

Executive Summary



Cargo-Hyperloop Holland

A pre-project feasibility for
connecting Noord- and Zuid
Holland via hyperloop

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Prepared by:



In collaboration with:



ABOUT STICHTING HYPERLOOP DEVELOPMENT PROGRAM:

The Stichting Hyperloop Development Program ("Stichting HDP") is the lead partner for the Hyperloop Development Program. Stichting HDP's goal is to facilitate development of hyperloop up to commercialization, to be further developed by commercial parties into concrete market propositions. To this end, the Stichting HDP promotes public-private partnerships, initiates and governs R&D programs, and creates awareness by dissemination of results.

DISCLAIMER:

The Hyperloop Development Program is co-financed by the Dutch Ministries of Economic Affairs and Climate Policy (EZK) and Infrastructure & Water Management (I&W).

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Hyperloop Development Program

– international public-private initiative supporting the technological advancement of the hyperloop and development of the European Hyperloop Center (EHC) in Groningen (an open test facility that will validate the technology for commercial operations).





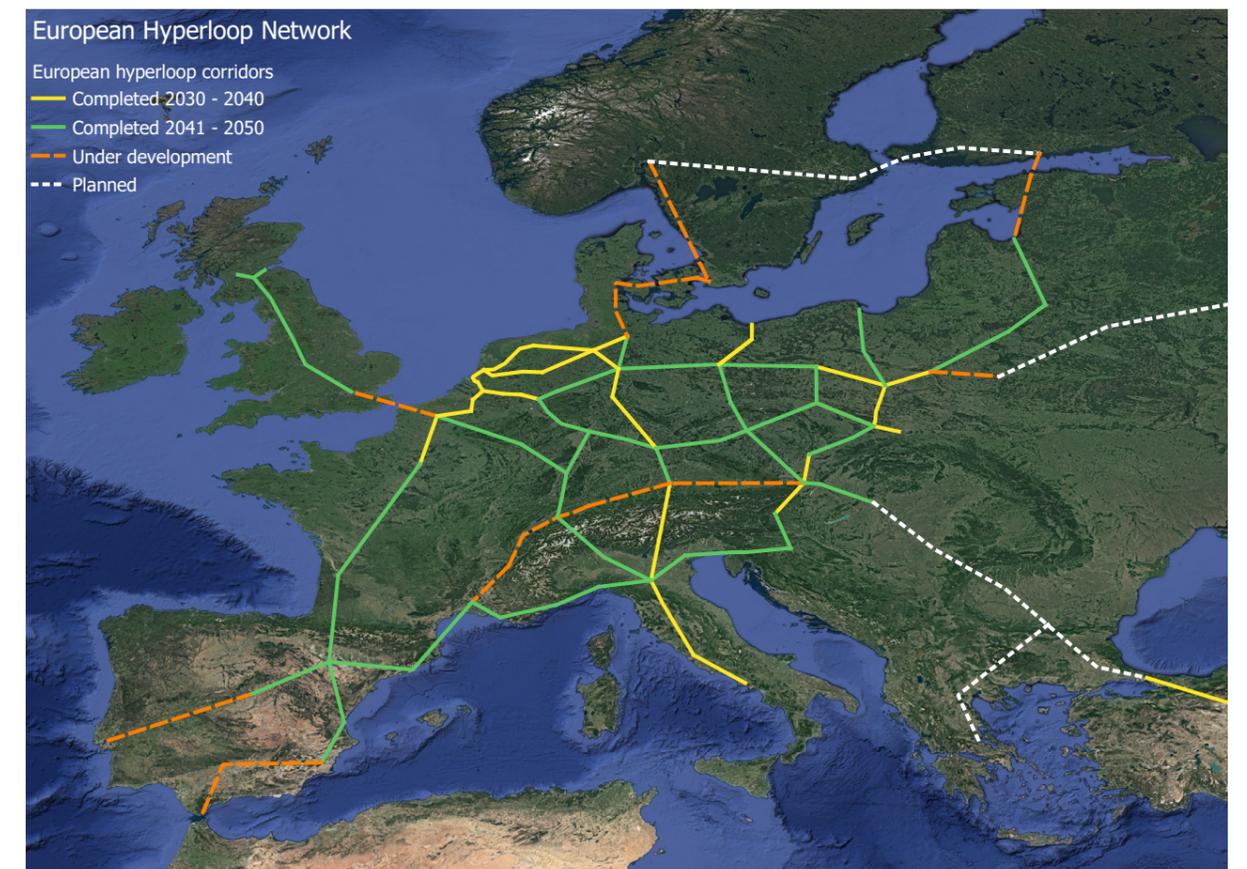
The Project

The Cargo Hyperloop Holland corridor is being investigated as the first step in creating a pan-European, emission-free hyperloop network. This network will make it possible to transport passengers and goods across Europe within hours, while drastically reducing emissions and road congestion.

The location of the first hyperloop corridor in the Netherlands has been selected based on the results of preparatory studies since

the formation of the Hyperloop Development Program. Hyperloop transport has since become an innovative industry with great potential as a strong driver of the future growth of the Dutch economy.

More than 30 private and public entities have signed the Cargo Hyperloop Holland Covenant in support of the development of the first commercial hyperloop corridor focused on cargo transport.



