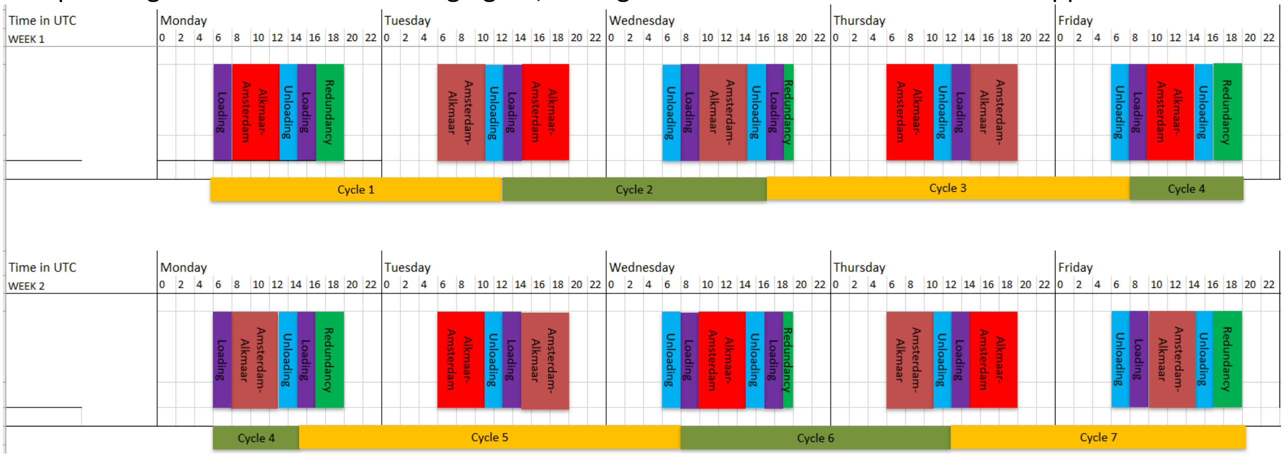


Figure 7: Schematic view of planning (Team NWC2, 2020)

This model is irrelevant to the type of ship being used, as processes have a fixed time duration.

4. Feasibility of the North-Holland Corridor

Last chapter the logistical model was discussed. To make this theoretical plan a reality, it must be financially feasible. In this chapter the financial feasibility of the corridor will be investigated. This will be done by looking at each financial factor that is involved in both transport by truck and by ship, and eventually comparing both to conclude how much money can potentially be saved by modal shift. With this chapter the sub question that will be looked at reads as follows: "Which challenges are involved with the feasibility of realizing an infrastructural logistic joint corridor in North-Holland?"

4.1 Calculation tool set up

To calculate if modal shift is feasible, the costs of transporting by truck and by ship will be compared. To do this several financial factors must be considered. First of all, the number of containers transported each round trip has a big impact on the benefit of transporting by ship. The more containers are transported each round trip, the more money is saved.
But this is not the only financial factor that is involved in this comparison. Handling cost, fuel cost, ship cost and truck driver cost all have to be considered to make a complete financial comparison.
For the restrictions, the minimal of 5000 containers transported each year has to be considered. To make a harbor cost effective, it must handle at least 5000 containers each year (Modderman, 2020). For the port of Amsterdam this is not a problem. But for the port of Alkmaar, this is an impotent factor consider. So, in this calculation there will be a restriction that a minimum of 5000 containers is transported each year.
Lastly an emission reduction must be present. Without an emission reduction, setting up a corridor won't be viable.

Note that the financial benefit is not a set restriction. If the emission reduction outweighs the financial drawback, it will still be worth it to set up the corridor. Preferably there is a financial benefit.

With these factors in mind, a calculation tool was set up. In this calculation tool are multiple variables to cover all the factors previously mentioned. Every variable can be altered to calculate the total savings for specific situations. These variables are divided in three categories: General variables, Ship variables and Truck variables. These categories consist of:

- **General variables:**
  - Amount of retours each week
  - Cost container handling truck
  - Cost container handling ship
  - Percentage of TEU transported (utilization)
  - CO_2 emission per liter diesel in kg

- **Ship variables:**
  - Required liter of fuel per 100 HP per hour
  - Cost per liter of fuel
  - Percentage of required power
  - Required container handlings
  - Cost container handling ship
  - Total sailing time retour in hours

- **Dortmunder:**
- Number of filled TEU transported each retour
- Maximum HP
- Yearly ship cost
- **Europa:**
- Number of filled TEU transported each retour
- Maximum HP
- Yearly ship cost

- **Truck variables:**
    - Total time in hours (This is the total time the truck driver is busy transporting the container. This includes loading time.)
    - Cost truck driver per hour (this includes fuel costs)
    - Required container handlings
    - Cost container handling truck
    - Length retours in kilometers
    - Amount of liters fuel required per 100 kilometers

- **Restrictions**
    - Minimal of 5000 containers transported each year
    - Emission reduction must be present.

4.2 Exploitation values calculation: Variables values

With this calculation tool the amount of potentially saved money was calculated. These values are called the exploitation values. This was done by maximizing the number of containers transported each year and calculating the saved amount of money, using the following values of variables in the previously set up calculation tool.

General variabels	
Amount of retours each week	3.5
Percentage of TEU transported	95.00%
CO2 emission per liter diesel in kg	2.606
Last mile cost for same industry terrain	€ 30.00
Last mile cost for destination within 5 kilometers	€ 50.00
Ship variabels	
Liter fuel per 100 HP per hour	17
Cost per liter fuel	€ 0.60
Percentage of required power	70.0%
Required container handling	8
Cost container handling ship	€ 17.50
Total sailing time retour in hours	10
Dortmunder	
Number of filled TEU transported each retour	32
Maximum HP	600
Yearly ship cost	€ 220,000.00
Europa	
Number of TEU transported each retour	72
Maximum HP	1080
Yearly ship cost	€ 320,000.00
Truck Variabels	
Total time driving in hours	2
Total time loading and unloading in hours	1
Cost truck driver per hour	€ 70.00
Required container handling	2
Cost container handling truck	€ 20.00
Length retour in kilometers	100
Amount of liters fuel required per 100 kilometers	35

Figure 8: Used variable values (Team NWC2, 2020)

First, the explanation of the used values. All the following values have been gathered in an interview with Kees Modderman from the Bureau Voorlichting Binnenvaart (Modderman, 2020).

4.2.1 General variables

The amount of retours each week is set to be maximized. How the number 3.5 was established was discussed in paragraph 3.5.

The percentage of containers transported each year is set to 95% to get a realistic calculation of the exploitation values.
The CO_2 emission per liter diesel in kg is set to 2.606 kg (anwb, 2020).
In figure 8 two variables about the last mile are also illustrated. These will not be used in the first calculation and therefore not discussed now. The variables are used and discussed in paragraph 4.5.

4.2.2 Handling variables

The handling variables are spread across the set categories, but for explanation convenience, they will now be discussed together.

The required amount of container handlings for a ship is set to eight. The path the container travels is illustrated in the following figure. The arrows represent the container handlings.

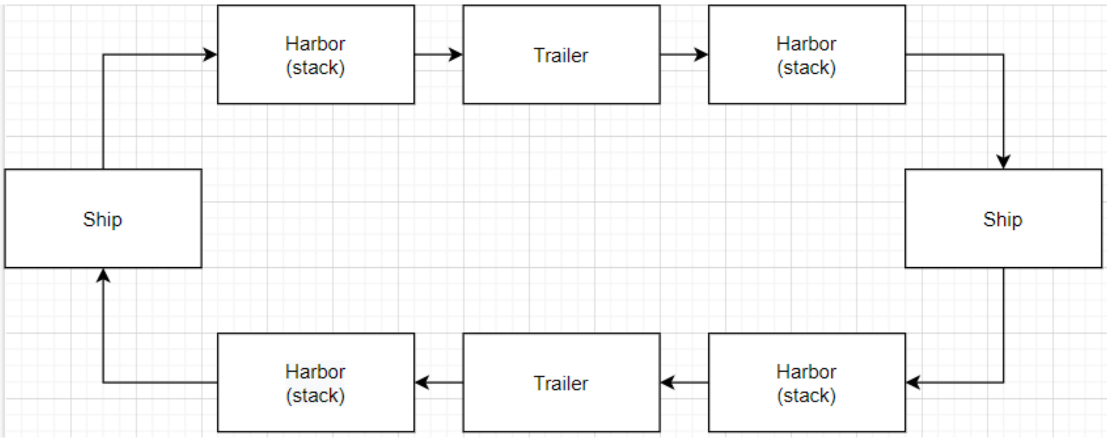


Figure 9: Handlings illustrated for ship (Team NWC2, 2020)

The harbor is the starting point for the empty container. The container first has to be set on a truck to be transported from the transshipment terminal (harbour) to the shipper. There the container gets loaded. This can be done without removing the container from the trailer, so this is not a container handling. From there the container gets transported to the harbor a removed from the trailer to the stack. When the ship is getting loaded the container is transported from the stack to the ship. Once the ship has arrived the container is removed to the stack of the harbor. Again, the container is put on the trailer for the last part of the trip. At the destination, the container is unloaded. This can again be done without removing the container from the truck. The container now returns to the harbor empty to be shipped to the starting harbor. This sums up to a total of eight container handlings.

For a truck, this number is only two. First from the stack on to the truck. The container can now be transported, loaded and unloaded without removing the container from the trailer. Once the shipping has been completed the container is again returned to the stack. This is illustrated in the following figure where the arrows again represent the container handlings.