The Cargo Hyperloop Holland project aims to address the multiple challenges of sustainability, connectivity and innovation by:

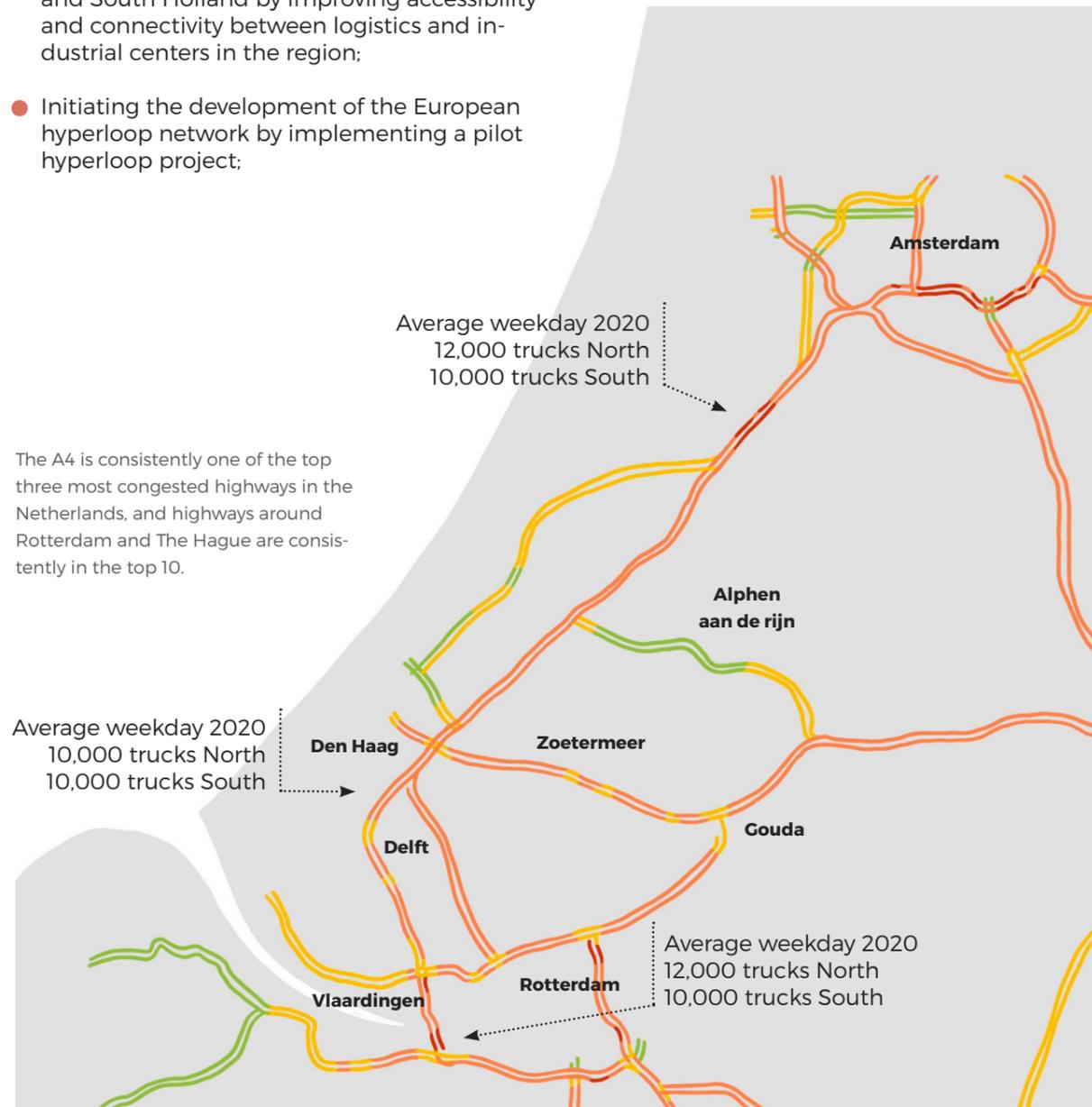
- Reducing levels of road traffic and congestion on the A4 between Amsterdam and Rotterdam by providing an additional transport modality;
- Reducing carbon and other transport-related emissions, thereby helping to achieve regional and national sustainability goals;
- Delivering future economic growth for North and South Holland by improving accessibility and connectivity between logistics and industrial centers in the region;
- Improving the reliability of transport and transport times for shippers in North and South Holland;
- Delivering savings and improving the efficiency of other transport infrastructure development schemes in the region.
- Initiating the development of the European hyperloop network by implementing a pilot hyperloop project;

The A4 is consistently one of the top three most congested highways in the Netherlands, and highways around Rotterdam and The Hague are consistently in the top 10.

Average weekday 2020
10,000 trucks North
10,000 trucks South

Average weekday 2020
12,000 trucks North
10,000 trucks South

Average weekday 2020
12,000 trucks North
10,000 trucks South



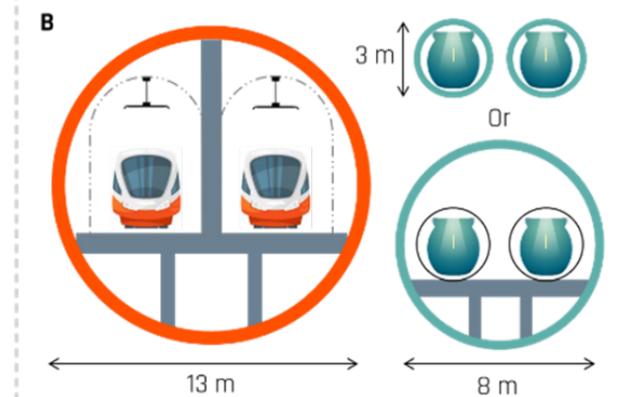
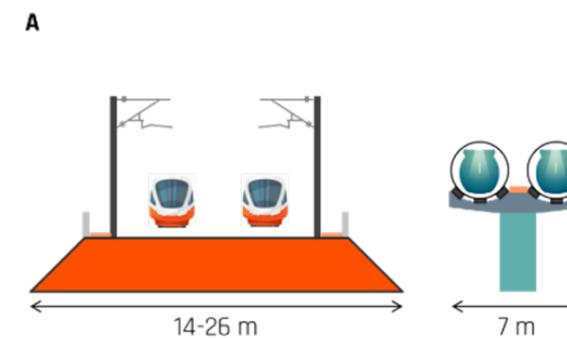
The Hyperloop System

The hyperloop is an electrically powered mode of land transportation consisting of vehicles travelling through a network of low-pressure tubes. The system is capable of high-speed and driverless operations, and offers a continuous capacity for transporting passengers and cargo towards their destinations without intermediate stops. The hyperloop infrastructure can be built above ground, at ground level or below ground. Vehicles that resemble small aircraft travel inside the tube, either separately or in short trains of coupled vehicles. The hyperloop system uses the same infrastructure for passenger and cargo transport.

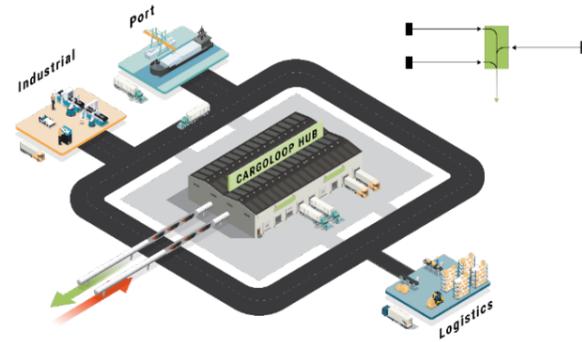
The hyperloop system combines existing technologies from different industries to form a new mobility concept. Instead of rail technologies with wheels on tracks, the system uses magnetic forces for levitation, guidance and propulsion. The low-pressure environment reduces air resistance and energy consumption and enables vehicles to reach maximum speeds of up to 700 km/h.

The hyperloop has the following key characteristics:

- High capacity. Over 20,000 passengers or 20,000 half pallets of cargo per hour per direction at 700 km/h
- High transit speeds. Operational speeds ranging from 100 km/h for local links to 700 km/h for major international links
- Low energy consumption. 38 Wh/passenger/kilometer at 700 km/h, and 15 Wh/ton/kilometer at 200 km/h
- Low maintenance. Making use of frictionless magnetic levitation and propulsion and switching without moving components means that there is minimal wear and tear
- Zero operational emissions. Electrically powered train supplied by renewable energy sources produces zero operational emissions
- Minimal infrastructure footprint. The small footprint of the elevated infrastructure enables the hyperloop to align with existing infrastructure and connect to and integrate with transport hubs
- Lower costs than any other comparable transport option



The Hyperloop for Cargo



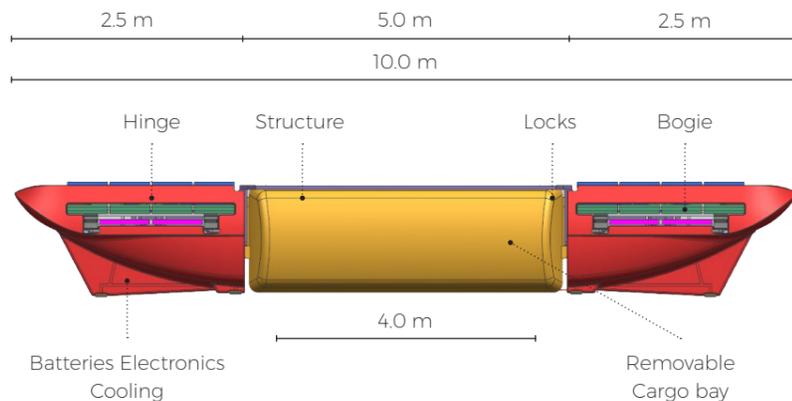
The hyperloop for cargo is a comprehensive logistics solution for moving small and medium-sized, standardized, and configurable shipment units. The use of hyperloop for cargo applications is mainly focused on time-sensitive, demand-sensitive and high-value products, such as fresh food, horticultural products, pharmaceuticals, e-commerce, fashion, electronics, and high technology equipment. The hyperloop provides a direct solution for current and future challenges in these industries by:

- Radically improving the agility and efficiency of logistics operations for just-in-time and on-demand deliveries of small and medium-sized shipments and packages, while minimizing costs and carbon footprint
- Unlocking new market opportunities and economies of scale for time-sensitive and demand-sensitive products (reducing market access times, increasing geographical coverage, enabling new types of services and products)
- Enabling a cost-effective transition to digital and automated logistics operations, thereby increasing responsiveness to demand volatility and changing customer requirements (logistics as a service, automated fulfillment, packaging modularization, physical internet)

The hyperloop also benefits other market segments by creating opportunities for supply chain optimization and automation, increasing the coverage of existing logistics facilities, and reducing the need for capital investments in new or expanded facilities.