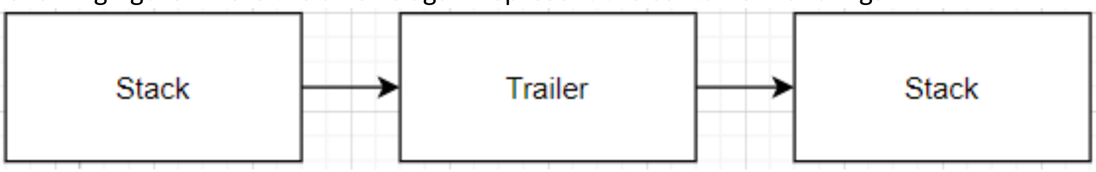


Figure 10: handlings illustrated for truck (Team NWC2, 2020)

The cost for a single handling on a seaport is 20.- euros. For the port in alkmaar is only 15.- euros. Beacause the ships require the same amount of handling of both ports, the average of 17.50 euros will be used to calculate with.

For the truck a handling will cost 20.- euros.

4.2.3 Ship variables

This calculation calculates two different scenarios. One is with the Dortmunder ship and one is with the Europa ship. the Dortmunder ship has a length of 67 meters and the Europa ship has a length of 85 meter. These two ships were chosen because they both don't exceed the restrictions of the route and to make a comparison between two different sizes of ships.

Figure 11: Dortmunder ship (Modderman, 2020)

It takes about five hours to sail from Alkmaar to Amsterdam. This includes the time spent at the lock. So, the total time sailing a retour between Alkmaar and Amsterdam is set on ten hours.

To calculation of fuel is done by looking at the horsepower of the ships. It takes 17 liters of diesel for every 100 used horsepower.
The cost of a litre diesel is 0.60 euros.
The Dortmunder ship has a maximum of 600 horsepower, the Europa ship has a maximum of 1080 horsepower.
Of course, the ships won't always be using their maximum power, so the percentage of required power is set to 70%. Because the route mostly consists of still waters and the ships won't be loaded to their maximum weight capacity (not to be confused with maximum container capacity), the engines won't have to work on full power. 70% is a good estimation of the amount of engine power needed.

The yearly cost to use a Dortmunder ship is 200,000. - euro. To account for the extra cost a sailor needs to make profit, this calculation will use 220,000. - euro, this includes personnel cost.
For the Europa ship this is 300,000. - euro. To again account for profit, this calculation will use 320,000. - euro, this includes personnel cost.

The number of filled TEU transported each retour for both ships is the maximum number of containers a ship can carry. This means that half of the containers transported in a retour will be empty. The Dortmunder ship can transport a total of 32 containers at once. So, the variable will be set on 32. For the Europa ship this number is 72.

4.2.4 Truck variables

The total time driving a retour between Alkmaar and Amsterdam is set to 2 hours.
The total time loading/unloading is set to 1 hour.
Because the time loading or unloading is within one hour, there won't be an extra charge for waiting time.
The cost for a truckdriver is set to 70.- euros an hour, this includes fuel cost. This is a little bit above the average of today. This is done to account for the kilometer charge and the rising cost of truck drivers.
The length of a retour between Amsterdam and Alkmaar is set to 100 kilometers and the amount of

fuel required for 100 kilometers is set to 35 liters. These last two variables are used to calculate the emission comparison.

4.3 Exploitation values calculation: Results

With the variable values previously discussed, the yearly savings and saving per container was calculated for each ship with the utilization (Percentage of TEU transported) set to 95%. The summary of this calculation is listed in the chart below.

Summary		
Percentage of TEU transported	95.00%	
Truck cost per TEU	€ 250.00	
Type	**Dortmunder**	**Europa**
Yearly transported containers	5320	11970
Cost per TEU	€ 195.45	€ 178.01
Saving per TEU	€ 54.55	€ 71.99
Total yearly saving	€ 290,230.00	€ 861,754.00
CO2 emission reduction	32.89%	46.32%

Figure 12: Summary of calculation with utilization set to 95% (Team NWC2, 2020)

As seen in the chart, the cost for transporting a container is cheaper per ship in both cases. Transporting with the Dortmunder ship saves 54,55. - euro each container which adds up to a yearly total of 290,230. - euro. For the Europa ship this is more than the Dortmunder ship, 71,99. - euro each container. This adds up to a yearly total of 861,754. - euro. For both ships the yearly transported containers is more than 5000 per year, this makes this calculation meet the set restriction.

This calculation tool also calculates the yearly fuel usage of both ships and calculates the fuel usage of a truck if it were to transport an equal number of containers. These calculations are listed in the chart below, the important numbers are highlighted.

Emission calculation		
Type	**Dortmunder**	**Europa**
Yearly fuel use in Liters	124,950.00	224,910.00
Yearly CO2 emission in kg	325,619.70	586,115.46
CO2 emission per TEU in kg	61.21	48.97
Truck fuel calculation		
Yearly fuel usage if a truck were to transport an even amount of TEU	186,200.00	418,950.00
Yearly CO2 emission in kg	485,237.20	1,091,783.70
CO2 emission per TEU in kg	91.21	91.21
CO2 emission reduction in percentage	32.89%	46.32%

Figure 13: Emission calculation (Team NWC2, 2020)

In this chart a significant reduction can be seen for both ships. The Dortmunder ship has a CO_2 reduction of 32.89% and the Europa ship of 46.32% compared to the traditional way of transport by truck. The CO_2 reduction will be discussed more in depth in chapter 6.1.

4.4 Exploitation values calculation: Results comparison

In this subchapter the same calculation as the previous subchapter will be done, except this time the percentage of TEU transported will be altered. In the last calculation the percentage of TEU transported was set to 90%. In the following examples all, other variables will stay the same while the percentage of TEU transported is changed.

4.4.1 Utilization set to 100%

First the scenario with the utilization set to **100%** was calculated. The summary of this calculation is listed in the chart below.

Summary		
Percentage of TEU transported	100.00%	
Truck cost per TEU	€ 250.00	
Type	**Dortmunder**	**Europa**
Yearly transported containers	5600	12600
Cost per TEU	€ 192.67	€ 176.11
Saving per TEU	€ 57.33	€ 73.89
Total yearly saving	€ 321,030.00	€ 931,054.00
CO2 emission reduction	36.25%	49.00%

Figure 14: Summary of calculation with utilization set to 100% (Team NWC2, 2020)

In this situation the expected happens. The savings and the emission reduction both increases. The reason why the 90% calculation is preferred is because it is more realistic to gather that number of containers. So, changing the percentage of TEU transported to 100% is more beneficial, but less realistic.

4.4.2 Utilization set to 89%

Next the scenario with the utilization set on **89%** was calculated. The summary of this calculation is listed in the chart below.

Summary		
Percentage of TEU transported	89.00%	
Truck cost per TEU	€ 250.00	
Type	**Dortmunder**	**Europa**
Yearly transported containers	4984	11214
Cost per TEU	€ 199.18	€ 180.57
Saving per TEU	€ 50.82	€ 69.43
Total yearly saving	€ 253,270.00	€ 778,594.00
CO2 emission reduction	28.37%	42.70%

Figure 15: Summary of calculation with utilization set to 89% (Team NWC2, 2020)

The reason why this scenario was chosen to be highlighted is to show the breakeven point from when the Dortmunder doesn't meet our restrictions. In this case the restriction of transporting at least 5000 containers yearly is not met, it is only 4984 containers. This means that with this scenario the harbor won't be cost effective. A solution for this problem could be to use a public quay with rented cranes to load and unload the containers. For this concept a further investigation has to be done. This concept will be further discussed in our recommendations.

4.4.3 Utilization set to 51%

Next the scenario with the utilization set on **51%** was calculated. The summary of this calculation is listed in the chart below.

Summary		
Percentage of TEU transported	51.00%	
Truck cost per TEU	€ 250.00	
Type	**Dortmunder**	**Europa**
Yearly transported containers	2856	6426
Cost per TEU	€ 243.28	€ 210.80
Saving per TEU	€ 6.72	€ 39.20
Total yearly saving	€ 19,190.00	€ 251,914.00
CO2 emission reduction	-25.00%	0.00%

Figure 16: Summary of calculation with utilization set to 51% (Team NWC2, 2020)

51% is the breakeven point for the Europa. In this case the emission reduction is the restriction that isn't met. The emission has a reduction of 0%. This is of course something that is not wanted. The goal of this innovation is among other things to decrease greenhouse gasses emission. So, no decrease in CO_2 makes this scenario (and scenarios with lower percentages of TEU transported) not valid. However, this does not mean that any scenario with a percentage of TEU transported above 51%, is viable. The less a ship is sailing, the more money it will costs to use a ship. This is because with less transport for the shipper, it has to sail less often. While it is not able to sail because of the lack of containers, it is not making any profit. Therefore, the yearly price to use a ship increases to compensate for this.

4.5 Last mile

There is one last factor that has to be considered which makes this whole project a lot harder to realize, this is the last mile. These costs do not apply to companies that have their own trucks and arrange the last mile by themselves. For the traditional way of transport by truck the last mile is not a problem, the truck can just dive directly to the destination. But for a ship this is a lot harder. Once the container has arrived at the harbor, it has to be transported to the destination by a truck. This costs money which can make or break the feasibility of this project. The harbor charge for these operations. The costs for transporting a container from and to the harbor are listed in the chart below (Sjoerdsma, 2020).

Distance	Cost
Same industry terrain	30.- / 45.- euros
Until 10 kilometers	90.- euros
10 kilometers / 20 kilometers	107.- euros
20 kilometers/ 30 kilometers	125.- euros

Figure 17: Last mile costs (Team NWC2, 2020)

As seen in the chart, these costs are high if compared to the saving per container previously calculated. Recap: the saving for a Dortmunder ship were 54,55.- euros per container and for the Europa ship 71,99.- euros per container with the utilization set to 95%. With this in mind the maximum range for the last mile for both ships can be calculated.