The shipment of small and medium-sized cargo units is an emerging challenge for the logistics market which has not yet been fully addressed by the transport industry, and the hyperloop for cargo is a complementary solution that addresses this issue. Full integration of the hyperloop within the logistics chains reduces operational stress on existing cargo transport modes.

Hyperloop vehicles for cargo are designed specifically to move cargo through hyperloop tubes at high speeds and with limited energy use. The hyperloop vehicle for cargo is designed to accommodate medium and small-sized shipments, and its cargo bay provides a cargo envelope of 4.0 x 1.2 x 1.2 meters, with a maximum payload of 2,500 kg.



The Cargo Hyperloop Holland Corridor

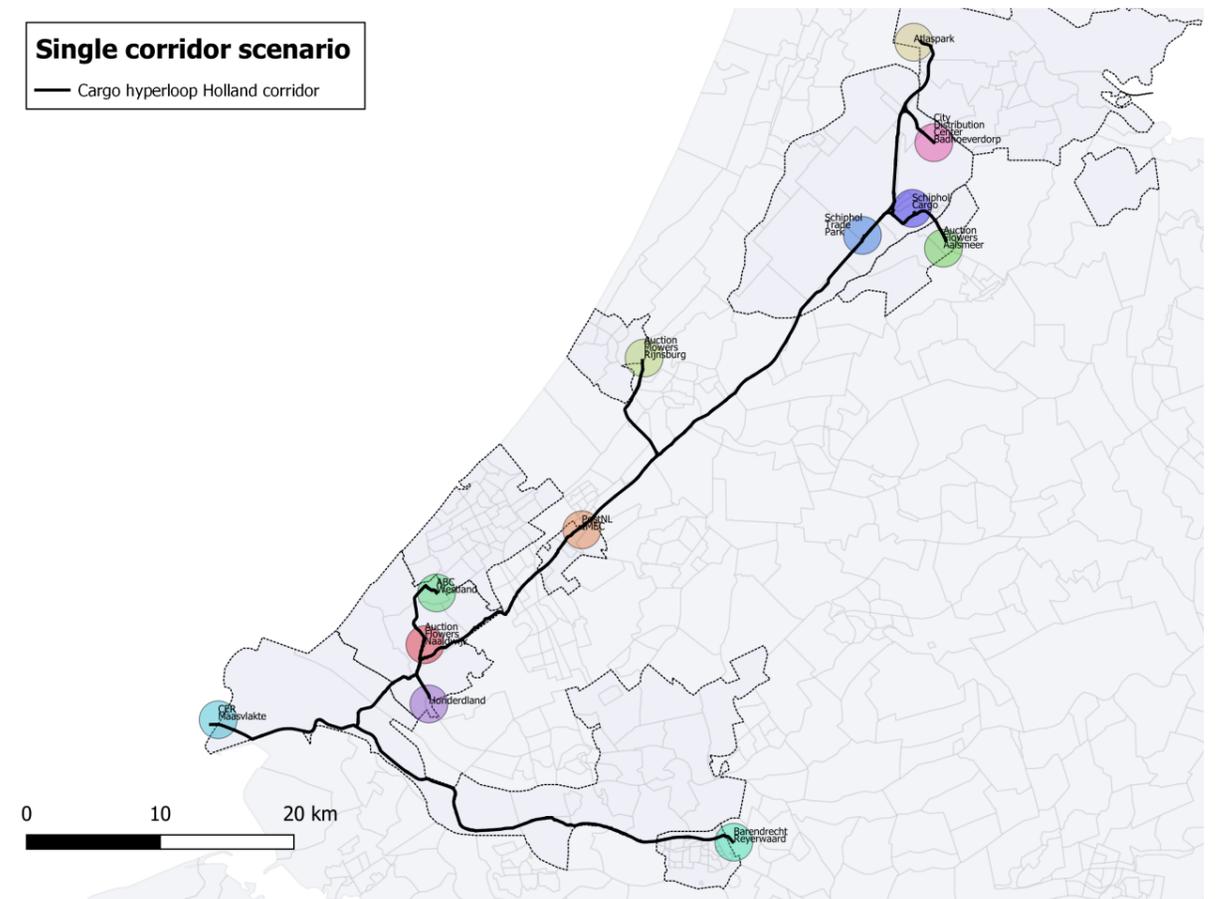
The locations of hubs along the Cargo Hyperloop Holland corridor have been identified in cooperation with a broad stakeholder community, ensuring that the corridor connects major logistics locations and provides hyperloop access points for the facilities making and distributing the main types of goods produced in the area. Of the 12 hubs identified along the corridor, five will serve

as regional hubs, providing services for larger areas, and the remaining seven will be local, focused on serving specific logistics facilities.