Last mile above 10 kilometers are instantly not feasible. The last mile cost is significantly higher than the saving per container, so therefore not feasible.
Last mile within the same industry terrain is feasible for both ships.
To calculate the maximum range for the last mile, the cost for 10 kilometers is used. The calculated values are listed in the chart below. These costs are only possible if the containers can be detached from the trucks.

Distance	Cost
Until 10 kilometers	90.- euros
6 kilometers	54.- euros
8 kilometers	72.- euros

Figure 18: Last mile costs (Team NWC2, 2020)

The maximum range for the Dortmunder ship is 6 kilometers, this costs 54.- euros for each container. For the Europa ship the maximum range is 8 kilometers, this costs 72 euros per container. These are the breakeven points from when the ships won't be losing a significant amount of money. With these maximum last mile ranges, the savings are calculated.

Last mile calculation	Dortmunder	Europa
Saving per TEU with final destination being within 6 kilometers	€ 0.55	
Yearly saving with final destination being within 6 kilometers	€ 2,950.00	
Saving per TEU with final destination being within 8 kilometers		€ -0.01
Yearly saving with final destination being within 8 kilometers		€ -86.00

Figure 19: Last mile breakeven point savings (Team NWC2, 2020)

As seen in the chart, if the last mile ranges is maximized to 6 and 8 kilometers, the saving for drop to minimal. The Dortmunder ship saves 55 eurocents per container. The Europa ship has a negative saving, this means it costs extra money compared to the truck. The extra cost for a container in case of the Europa ship is only 1 eurocent. This is an insignificant amount of money so therefore 8 kilometers was the chosen breakeven point.

To sum up this paragraph: the Dortmunder ship is only viable if the required demand is available within 6 kilometers from the harbor. For the Europa ship situation, the required demand has to be available within 8 kilometers from the harbor.

4.6 Exploitation values calculation: Conclusion

Because of all the previous discussed factors the scenario 95% was chosen to be the most realistic and viable scenario. With the with the percentage of TEU transported set to 95%, the Dortmunder ship generates a saving of 54.55 euro and a CO_2 emission reduction of 32.89% per transported container and the Europa ship generates a saving of 71.99 and a CO_2 emission reduction of 46.32% per transported container. With these savings the maximum last mile range for the Dortmunder ship is 6 kilometers, for the Europa ship the maximum last mile range is 8 kilometers. Both ships meet the restriction of transporting over 5000 containers each year. This means that theoretically this project is feasible, but only if the required demand is available within the maximum last mile ranges.
To answer the sub question *"Which challenges are involved with the feasibility of realizing an*

infrastructural logistic joint corridor in North-Holland?". The biggest challenge to realizing an infrastructural logistic joint corridor in North-Holland is the demand. If the demand within the limited is available, the joint corridor is feasible.

5. Current Hubs/routes out of Amsterdam

Amsterdam has 3 ways of transport possibilities. By truck, by train and by ship. With these modes of transport, shipments into Amsterdam can transfer to other modes of transport for the optimal transportation to the destination.

5.1 Train

The port of Amsterdam has the facilities for transfer from ship to train or from train to ship.

The rail network of the port of Amsterdam connects to:

- The Rhine – Alpine to destinations in central & South Germany, Austria, Switzerland and Northern Italy
- The North Sea Baltic to destinations in Central and east Germany and Poland.
- The North Sea Mediterranean for destinations in the UK, France and Belgium.

These rail networks are big freight transport corridors all connected to the port of Amsterdam. These Rail Transport Corridors connect to other Rail Transport Corridors throughout the whole of Europe. (Port of Amsterdam, 2020)

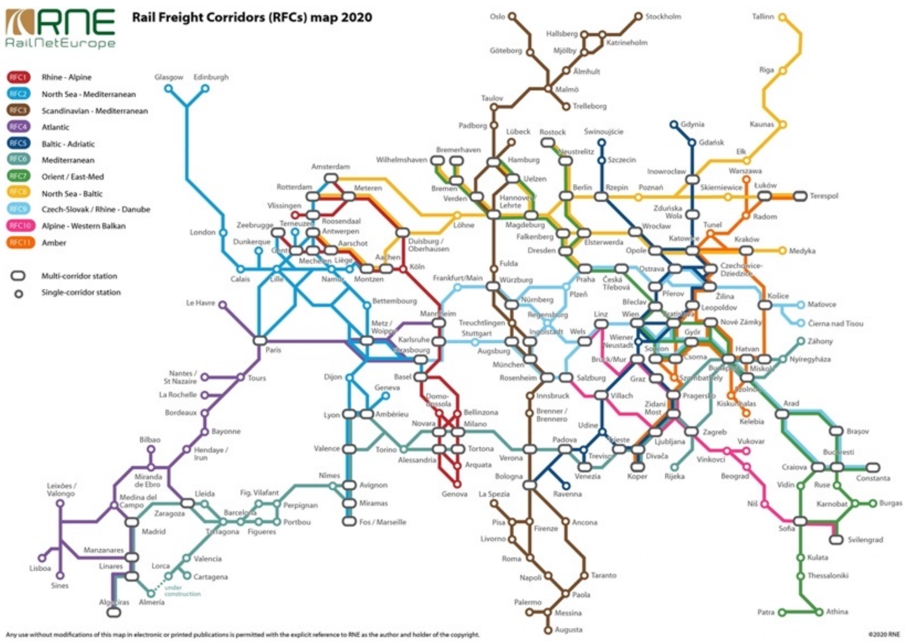


Figure 20: Rail Freight Corridor (Rail Net Europe, 2020)

5.2 Ship

Amsterdam is a versatile port for different sizes of ships. This varies from large Ocean-going container ships, tankers, or other bulk transport to small inland ships transporting the goods from the large ocean-going ships through the smaller water ways through the Netherlands and the rest of Europe.

5.2.1 Inland Waterway Transport

The Netherlands is rich of many waterways not only connecting cities within the boarders but also connecting to cities to the rest of Europe. The Port of Amsterdam is connected to the Rijn. This gives the port of Amsterdam connections by IWT to many cities and countries within Europe. Specifically, Germany, Austria, Switzerland and of course the inland of The Netherlands. The Port of Amsterdam has also a special joint venture with the Ports of Rotterdam and Utrecht for a transport corridor. (Port of Rotterdam, 2020) (Port Of Amsterdam, 2020)

5.2.2 Short Sea

Short Sea is a mode of shipping which the route is partially by Sea. The connections of the Port of Amsterdam by Short Sea are to the United Kingdom, The Baltic states and Russia. (Port of Amsterdam, 2020)

5.2.3 Deep sea

The Port of Amsterdam is not only a port for Inland Waterway Transport but also a port were large, international Ocean-Going ships dock. This means that the Port of Amsterdam is connected to the whole world. And transfer of goods is not limited to Inland Waterway Transport of Short Sea transport. (Port of Amsterdam, 2020)

5.3 Road

The Port of Amsterdam has also good connections to the Motorway network of The Netherlands. The Dutch Motorway A5 runs close to the Port and is good accessible from the Port and vice versa. And with Schiphol nearby the transfer from ship to airplane is also a possibility. (Port of Amsterdam, 2020)

5.4 Chapter Conclusion

The port of Amsterdam is the second largest port of the Netherlands and has a diverse route network connecting to the rest of the Netherlands as the rest of Europe and the world. This is accomplished with the use of 3 modes of transport. By road, train and sea. The port of Amsterdam has a good connection to the road network of the Netherlands. By train the port of Amsterdam is connected to 3 large rail transport corridors connecting to the whole of Europe. And as last by ship. The port of Amsterdam has 3 modes of shipping which it is connected to the rest of the Netherlands and to the world. By inland shipping, by short sea and by deepsea. The port of Amsterdam is an excellent port for transportation by the different modes of transport and transferring from one mode of transport to the other mode of transport.

6. Sustainability within the NH-corridor

Various goals have been set for in the future that need to align with developing a future-proof modal shift concept whilst operating on a sustainable manner. Co-operation within the operation is mandatory as nowadays it is for upmost important to focus on sustainability within one's operation. Not only to align with more strict regulations in order to operate, but also to benefit for a higher quality of living, potential reduction of costs and improving brand image which will reflect on a higher competitive advantage.

An analysis comparing the emission of trucks and ships can be conducted in order to get a hand sight of how beneficial Inland Waterway Transport really is based on distance, frequency, type of fuel and number of TEU transported. Currently, there are various alternatives when it comes to using marine fuel, these developments will be discussed later in paragraph 6.2 and finally the most relevant benefits of operating in a sustainable manner within the NH-corridor will be mentioned in paragraph 6.3

6.1 CO_2-emission comparison of current and future transport

6.1.1 Comparison truck and ship

To compare the emission of transport by truck and ship, the results of the previously set up calculation tool will be used. The calculation tool calculates the required amount of fuel needed to complete a retour between Amsterdam and Alkmaar for both ships and an average truck. With these fuel amounts, the CO_2 emission can be calculated. Each liter of burned diesel releases 2.606 kilos of CO_2 gas (anwb, 2020). With the use of this information the total emission and emission reduction is calculated. The results of this are listed in the chart below.

Emission calculation		
Type	**Dortmunder**	**Europa**
Yearly fuel use in Liters	124,950.00	224,910.00
Yearly CO2 emission in kg	325,619.70	586,115.46
CO2 emission per TEU in kg	61.21	48.97
Truck fuel calculation		
Yearly fuel usage if a truck were to transport an even amount of TEU	186,200.00	418,950.00
Yearly CO2 emission in kg	485,237.20	1,091,783.70
CO2 emission per TEU in kg	91.21	91.21
CO2 emission reduction in percentage	32.89%	46.32%

Figure 21: Emission calculation with utilization set to 95% (Team NWC2, 2020)

To transport one container via a truck, 91.21 kg of CO_2 is emitted. For the Dortmunder the CO_2 emission per container is 61.21 kg. In this situation the Dortmunder transports a total of 5320 containers each year. This totals to 325,619.70 kg of yearly emitted CO_2 for the Dortmunder. If a truck were to transport 5320 containers each year, it would emit a total of 485,237.20 kg of CO_2 yearly.
For the Europa ship the CO_2 emission per container is 48.97 kg. In this situation the Europa ship transports a total of 11970 containers each year. This totals to 586,115.46 kg of yearly emitted CO_2 for the Europa ship. If a truck were to transport 11970 containers each year, it would emit a total of 1,091,783.70 kg of CO_2 yearly. To put these numbers in perspective a graph has been set up. In the graph the yearly emitted CO_2 in kg has been illustrated for both situations comparing ship and truck.

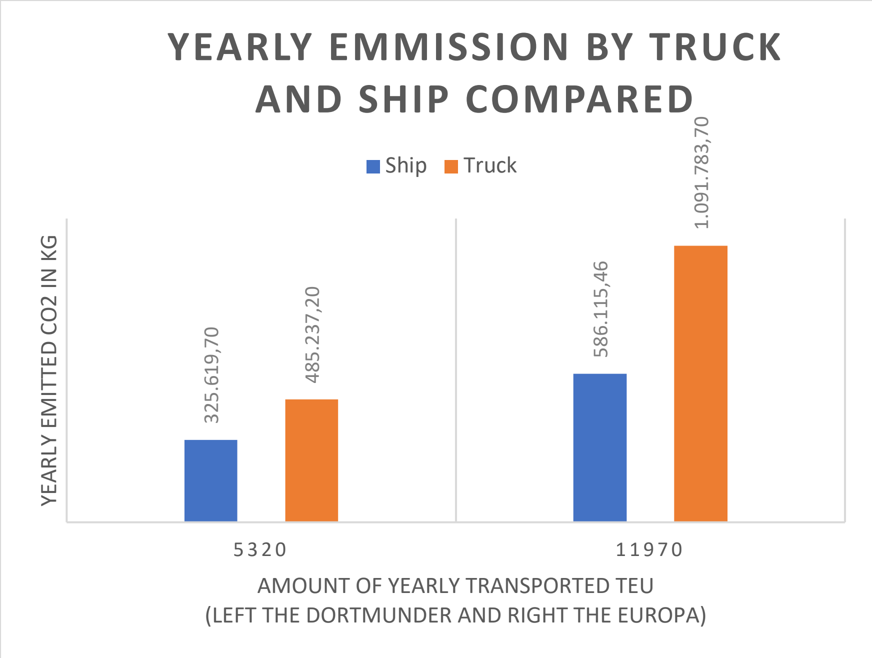


Figure 22: Truck and ship emissions compared (Team NWC2, 2020)

For the Dortmunder this is a reduction of 32.89% of emitted CO_2 compared to the traditional way of transport by truck. For the Europa ship this number is even bigger, 46.32% less emitted CO_2.

6.2 Sustainable future alternatives

6.2.1 LNG

The engines of ships are not the most environmentally friendly and produce a high number of Carbon dioxide (CO_2). Although as mentioned in paragraph 6.1, ships account on a greater scale for a lower number of CO_2 and operate with a lower ecological footprint when calculated in total tonnages of transported goods.

However, in order to reduce the number of emissions and to eliminate most of the greenhouse gasses (GHG) an alternative to the current marine fuel can be considered, which is known as Liquified Natural Gas (LNG) (Hildegard Suntinger, 2020). Although hydrogen offers zero-emissions, providing it into large quantities to fuel ships is still a challenge as this alternative comes with a large scarcity and requires high energy to produce it. An alternative for a zero-emission operation is the provision of battery-cells for ships. The chemistry and technology sector however are currently not advanced enough to produce battery cells large and powerful enough to act as an energy source for ships (Rivieramm, 2020). However, a potential concept regarding this power source will be discusses later in this paragraph.

Downside of LNG is that there is a potential of a 2.5% methane slip. This slip can account for 25x times more adverse climate impact than CO_2. However, manufactures continue to work and develop higher quality engines to minimize this. This power source eliminates 100% of **sulphur oxides (SOx)**, **particulate matter** (PMx), cut of 90% **nitrogen oxide** (NOx) escapes and finally a 20-25% **CO_2 reduction**. Therefore, LNG plays a key role to make the transition from marine fuel and is currently the only economic and widely available fuel alternative for deep sea and Inland Waterway Transport (Rivieramm, 2020).

6.2.2 ZES-packs

Within the Netherlands a combining 21% of CO_2 is accounted within the entire national transport sector. Hereby, Inland Waterway Transport is responsible for 5% of the emission (Zero Emission Services, 2020). This is where the company ZES (Zero Emission Services) comes to strive for an 100% green energy transition from marine fuel, and as a result to reach the climate agreements (49% fewer GHG compared to 1990) made for in 2030 (Klimaatakkoord, 2020). ZES offers a future proof concept with so called ZESPacks containers. These TEU containers operate as a main power source for ships and are green energy driven. Inland ships require between the 500-1000 kiloWatt (kW) Solely, **one** of these containers can provide 2000 kiloWatt per hour (kWH) of energy and thrive for a 2-4-hour sail journey, covering a distance of 25-50 Kilometers (zeroemissionservices, 2020). Once the energy driven containers are running low on power, they can be exchanged with a full one from a charging station placed nearby one of the transshipment terminals, as illustrated in *figure 23.* These required facilities can be paid from the subsidy regulation of €1.000.000 & €3.245.105 that has been made available by the province of Noord-Holland for physical adjustments in transshipment terminals. As articles 3.1.a and 3.1.b states that physical measures (required facilities) need to be able to reduce emission levels (NOx and CO_2) and by making a transition to renewable energy sources (Provincie Noord-Holland, 2020).

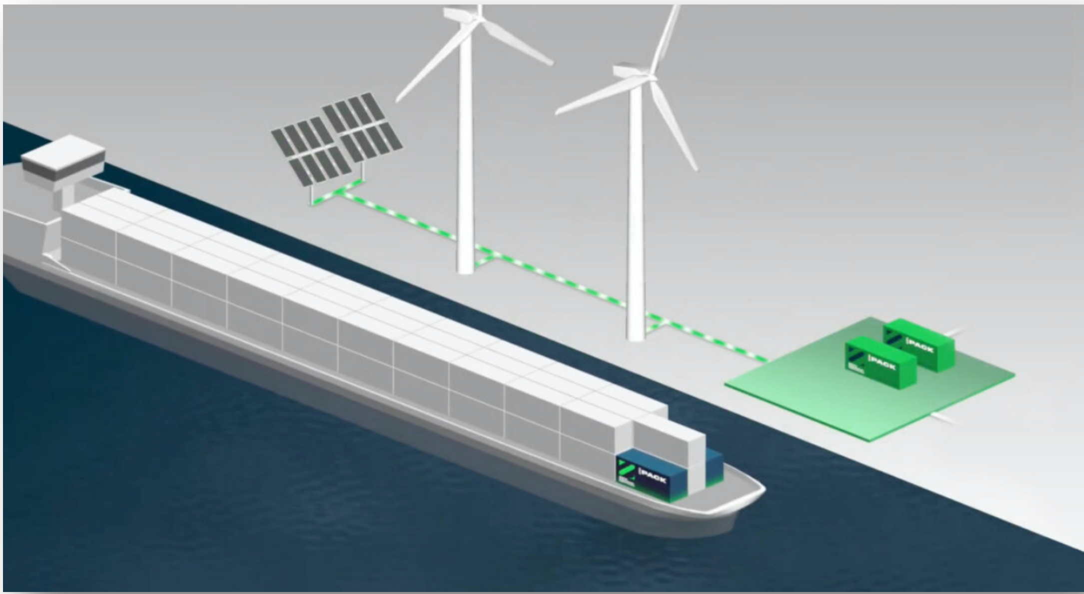


Figure 23: ZES-concept (zeroemissionservices, 2020)

The number of containers transported needs to be as high as possible in order to reduce the costs per container to strive for a cost-effective operation and to make this concept a reality. As only one ZESPack requires an estimated investment of 1 million euros it is expected that the mentioned subsidiary regulation is not enough to facilitate the project to its full potential. However, as most of the Inland Waterway Transports are mainly being operated within a fixed route, planning the required number of ZESPack's, charging stations and other necessary facilities are much easier to forecast resulting in more reliability. The company expects that one ZESPack loses a capacity with 20% once each 10 years, at the end of its lifespan the materials can be re-used and potentially change the power source to hydrogen if the sector is developed advanced enough, making it a zero-emission and future proof concept (zeroemissionservices, 2020).

6.3 Benefits of a sustainable operation

Research has shown that integrating sustainability within a business's operation can lead to breakthrough results. This paragraph will contain the main key benefits of a sustainable operation within the North-Holland corridor and the impacts it has on the behavior and selection of customers for product and services offered.

6.3.1 Regulations

Current and future developments strive for a reduction/elimination of emissions. These developments can increase Noord West Connects ability to prepare and comply with enacting regulations and milestones that has been set by the government for in the future. Not complying to the regulations may result in obstruction in one's operation or not being able to operate at all. This can lead to a reduction of shareholders value, company image, loss of customers and potentially the entire business if there is minimum to no progress achieved.