The total length of the corridor is 149 km, with 26 switches located at the junctions leading to hubs. 67% of the corridor is designed at grade, 5% is elevated, 21% is below ground and 7% makes up the transition sections. Most of the corridor is designed as a single

Single corridor scenario

— Cargo hyperloop Holland corridor





tube line (64% of the corridor length), while the remaining 36% would have a double tube configuration.

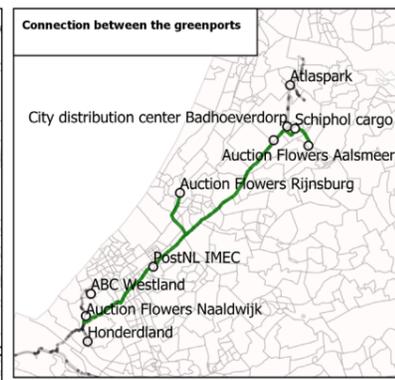
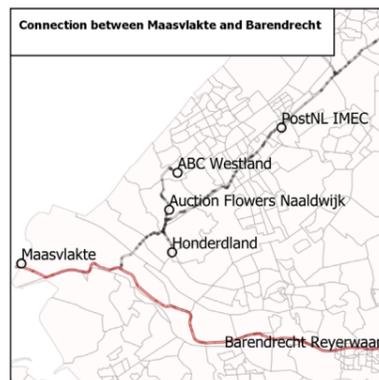
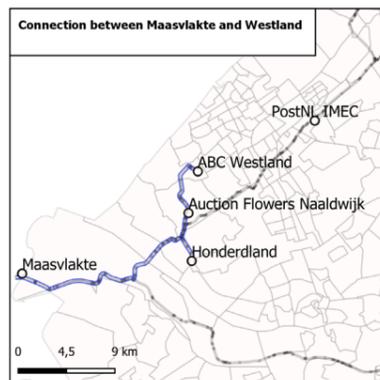
The alignment of the Cargo Hyperloop Holland corridor has been evaluated to identify the risk of any potential conflicts with existing infrastructure, protected areas and planned developments. The major risks relate to conflicts with the future widening of the A4 and an additional runway planned for Schiphol airport. The conflict with the widening of the A4 has been resolved by adjusting the alignment. The plans for an additional runway will be further discussed with Schiphol Airport and the government.

The current alignment allows for a maximum speed of up to 400 km/h along almost 50% of the route. In the remaining sections, the speed is limited to 200 km/h, 150 km/h or 100 km/h, due to spatial integration requirements.

The Cargo Hyperloop Holland corridor is divided into three sections that have been



considered separately (alongside the corridor) in order to identify the most viable potential pilot route.



Demand Projections

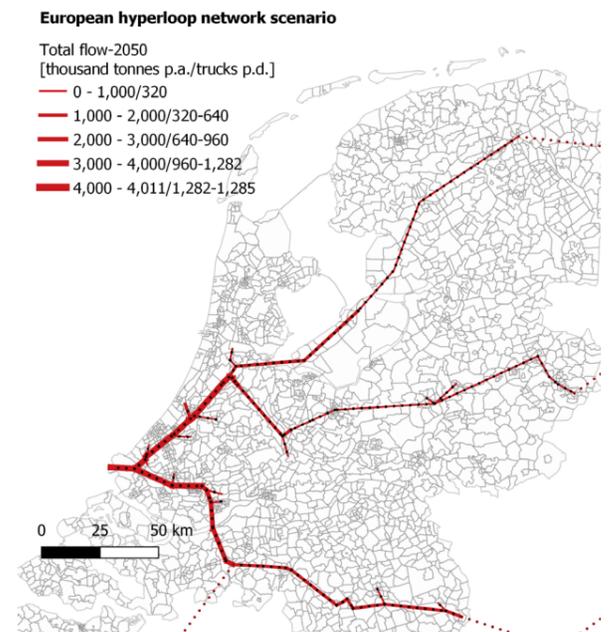
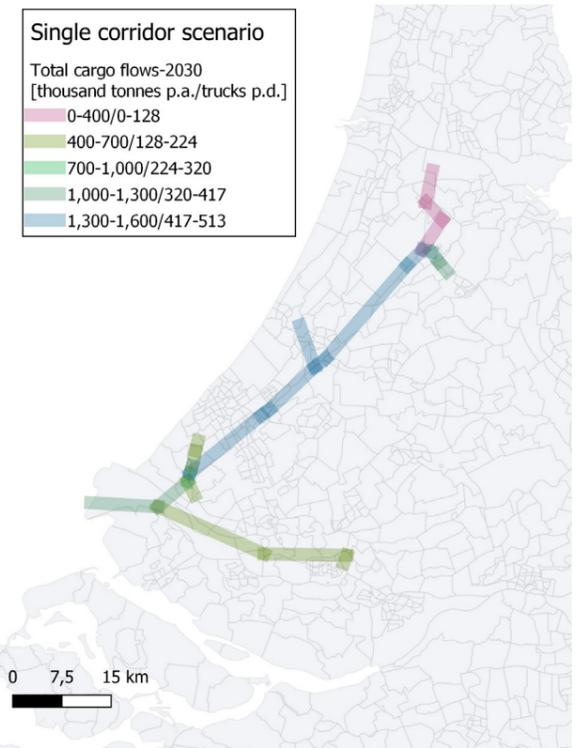
In 2030, when the Cargo Hyperloop Holland corridor will be completed as the first hyperloop corridor in Europe, it is expected to attract 3.4 million tonnes of cargo. Upon completion of the Dutch hyperloop network in 2040, the volume transported along the corridor will increase to 5.6 million tonnes. The demand will continue to grow as the European network is expanded, reaching 7.9 million tonnes in 2050.