6.3.2 Brand image & Competitive advantage

A report that has been conducted in 2019 stated that 76% consumers are critical when it comes to commitment of a company in regard to sustainability and well-being of people (duurzaam-ondernemen, 2019). Brand awareness is easier recognized by the customer and improved if a company is practicing sustainability (reduction of emission, waste and reserving resources) like promised. A competitive advantage will be achieved for Noord-West Connect, as a certain percentage of customers are supporting companies practicing the mentioned sustainable habits and are more willing to purchase goods and services even if they are costlier than a competitor. (Michael Rogers, 2016). Firstly, this extends the interest from companies (the customers) that are willing to cooperate with Noord-West Connect and implement (more) sustainability within their own supply chain and more collaboration can take place between companies in order to preach for continuous development and improvement of the operation, both results in higher competitiveness within the region.

6.3.3 Reduced environmental impact

The first supply chain scenario stated that shipments are being sent from sender to receiver with the use of singular vehicles, trucks. Within the North Holland Corridor concept, the first part of the supply chain starts with empty trucks loading TEU containers from the loading point and head towards the harbor. From this point onward, the unloading phase takes place at the transshipment terminal and are loaded onto the Dortmunder/Europa ship making the entire supply chain a combination of trucks & ships. Due to the high payload in total tonnages of transported goods and a lower movement requirement of a Dortmunder/Europa ship in comparison to a truck, this modal shift combination has realized a reduction of 32.89% CO_2 per TEU container for the Dortmunder (with a yearly distributed basis of 5.320 TEU containers) and 46.32% CO_2 reduction is accounted per TEU container for the Europa ship (with 11.970 TEU containers yearly distributed) when compared to the transportation of one TEU container via a truck. This results in a lower ecological carbon footprint within the entire operation.

6.4 Conclusion

A transition of the current power source (marine fuels) is required in order to strive for a more sustainable operation. Hydrogen, a zero-emission solution is currently not an option as it comes with a large scarcity and requires high energy to produce it, besides the chemistry and technology sector are not advanced enough to produce battery cells large and powerful enough to facilitate that much power for ships. Green energy driven ZESPack containers could be an alternative for a zero-emission operation but the payload needs to be as high as possible to reduce the costs per container and a very high investment is mandatory, as the offered subsidy regulation from the province is not enough to realize this concept fully. So, a potential temporarily solution could be LNG, this source is economic and widely available, however usually a 2.5% methane slip can be expected, which can result for a 25x higher climate impact than CO_2. Manufactures however continue to improve the engines to minimize this methane slip. LNG eliminates most of the GHG and cuts CO_2 levels to 20-25% resulting in a higher sustainable operation.

Applying these developments will increase NWC’s ability to prepare and comply with regulations and milestones set by the government. These actions are recognized by the customers resulting in higher brand awareness and more customers supporting and willing to purchase goods and services from a company that is practicing sustainability. This not only extends the interest from companies willing to cooperate and implement (more) sustainability within their supply chain, but collaboration for continuous development and improvement for the operation is expected, resulting in a higher competitive advantage. Finally, the Dortmunder realized a reduction of 32.89% and the Europa ship 46.32% of CO_2 per TEU container transported compared to a truck transporting one TEU. As the ships have a higher payload, more containers can be transported resulting in a lower number of CO_2 emitted per TEU container.

7. Future proof aspects

Every logistic company is preparing themselves for the future in logistics. The need of innovating has never been bigger than right now. Implementation of new technology is vital to get on with all recent developments in the industry. In this chapter Smart ports are discussed. The various IT solution that are available right know will change the logistic scene.
Lastly, in this chapter the benefits and implementation of physical internet are elaborated.
With these relevant and future proof topics our team can provide an answer to the sub question:
How can the implementation of the infrastructural logistic joint corridor in North-Holland be realized?

7.1 Smart ports

With ports being the fundamental link within the transport system, the use for ports now and in the future is and will remain vital. To get ports more efficient, they are becoming smart. To get a smart port the essence that all stakeholders involved will join is mandatory.
A Smart port is a port with a digital twin. A smart port will use various amount of data generated by the operation. To get such a system off the ground it needs uniform input. These inputs provided by all the stakeholders are at any time available for all actors involved. Direct benefits are that all the nodes in the system can react to what is provided to them in real time.

With this infrastructure many useful features come available as well as relevant side topics. Below are the most relevant topics discussed.

7.1.1 Big Data

The use of big data is mandatory for a future proof logistic chain. Big data as the name itself reveals uses enormous set of diverse data that can or cannot have a direct link with each other. By the usage of a big data analytics tool, data sets that are normally too big or too complex can be analyzed. Many of these data sets can have many variables.
In the case of a container being shipped on a vessel for example, it is useful to know what the destination is, does it carry dangerous goods, what is the weight of a container, are there any other restraints? List like these are endless, especially in our digital world that will become even more digital very soon. (Breur, 2016)

Big data comes with various challenges besides only analyzing those data. Data needs to be stored, the right and useful data has to be separated from potential false data. Big data becomes more interesting if it is shared with others. Big data has to be up to date, so accurate conclusions can be made at any time. This last factor is especially important as big data often doesn’t take a sample, but big data observes the complete trend. Therefore, big data needs specialized software as previous intended. (Hilbert & López, 2011)

Existing usage of big data aims at possible trends that can be concluded out of a pattern that the data provides us. What is even more relevant is that those patterns can be used to make predictions. Predictions that can warn us for trends that occur. Especially in sectors where faults are highly unwanted. Topics like medial deceases, system failures or human behavior can be predicted. (The Economist, 2010)

Big data has many characteristics, but the most important once are the 5V's as can be seen in Figure 24.

- Velocity
  The speed data is available and renewed in the database.
- Volume
  Quantity of data is imported, as more files are added to the database more information becomes available to work with.
- Variety
  Variety determines what type of data is used and what kind it is.
- Value
  Big data only becomes interesting when value can be extracted out of the date.
- Veracity
  Veracity is one of the most important topics within the types of characteristics as veracity determines the reliability of the data.

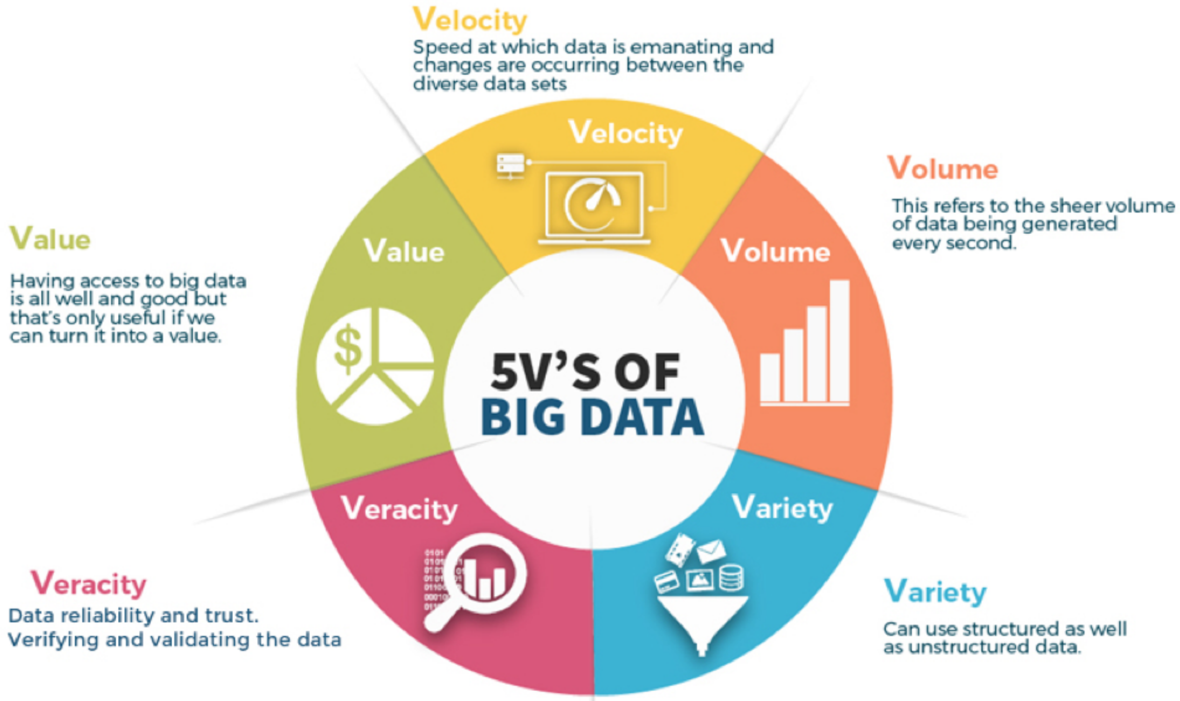


Figure 24: 5 V's of big data (Tech Entice, 2019)

7.1.2 Internet of things

Big data is nowadays automatically generated with the help of internet of things (IoT).
IoT is the link of tradition technology with the internet and databases. IoT helps to generate enormous quantities of data though sensors and software that log their processes to the internet.

These technologies have revolutionized the monitoring of processes through these real-time analytics. Therefore, the use of internet of things can deliberate a massive positive effect on the elaboration of the smartness of our ports. Port authorities are able to anticipate at situations as well as port security, all ship handlers and all other companies involved.
A collaborative decision-making system can be set up, something what is already introduced in airports where margins are even smaller than in the maritime sector. (Rouse, 2019)

7.1.3 Artificial intelligence

From Internet of things, it is a small step to the usage of artificial intelligence (Ai).
Ai is the task of understanding and gaining knowledge by machines. Ai can be seen as the equation of the human cognitive functions like solving problems and learning. (Russell & Norvig, 2019)

Artificial intelligence can be categorized into 4 types to understand the use and benefits of them.

1. **Reactive machines**
   Reactive machines are able to identify programmed topics and react to that. These reactions are preprogrammed algorithms that can be activated based on their findings
2. **Limited memory**
   Limited memory is similar as topic 1, but this system can react in real time based on what they have identified in the short past timeframe. A very clear example is adaptive cruise control in a car. When the car in front brakes, the system automatically reacts.
3. **Theory of mind**
   At phase three comes the difference mindset in the AI process. Machines will have a "theory of mind". In short this gives machines the understanding technique so that the machine can pro-active react on that situation.
4. **Self-awareness**
   Self-awareness is 2.0 version of the AI: Theory of mind phase. About this type of AI is still a lot unknown, but fact is that machines will be able to understand what they are doing and what the consequences of those actions will have.

As some topics within the world of artificial intelligence are still science fictions, many of the already existing features can observe and provide optimization plans for a more efficient logistic operation. (Hintze, 2016)

7.1.4 Blockchain

The IT topics that have been discussed previous will have no use at all if the outcomes are not sharable with each other within the industry. To get to a more open and more secure way of sharing files and information blockchain will be used more and more in the future.

Users are connected to other users by the blockchain network. This direct link provides that the traditional way of communicating via a server becomes irrelevant. Through the various direct links, the system works more efficient. One of the biggest pros for users of blockchain networks are the safety and privacy aspects of the network. Because users communicate directly via other users with each other, tracking becomes very difficult. The same goes for the inscription of the data send. Only the sender and the receiver are able to decrypt the date though their unique digital key that blockchain provides.

The practical use of blockchain is elaborated in the following figure:

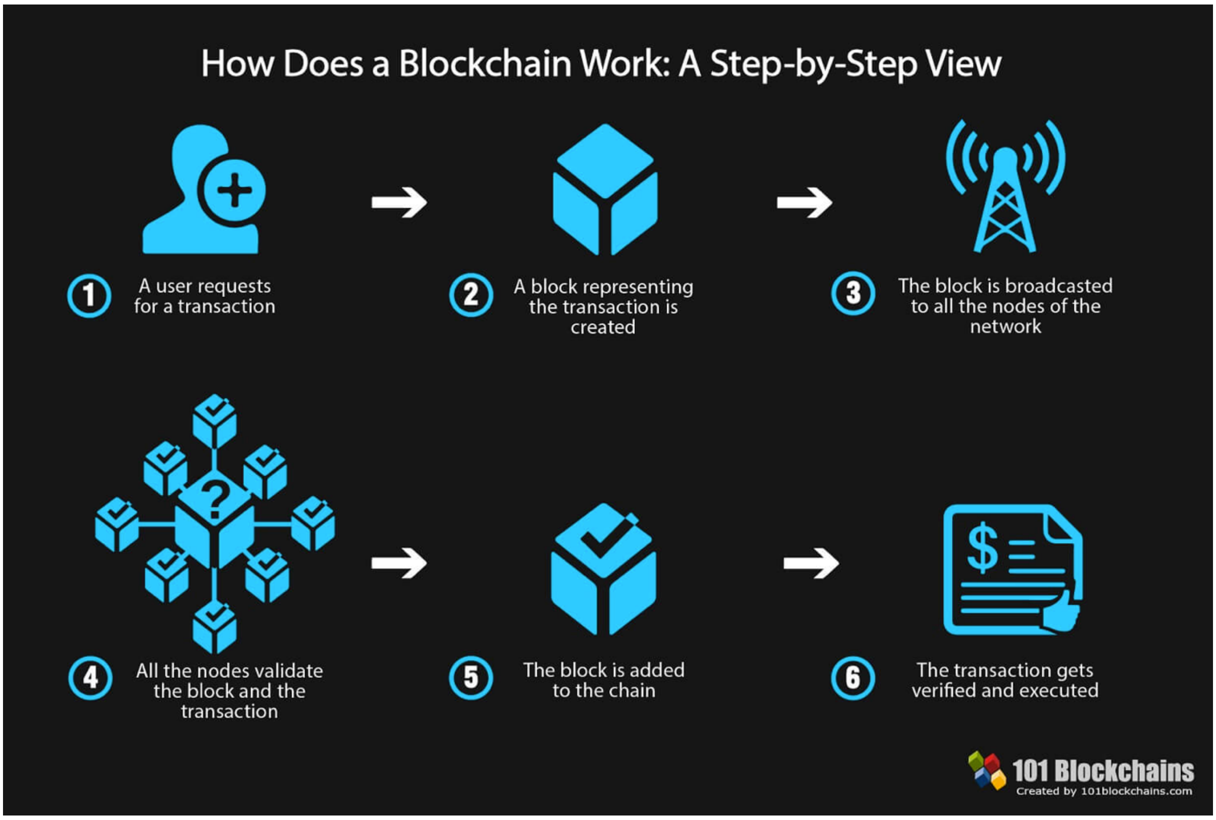


Figure 25: How does blockchain work: A Step-by-Step View (101Blockchains.com, 2018)

7.2 Physical internet

Physical internet (PI) can be categorized in two directions:

1. Transportation infrastructure
   Better digital networks that are set up to accommodate future demands of faster digital solutions.
2. Physical internet in logistics
   Physical internet in logistics means an open logistic system to improve efficiency and striving towards a more sustainable operation.
   (Montreuil, 2011)

The opportunities that come available with the implementation of PI are game changing for the industry.
The idea behind PI in logistics is that traditional transport and warehouses will work together so that the goods that have to be transported will follow the most optimum way possible. (Vis, 2020)

Within the PI five main areas were determined among the stakeholders:

1. Access and adoption
2. Governance
3. System design
4. PI nodes
5. PI network services

To each area, various topics are assigned as well as the milestones that have to be achieved. These were set up at the International Physical Internet Conference in July in London, 9-11 July 2019. (Alice, 2018) The outcome of this conference can be seen in figure 26.

Main area	Topics	Milestones
1. Access and adoption	• Mental shift • New role of LSP's in value chains • Advanced role of ports and hubs in value chains • Access model for shippers • Definition of data requirements for shipping on PI • Shared assets, warehouses, vehicles, infrastructure • Modelling and visualization of PI • Building the cornerstone for network integration • Last-mile platforms and Start-ups • Role of human's vs autonomous	• Increase awareness by convincing business case/ scenario including revenue model, gain- sharing and description of the different roles • Raise visibility of PI/ show benefits to join. • Prepare employees for PI by gamification for education
2. Governance	• Sustainability • Standardization, harmonization • Regulation, legislation • Define common interest and goals of stakeholders • Humans education and mind shift skills • Build trust among users, clear governance • Clear rules on liability • New competition rules & principles	• Checklist for legal issues • Decision on what needs to be governed • Establish legitimate body
3. System Design	• Smart contract/ blockchain approach, model for Operating System • Federative platform for documents and data sharing • Gain-sharing • Simulation possibilities • System design should be flexible to adapt • Virtualization and visualization of PI • Multimodal Logistics Networks interconnectivity	• Definition of PI functions and processes • Coverage of existing nodes and networks • Simulation model to understand the practicality of PI • Successful demonstrations of connected networks
4. PI Nodes	• Shared assets, warehouses, vehicles and infrastructure • Autonomous handling of goods • Autonomous hubs • Harmonizing transport modes • Standard containers to handle • Node operational protocols • Automated material handling • Digital marketplace and platforms • Modularization and seamless transshipment	• Definition of characteristics of nodes, capabilities and requirements • Services publication (nodes will publish and allocate capacity to PI)
5. PI network services	• Supply Chain visibility • Open, living networks • Autonomous hubs, goods • Synchromodality • Standard operational protocols • Visibility of available mode capacity • Collaboration/ bundling flows/ shared assets • Operational tools • E-transport documents	• Definition of rules, protocols and services • Define routing algorithms to search for efficient route • Real-time connectivity of different networks

Figure 26: Outcome International Physical Internet Conference (Alice, 2018)

In link to this minor the implementation of physical internet could boost up the future container terminal that is planned to be built in the Boekelermeer near Alkmaar. The open source of PI allows small and larger shipments to get from point A to B more efficiently, especially in the region of Noord-Hollland, as there are no other options than traditional road transport.

7.3 conclusion

It is obviously that smart solutions will become a fixed topic within the logistic chain as well as in the appliance of ports. The benefits that innovations like big data can generate with the help the internet of things, Artificial intelligence and Blockchain are endless.

To answer the sub question: *How can the implementation of the infrastructural logistic joint corridor in North-Holland be realized?* The answer lies within new techniques and a new way of working. The joint corridor can only be realized when there is enough demand, as also stated in chapter 4. This demand can be generated by the use of Physical Internet within logistics. Physical Internet within logistics is only possible when data engineers will be able to intergrade all information generated by IT improvements as stated above.

8. Industry Vision

In order to get a better understanding of the demand and the expectation from the sector, the team of Noord West Connect 2 teamed up with Jaap Schuurman, director of Stad Alkmaar: one of Hollands oldest and still existing logistics and transport company. The logistical problem from professional perspective is discussed, potential partners have been researched and at last the future vison within Noord-Holland logistics is examined.

Within this chapter our team is able to answer the following sub questions, which were formulated in the Minor Study Plan:

How can our team inventories potential actors who are willing to join the infrastructural logistic joint corridor in North-Holland?

- *What makes an actor qualified to be a potential joint corridor user?*
- *Which bottlenecks will companies encounter that are willing to shift to inland- and rail shipping?*
- *Which development solutions or concepts are mandatory for the potential companies to organise an infrastructural logistic joint corridor in North-Holland?*

8.1 Logistical problem

The logistical problem that our society is stuck with now can be formed into a single question.
Who owns the (logistic) problem?

To get an accurate answer to that question, all actors have to be considered.
The actors are:

- The (end) customer
- The Shipping/logistical company
- The company that has to get their products shipped.

The only need for the customer is most cases that they want their products delivered in the fastest way possible. The shipping company is often more interested in the most optimal way of transport. But in the end, the company that has to get their products shipped is paying for the shipping service. So, they decide is most cases how the transport is being executed.
The problem can also be given to the customer, because our expectation of the logistic system is extremely high nowadays.