The Cargo Hyperloop Holland corridor will also play an important role in relieving congestion on the Dutch road network. In 2030 - the first fully operational year - the corridor will enable the removal of 1,091 trucks daily from the A4 expressway between Rotterdam and Amsterdam and adjacent roads.

The expansion of the network will see the corridor increase even more in importance as an alternative to road transport, and will be expected to capture an equivalent of 2,517 trucks per day by 2050.

Assessment scenarios:

- Single section scenario - all three sections of the Cargo Hyperloop corridor are considered separately.
- Single corridor scenario - the Cargo Hyperloop Holland corridor is considered as a whole, and no other parts of the future hyperloop network are considered
- Dutch hyperloop network scenario - the Cargo Hyperloop Holland corridor and its sections are part of the future Dutch hyperloop network.
- European hyperloop network scenario - the Cargo Hyperloop Holland corridor is part of the European hyperloop network.



Project costs and revenues

Based on the system specifications as well as the design of the route alignment, Hardt derived the costs for the various assessment scenarios and had an independent external party¹ verify them. The costs associated with land acquisition and visual pollution of the environment have not been taken into account.

Revenues have been determined based on the demand assessment and by applying a price of €0.25/t/km, which is in the middle of the range of prices typically charged in the Netherlands for road transportation.

Cost Items (in real values, in million €) ²	Maasvlakte - Westland	Maasvlakte - Barendrecht	Greenports	Corridor	Corridor (with NL network)	Corridor (with NL & EU network)
Linear infrastructure	335	223	743		1,390	
Hub	27	12	30		47	
Other costs	20	13	44		80	
Grand Total	382	235	817		1,473	
Costs per km	13.2	5.2	13.9		9.8	
Number of vehicles	60	25	150	349	501	621
Cost of vehicles	113	4.7	28.2	65.6	94.2	116.7
SG&A variable cost	6.9	3.8	24.1	58.8	79.2	89.7
Energy variable cost	1.2	0.7	4.1	10.0	13.5	15.3
Maintenance vehicles variable cost	4.7	1.9	11.8	27.3	37.8	44.5
Insurance of assets variable cost	47.2	27.6	103.1	194.2	196.4	197.6
Infrastructure mainte- nance fixed cost	16.3	9.5	34.8	64.7	64.7	64.7
Total opex	76.1	43.4	177.9	355.1	391.6	411.7
Average annual opex	2.5	1.4	5.9	11.8	13.1	13.7

1 Balance

2 Total values may deviate due to rounding

Economic Impacts

The development of the Cargo Hyperloop Holland corridor will provide a new opportunity for the logistics sector to use a sustainable and fast mode of transportation, first at the regional level, and then nationally and at the European scale. The implementation of the Cargo Hyperloop Holland corridor will result in significant positive socio-economic impacts, contributing to achieving national and European strategic objectives.

- The introduction of the Cargo Hyperloop Holland corridor will improve the competitiveness of businesses in the region due to the optimization of logistics processes, allowing users to achieve tangible gains in transit time and reliability. These benefits range from €1.3 billion with the corridor being considered separately, to €1.9 billion for the corridor being a part of wider Dutch and European hyperloop networks.
- There is the potential to reduce carbon emissions due to freight transport operations in the corridor by 1 million tonnes in 2050. Taking into account the CO₂ emitted during construction, by 2050 the corridor implementation will result in a net CO₂ reduction of up to 0.6 million tonnes. Further technical work with industrial partners will be conducted to minimize hyperloop construction emissions and therefore bring even more positive net impacts.