This case brings us to the answer on the sub question: *Which bottlenecks will companies encounter that are willing to shift to inland- and rail shipping?*
The problem is the mindset to change to a more sustainable way of transport. This can be done by achieving the milestones that are linked to the access and adoption area from the Physical Internet implementation.

8.2 Potential partners

To get the North Holland corridor off the ground, potential partners are the most important factor. With the help of Jaap Schuurman a list has been made of companies that have a daily supply of containers. These companies together receive an estimated of over 100 TEU on a daily arrival. (Schuurman, 2020)

The sub question: *What makes an actor qualified to be a potential joint corridor user?* Can be answered with the listed information above. A reliable flow of weekly incoming and outgoing containers is mandatory to realize a joint corridor.

Further potential partners for the new North Holland corridor and the Boekelermeer terminal could be the company: a company specialized in concrete which will be located right next to the terminal. This company gets their supply in bulk, so containers cannot be used in this situation, but bulk ships can be unloaded perfectly at the new terminal, making the new dock even more efficient.

Last partner is a shipping company that wants to settle around the new transshipment terminal. This company can then use the terminal and potentially be one of the main users.

8.3 Vision

For Noord-Holland a vision on the Inland Waterway Transport's sector has been created by the Koninklijke BLN-Schuttevaer. They have come up with ten points that deliberate on the growth of the sector.
The main slogan they are spreading is: Transport over water where it is possible and over land where it is necessary. The sub question "*Which development solutions or concepts are mandatory for the potential companies to organise an infrastructural logistic joint corridor in North-Holland?"* Can be answered though the following points.

1. A solid structure for moving people and goods on water.
2. Transport on water has to be the most durable way possible.
3. Replacing bridges by aqueduct
4. Transport on water is fully aware of newest trends and the future.
5. Multiple terminals to shift goods to feed the Inland Waterway Transport routes.
6. Smaller waterways will be improved to accommodate more vessels.
7. Regional transport of pedestrians on water is optimized.
8. All potential business parks, docks and transit points are being used for transport on water.
9. The nautical labor market is more attractive, and education is acknowledged within Europe.
10. All topics above are realized.

(Koninklijke BLN-Schuttevaer, 2020)

As all topics above are all visions. The topics will not have to be realized, although topic 10 aims at it. It is about what the industry is striving for. Without a vision, the possibility of more transport on water and more joint corridors are not realistic.

8.4 conclusion

To answer the sub question: *How can our team inventories potential actors who are willing to join the infrastructural logistic joint corridor in North-Holland?* The team of Noord West Connect 2 teamed up with Stad Alkmaar and discussed to get a clear response out of the industry.

Stad Alkmaar came up with a more common question: *Who owns the (logistic) problem?*
The visions discussed in 8.3 are stated to improve Inland Waterway Transport and to optimise the logistic sector. In the end the sector needs a change to keep up with the time of living: on efficiency and on environmentally grounds. This statement provides an answer to the question *Which development solutions or concepts are mandatory for the potential companies to organise an infrastructural logistic joint corridor in North-Holland?*

What makes an actor qualified to be a potential joint corridor user? Can be answered easily: a reliable flow of weekly incoming and outgoing containers is mandatory to realize a joint corridor. At last *Which bottlenecks will companies encounter that are willing to shift to inland- and rail shipping?* The bottlenecks are the lack of a sufficient national infrastructural network where companies can team up. This can be solved by achieving the milestones that are linked to the access and adoption area from the Physical Internet implementation.

9. Conclusion

The goal of this advisory report was to create a logistical model for inland waterway shipping deliberating on modal shift within Noord-Holland. To get this model of the ground research has been done on various topics. These include the feasibility, future proof aspects and the industry vision.

Feasibility

Theoretically this project is feasible, but only if the required demand is available within the maximum last mile ranges. In the calculated scenario the Dortmunder ship has a saving of 54.55 euro and a CO_2 emission reduction of 32.89% per transported container and the Europa ship has a saving of 71.99 and a CO_2 emission reduction of 46.32% per transported container. With these savings the maximum last mile range for the Dortmunder ship is 6 kilometers, for the Europa ship the maximum last mile range is 8 kilometers. Both ships meet the restriction of transporting enough containers to make a harbor financially feasible.
To answer the sub question *"Which challenges are involved with the feasibility of realizing an infrastructural logistic joint corridor in North-Holland?".* The biggest challenge to realizing an infrastructural logistic joint corridor in North-Holland is the demand. If the demand within the limited is available, the joint corridor is feasible.

Future proof aspects

It is obviously that smart solutions will become a fixed topic within the logistic chain as well as in the appliance of ports. The benefits that innovations like big data can generate with the help the internet of things, Artificial intelligence and Blockchain are endless.

To answer the sub question: *How can the implementation of the infrastructural logistic joint corridor in North-Holland be realized?* The answer lies within new techniques and a new way of working. The joint corridor can only be realized when there is enough demand, as also stated in chapter 4. This demand can be generated by the use of Physical Internet within logistics. Physical Internet within logistics is only possible when data engineers will be able to intergrade all information generated by IT improvements as stated above.

Industry vision

To answer the sub question: *How can our team inventories potential actors who are willing to join the infrastructural logistic joint corridor in North-Holland?* The team of Noord West Connect 2 teamed up with Stad Alkmaar and discussed to get a clear response out of the industry.

Stad Alkmaar came up with a more common question: *Who owns the (logistic) problem?*
The visions discussed in 8.3 are stated to improve Inland Waterway Transport and to optimise the logistic sector. In the end the sector needs a change to keep up with the time of living: on efficiency and on environmentally grounds. This statement provides an answer to the question *Which development solutions or concepts are mandatory for the potential companies to organise an infrastructural logistic joint corridor in North-Holland?*

What makes an actor qualified to be a potential joint corridor user? Can be answered easily: a reliable flow of weekly incoming and outgoing containers is mandatory to realize a joint corridor. At last *Which bottlenecks will companies encounter that are willing to shift to inland- and rail shipping?* The bottlenecks are the lack of a sufficient national infrastructural network where companies can up. This can be solved by achieving the milestones that are linked to the access and adoption area from the Physical Internet implementation.

Logistical model

The logistical model that Team Noord West Connect 2 has designed can be seen in the schedule below. This model has been based on a 14-hour workday, providing the optimal working schedule available.

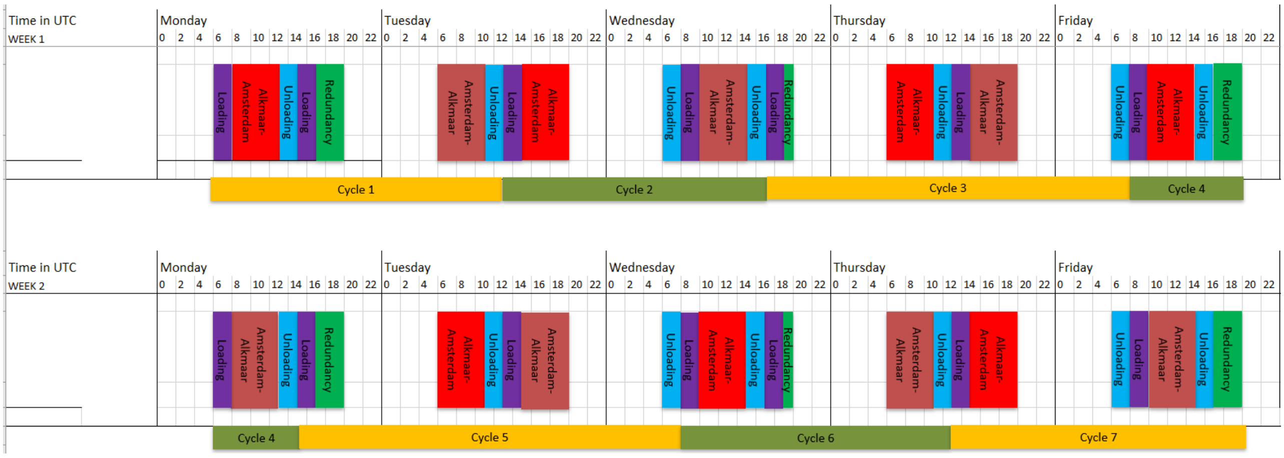


Figure 27: Schematic view of planning (Team NWC2, 2020)

The schedule provides a two-weekly planning, which completes seven cycles in total.

This schedule together with the sub questions answered above give provide combined a sufficient answer to the main question: *By which infrastructural and logistical transport solutions can our team of Off-Road runners organise an infrastructural logistic joint corridor in Noord-Holland in the upcoming year?* An optimized logistical model!

10. Recommendation

Research demand

To make this plan feasible, the required demand must be available. Therefore, team Noord West Connect recommend investigating if the required demand is available within the maximum last mile ranges. If the demand is available, the project can be realized. If the required demand is not available alternative solutions can be investigated, the following recommendations discuss some of these alternative solutions.

Public quay

In this report, the project was set up with the assumption of a container terminal in Alkmaar. All calculations were made with costs and restrictions involved with using a container terminal. An alternative to the container terminal could be a public quay. A public quay is a quay set up by the government. At the quay a crane can be hired to load and unload the ships. This way the requirement of transporting 5000 containers each year is not required anymore. This changes the cost per container. To investigate if this is a better alternative, team Noord West Connect 2 recommend doing a detail research investigating the costs of using a public quay compared to the already investigated container terminal.

Further optimization of available hours

While planning the schedule for the ships, 14 available hours a day was assumed. In the investigated schedule the load and unload time were planned within these 14 hours. The loading and unloading can also be done outside these 14 hours. So, to optimize the schedule even further, a planning can be made where some of the loading and unloading takes place outside of these 14 available hours. Team Noord West Connect 2 recommend optimizing the schedule even further to maximize the weekly retours.

Lean and Green app

With the provided schedule within the logistic model, the shipping times should be linked to the Lean and Green app. This makes it available to let al partners join the corridor that is created. The Lean and Green app could also be used to lay a foundation the implantation of Physical Internet.

Investigate in further routes

This advisory report has focussed primary on goods transported within TEU at the Amsterdam – Alkmaar trajectory. The logistic model has been based on this research. It is useful to do further research on the flow of goods out and to of Alkmaar to other locations within the Netherlands. This in order to fill up routes that go further than Amsterdam. In chapter 5 the current routes out of Amsterdam are specified, when enough demand is gathered one of the already existing could be expanded to Alkmaar.

Bibliography

(n.d.).

101Blockchains.com. (2018). *How does Blockchain work.*

Alice. (2018, 10 12). *Progress of SENSE project on developing Physical Internet (PI)*. Retrieved from Alice: https://www.etp-logistics.eu/?p=2623

anwb. (2020). *Alles over uitstoot*. Retrieved from anwb: https://www.anwb.nl/auto/nieuws-en-tips/alles-over-uitstoot#:~:text=CO2%20%2D%20Koolstofdioxide&text=Voor%20elke%20liter%20benzine%20die,LPG%20is%20dat%201610%20gram.

Bouw Bedrijf Puremerend. (2020, 10 27). *Kaart Noord Holland*. Retrieved from bouwbedrijfpurmerend: https://www.bouwbedrijfpurmerend.nl/bouwbedrijf-purmerend-uitbouw-aanbouw-en-verbouwing/noord-holland-groot/

Breur, T. (2016). Statistical Power Analysis and the contemporary "crisis" in social sciences. *Journal of Marketing Analytics*.

duurzaam-ondernemen. (2019, Oktober 9). *Consument kritisch over duurzaamheid bij bedrijven*. Retrieved December 13, 2020, from Duurzaam-ondernemen: https://www.duurzaam-ondernemen.nl/consument-kritisch-over-duurzaamheid-bedrijven/

Een vandaag. (2020, 01 20). *zelf varend schip de oplossing*. Retrieved from Een vandaag: https://eenvandaag.avrotros.nl/item/zelfvarend-schip-is-de-oplossing-voor-het-personeelstekort-in-de-binnenvaart/

Hilbert, M., & López, P. (2011). The World's Technological Capacity to Store, Communicate, and Compute Information.

Hildegard Suntinger. (2020, Augustus 4). *Inland waterway shipping can make freight transport much more sustainable*. Retrieved December 9, 2020, from Innovationorigins: https://innovationorigins.com/inland-waterway-shipping-can-make-freight-transport-much-more-sustainable/

Hintze, A. (2016, 11 14). *Understanding the Four Types of Artificial Intelligence* . Retrieved from Government Technology: https://www.govtech.com/computing/Understanding-the-Four-Types-of-Artificial-Intelligence.html

Klimaatakkoord. (2020, n.d. n.d.). *Wat is het doel van het Klimaatakkoord?* Retrieved December 9, 2020, from klimaatakkoord: https://www.klimaatakkoord.nl/klimaatakkoord/vraag-en-antwoord/wat-is-het-doel-van-het-klimaatakkoord

Koninklijke BLN-Schuttevaer. (2020). *Ware koers NH 2030 .*

Michael Rogers. (2016, March 29). *6 Benefits of Becoming a Sustainable Business*. Retrieved December 12, 2020, from environmentalleader: https://www.environmentalleader.com/2016/03/6-benefits-of-becoming-a-sustainable-business/

Ministry of Infrastructure and Water Management . (2020, n.d. n.d.). *6a-Modal Shift*. Retrieved November 4, 2020, from Kenniscentrum InfoMil: https://www.infomil.nl/onderwerpen/duurzaamheid-energie/energiebesparing/kennisbank/@206612/6a-modal-shift/

Modderman, K. (2020). (T. N. 2, Interviewer)

Montreuil, B. (2011). *Towards a Physical Internet: Meeting the global Logistics Sustainability Grand Challenge.*

Overheid. (2020, n.d. n.d.). *Toegestane afmetingen en diepgang vaarweggedeelten*. Retrieved November 28, 2020, from Binnenvaartkennis: https://www.binnenvaartkennis.nl/toegestane-afmetingen-en-diepgang-vaarweggedeelten/

Pantela. (2018, Februari 27). *De binnenvaart heeft potentie*. Retrieved November 17, 2020, from Eindrapport Toekomst goederenvervoer over water in Noord-Holland: https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=&cad=rja&uact=8&ved=2ahUKEwjimo3Eq5btAhWS66QKHffAAIAQFjAAegQIARAC&url=https%3A%2F%2Fwww.noo

rd-
holland.nl%2FOnderwerpen%2FVerkeer_vervoer%2FBeleid%2FEindrapport_toekomst_goederenvervoer_over_wat

Pantela. (2018, Februari 27). *Goederensoort*. Retrieved November 16, 2020, from Eindrapport Toekomst goederenvervoer over water in Noord-Holland: https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=&cad=rja&uact=8&ved=2ahUKEwjimo3Eq5btAhWS66QKHffAAIAQFjAAegQIARAC&url=https%3A%2F%2Fwww.noord-holland.nl%2FOnderwerpen%2FVerkeer_vervoer%2FBeleid%2FEindrapport_toekomst_goederenvervoer_over_wat

Pantela. (2018, Februari 27). *Vaarweg 2a: Zaan-Alkmaar*. Retrieved Novemer 16, 2020, from Eindrapport Toekomst goederenvervoer over water in Noord-Holland: https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=&cad=rja&uact=8&ved=2ahUKEwjimo3Eq5btAhWS66QKHffAAIAQFjAAegQIARAC&url=https%3A%2F%2Fwww.noord-holland.nl%2FOnderwerpen%2FVerkeer_vervoer%2FBeleid%2FEindrapport_toekomst_goederenvervoer_over_wat

Port Of Amsterdam. (2020, December 21). *Binnenvaart*. Retrieved from Port of Amsterdam: https://www.portofamsterdam.com/nl/business/verbindingen/binnenvaart

Port of Amsterdam. (2020, December 31). *Diensten en voorzieningen*. Retrieved from port of amsterdam: https://www.portofamsterdam.com/nl/scheepvaart/zeevaart/diensten-en-voorzieningen

Port of Amsterdam. (2020, December 21). *Spoorvervoer*. Retrieved from Port of Amsterdam: https://www.portofamsterdam.com/nl/business/verbindingen/spoorvervoer

Port of Amsterdam. (2020, December 21). *Wegtransport*. Retrieved from Port of Amsterdam: https://www.portofamsterdam.com/nl/business/verbindingen/wegtransport

Port of Amsterdam. (2020, December 21). *Zeevaart*. Retrieved from Port of Amsterdam: https://www.portofamsterdam.com/nl/business/verbindingen/zeevaart

Port of Rotterdam. (2020, December 2020). *Northwest central corridor.* Retrieved from Amsterdam Logistics: https://amsterdamlogistics.nl/wp-content/uploads/2019/02/por-045_infographic_noordwest_corridor_08.pdf

Provincie Noord-Holland. (2020, n.d. n.d.). *Duurzame Zeehavens Noord-Holland 2020, subsidie*. Retrieved Decemeber 12, 2020, from Provincie Noord-Holland: https://www.noord-holland.nl/Loket/Producten_en_Diensten/Producten_op_alfabet/D/Duurzame_Zeehavens_Noord_Holland_2020_subsidie

Rail Net Europe. (2020, December 21). *Rail Feight Corridors General Information.* Retrieved from rne.eu: https://rne.eu/rail-freight-corridors/rail-freight-corridors-general-information/

Rijkswaterstaat. (2020). Vaarweg informatie. https://vaarweginformatie.nl/frp/main/#/geo/map.

Rivieramm. (2020, n.d. n.d.). *LNG fuel and the ship emissions debate*. Retrieved December 8, 2020, from Rivieramm: https://www.rivieramm.com/opinion/opinion/lng-fuel-and-the-ship-emissions-debate-23849

Rouse, M. (2019). *Internet of Things (IoT).*

Russell, S. J., & Norvig, P. (2019). Artificial Intelligence: A Modern Approach (3rd ed.) .

Schuurman, J. (2020, 12 10).

Sjoerdsma, S. (2020, December 17). Noord West Connect DRAFT discussion. (T. N. 2, Interviewer)

Team NWC2. (2020). Amsterdam University of Applied Sciences.

Tech Entice. (2019). *5V's of Big Data.* https://www.techentice.com/the-data-veracity-big-data/.

The Economist. (2010). Data, data everywhere.

Vis, I. (2020). *Towards virtual ports in a Physical Internet*. Retrieved from TKI Dinalog: https://www.dinalog.nl/project/towards-virtual-ports-a-physical-internet/

Wel ingelichte kringen. (2020, 10 20). *eerlijke concurrentie wegtransport*. Retrieved from wel ingelichte kringen: https://www.welingelichtekringen.nl/anp/eerlijke-concurrentie-wegtransport-naderbij

Zero Emission Services. (2020, n.d. n.d.). *Belangrijke stap voor klimaatakkoord*. Retrieved December 9, 2020, from Zero Emission Services: https://zeroemissionservices.nl

zeroemissionservices. (2020, n.d. n.d.). *Het opladen van de containers*. Retrieved December 9, 2020, from zeroemissionservices: https://zeroemissionservices.nl/opladen/

List of Appendices

Appendix 1: The classifications of the ships considered to be used

Appendix 2: Schematic view of the planning