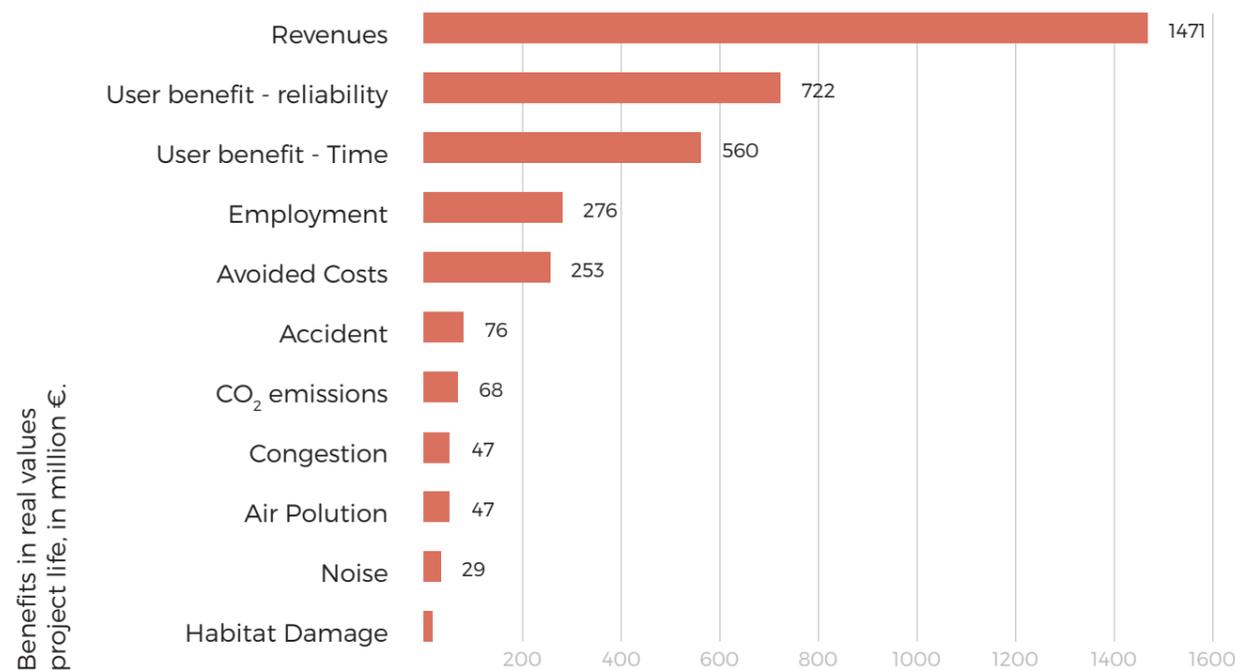
- A whole new industry is developing around the hyperloop technology. The implementation of the Cargo Hyperloop Holland corridor will boost this industry with the creation of 18,000 new jobs in the Netherlands and Europe³ that are directly and indirectly related to the construction works, and a further 3,000 jobs created by the project in other sectors of the Dutch and European economy.

The assessment also includes other impacts such as reduction of the negative external costs associated with road transport via truck (for example accidents, air pollution, noise, congestion, habitat damage) and infrastructure costs that can be avoided by shifting cargo to the hyperloop system.

3 Due to low unemployment rates in the Netherlands, it is expected that the construction of the corridor will also attract workers from other European countries

(tonnes of CO ₂ x 1000)	Maasvlakte - Westland	Maasvlakte - Barendrecht	Greenports	Corridor only	Corridor with NL network	Corridor with NL and EU network
CO ₂ emissions during production and construction	58.7	72.5	180.0	326.4	326.4	326.4
CO ₂ emissions during operations	0.9	0.5	3.3	8.0	10.3	11.2
CO ₂ emission savings	70.9	39.5	249.0	608.2	809.4	909.2
Net CO₂ emissions	-11.2	33.5	-65.7	-273.7	-472.8	-571.6

(Number of jobs x 1000)	Maasvlakte - Westland	Maasvlakte - Barendrecht	Greenports	Corridor (with NL (and EU) network)
Direct jobs	3.2	1.9	7.1	13.2
Indirect jobs	1.2	0.7	2.6	5.0
Induced jobs	0.7	0.4	1.5	2.8
Total jobs	5.1	3.0	11.2	20.9



Economic Performance

The corridor shows strong economic performance, with an economic value of approximately €1.1 billion. This value increases by approximately 50% when the network effects generated by the Dutch hyperloop network are considered, and reaches €2 billion (further uplift of 17%) after the expansion of the hyperloop network within Europe.

The economic value could be affected by changes in construction costs, demand volumes or revenues. A sensitivity analysis of the project confirmed that only drastic changes in these variables (by >29%) would bring negative economic results, and considering the risks and uncertainties associated with the project, this outcome seems rather unlikely.

(Present values x million €)	Maasvlakte - Westland	Maasvlakte - Barendrecht	Greenports	Corridor only	Corridor with NL network	Corridor with NL and EU network
Benefits	295.5	164.9	979.5	2,282.3	2,885.5	3,184.5
Revenues	103.2	57.4	362.5	885.5	1,168.7	1,302.6
Economic Impact	192.3	107.5	617.0	1,396.8	1,716.8	1,881.9
Costs (at shadow prices)	283.5	163.6	616.9	1,168.4	1,199.1	1,204.6
Capex + Devex	321.3	185.9	690.5	1,294.3	1,312.6	1,325.1
Opex	42.5	24.2	98.1	194.7	211.0	218.8
Residual value	-80.3	-46.5	-171.7	-320.5	-324.6	-330.3
B/C Ratio	1.04	1.01	1.59	1.95	2.41	2.62
ENPV	12.1	1.3	362.6	1,113.8	1,686.4	1,970.8
ERR	0.22%	0.04%	2.84%	4.47%	5.95%	6.42%

* Total values may deviate due to rounding

Based on the economic results achieved for the corridor and its sections, the implementation of the full Cargo Hyperloop Holland corridor is recommended as it brings the full scope of economic benefits.

Another option is to consider implementing the Greenports section as a shorter pilot, as it is economically viable on its own and performs the best out of the single sections that were assessed. The pilot route would bring limited benefits compared to the whole corridor, but it would serve as a demonstration of the hyperloop's commercial capabilities. This in

turn would help to build social support and encourage the public to adopt the hyperloop, as well as providing lessons and experience that could be applied to large-scale deployment.

The Cargo Hyperloop Holland corridor and the potential Greenports pilot route will be the first hyperloop routes in Europe and a starting point to develop future continental network for cargo and passengers. From this perspective, both the corridor and the pilot route infrastructure should be suitable for transporting goods and passengers, when the network is expanded.

Risks and Opportunities

As is the case for every transport infrastructure project, the economic effects of the Cargo Hyperloop Holland project are subject to risks and uncertainties related to costs, revenues and expected demand. To minimize these risks, external verification of the technical parameters and related costs has been obtained as follows.

- An independent external party (Antea) has validated the alignment of the Cargo Hyperloop Holland corridor. The major risks in the alignment related to conflicts with future infrastructure developments (the widening of the A4 and an additional runway for Schiphol Airport). The conflict with the widening of the A4 has been alleviated by adjusting the alignment. The plans for an additional runway will be further discussed with Schiphol Airport and the government.
- An independent reviewer (Balance) also confirmed the construction cost estimates for the corridor, with accuracy levels of 50%. Further detailed work on the next stages of the project is necessary to ensure selection of the most appropriate tunneling technology and further optimize the capital expenditure for the project.
- On the demand side, the corridor unlocks huge opportunities for its users in terms of reduced transit times and improved reliability. To fully utilize this potential, future users will need to revise some of their current logistics processes:
- Containerized cargo will be palletized at the hyperloop hub before being transported to its destination. The destuffing of containers will be included in the hyperloop hub services.

- First/last mile connections complementing the hyperloop services could potentially be organized by the hyperloop users themselves. Alternatively, hyperloop-affiliated partners could integrate the first/last mile services in their offerings, to ensure full compliance with hyperloop standards for handling quality, speed and reliability.

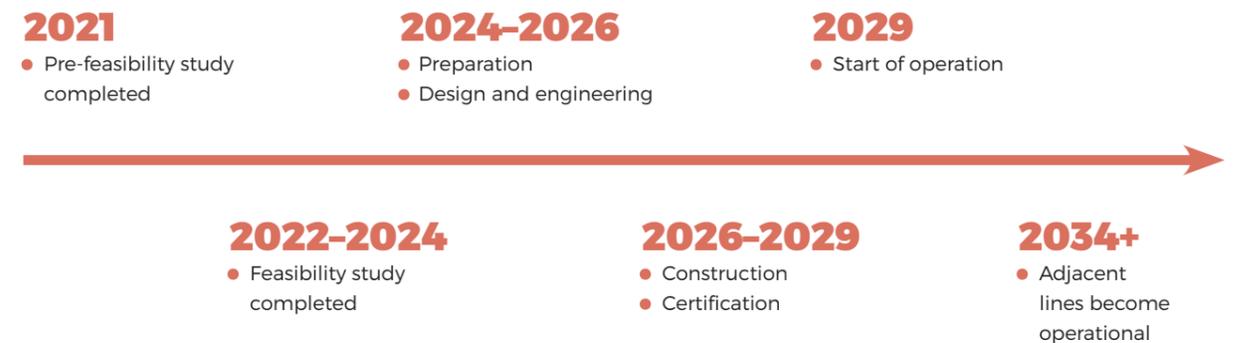
Not all potential users of the hyperloop system are expected to adopt these changes. As confirmed by the sensitivity analysis, even with a decrease in demand of more than 30%, there will still be a positive economic case for implementing the corridor.

The prices for hyperloop services and revenues generated by the project will be established to create an offer that is competitive in comparison to existing services, encourage a modal shift towards the hyperloop, and ensure the project's economic viability. Since a hybrid public-private model is the most promising option for the project delivery, the government will play an essential role in the implementation of the corridor and in ensuring the adoption of an optimal price for hyperloop services. Public sector participation in the project delivery is also essential because most of the benefits generated by the project are not reflected in purely financial outcomes. Their materialization will also require a coordinated regional and national effort, which will be situated largely in the public sector domain.

Project Realization

The Cargo Hyperloop Holland project is to be realized in accordance with a general transport infrastructure development framework, with a decision-making process repeated after each preparatory phase. The initial two steps (the concept study and the pre-feasibility study), have been completed so far. As the results of the pre-feasibility assessment are positive and have demonstrated the feasibility of the project at this stage, the project will move to the next

realization step. This is the feasibility study, in which project partners, supported by project promoters and stakeholders, will undertake a detailed assessment in order to make the final go/no-go decision about the implementation of the project. The preparatory process will be finalized by 2024, and the design, engineering and construction will commence. The project will become operational in 2029.



A range of project delivery model options for the Cargo Hyperloop Holland project have been considered with respect to organizing and financing the design, construction, operation, and maintenance of the corridor. These options vary in the degree of separation of roles and whether the role is fulfilled by the public or the private sector. The most promising option is a hybrid public-private model, in which the delivery and ownership of the infrastructure is provided by the public sector, and the transport services are provided by private companies. The exact structure and combination of roles is to be determined in later studies.

After successfully demonstrating the economic viability of the Cargo Hyperloop Holland corridor, the next steps will focus on establishing government leadership for the project, initiating the necessary regulatory adjustments, and conducting further research on the technical aspects of the route, including the passenger transport application, and its future role as part of a European hyperloop network.

