OVER THE ELEVOPOLDER

COLOFON

Over the Flevopolder: A landscape architectural design research on the implementation of an innovative railroad in the Dutch cultural landscape as a superior alternative to the Lelyline. A case-study between Amsterdam and Zwolle.

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TUDelft

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I would like to thank Adriaan Geuze for his guidance throughout the entire project. His unique metaphors consistently brought me and my fellow students to new perspectives and insights. I would also like to thank Rients Dijkstra for providing structure and valuable guidance. Additionally, special thanks go to Giordana and Bai, my fellow students, with whom I have learned a great deal over the past year.

ABSTRACT

Promoting sustainable travel involves encouraging train travel as a preferred mode of transportation. However, train travel in the Netherlands faces challenges with delays and slow speeds, including the planned Lelyline. This report explores an innovative high-speed train viaduct inspired by Chinese rail construction techniques as an attractive alternative to the Lelyline. By adopting modular construction and straight alignments, this research aims to create an efficient and visually captivating transportation solution that respects the cultural landscape. The case study focuses on a straight trajectory across the Flevopolder between Amsterdam South and Zwolle. The viaduct integrates with the landscape, enhancing biodiversity through an ecological corridor in its shadow, benefiting agriculture and the nature network. Additionally, it offers panoramic views, recreational value, and serves as a marker of historical significance.

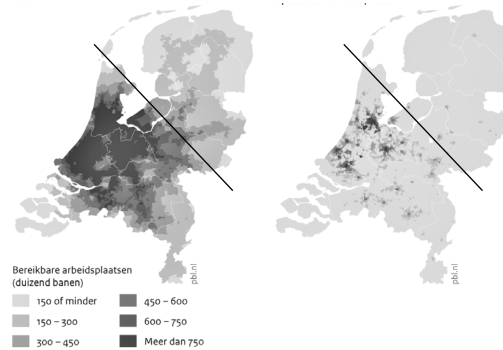
This research showcases the potential of a sustainable train landscape that aligns with the Dutch cultural context, providing valuable insights for future transportation projects.

Key words: Lelyline, innovative high-speed rail technique, Flevopolder, Amsterdam South, Zwolle, collateral benefits, shadow ecology

CONTENTS

PHASE I

PHASE II



▲ 1.1 Accessibility of workplaces between 7 and 9 AM by car (left) and public transport and bike (right). North of the Netherlands is left behind. Image: ANP (2022)

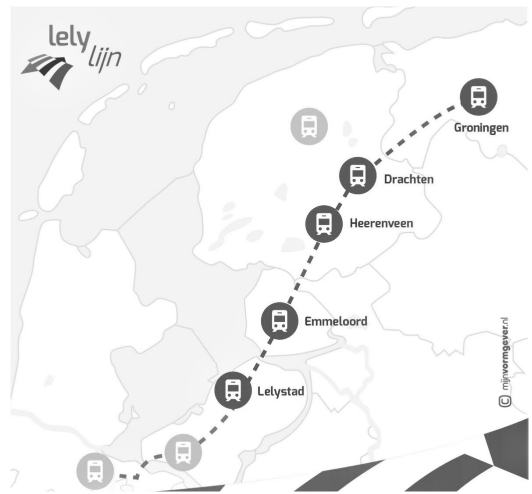
01.INTRODUCING INNOVATIVE RAILROADS

Lelyline

In 1839, the first railroad in the Netherlands was opened. Since then, trains have been an integral part of the Dutch landscape and culture. Along the tracks, cities have developed and grown significantly. In the development of the Dutch train network, however, connection to the north has been left behind (fig. 1.1). Therefore, a plan has been ready for years to connect Amsterdam and Groningen with a new train track via Almere, Lelystad, Emmeloord, Heerenveen and Drachten: the Lelyline (fig. 1.2). By improving the accessibility of these northern cities, the Lelyline could ensure further urbanization by creating a more attractive business climate for commuters.

Not only nationally, but also internationally the Lelyline is receiving a lot of attention, as the line should be a step towards a connection to Hamburg, Germany. Therefore, in early December 2022 the Lelyline is included in the expanded TEN-T (Trans-European Transport Network) network, giving the plan a chance to receive European subsidies (Ministerie van Infrastructuur en Waterstaat, 2022).

About the Lelyline:
- High-speed track between Groningen - Amsterdam
- 1:30h expected travel time (now 2:27h)
- Design speed of 200 km/h
- Stops at Groningen, Drachten, Heerenveen, Emmeloord, Lelystad, Almere CS, Amsterdam South



▲ 1.2 Route of the Lelyline. Image: mijnvormgever.nl

Dutch rail technique

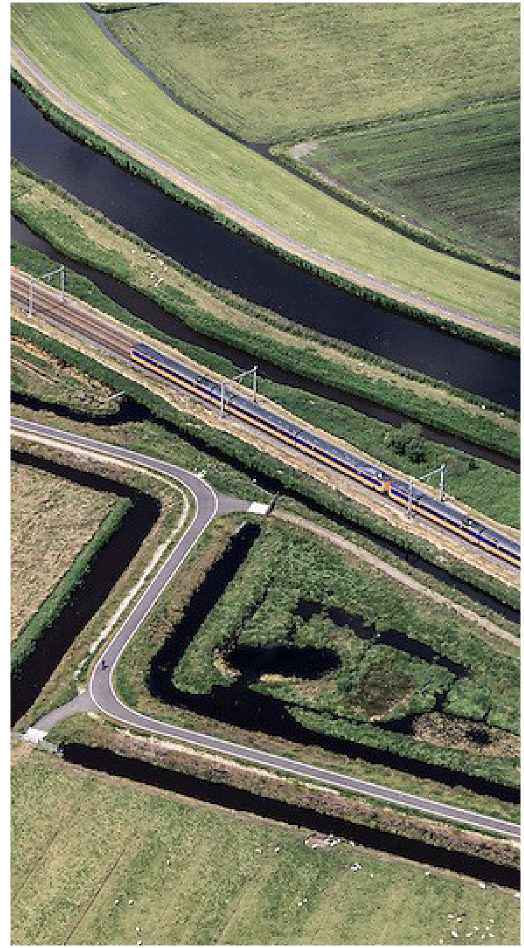
The Lelyline will be constructed as rails at ground level, as usual in the Netherlands, with civil engineering structures where necessary. Because our means of transport have become faster and faster and therefore through roads and railroads are better protected for security, infrastructures form physical barriers in the landscape. By means of tunnels and bridges, attempts are being made to prevent this, nevertheless the landscape is becoming increasingly fragmented (fig. 1.3) (Luiten, 2016).

"Fragmentation is a given and for cohesion one must act."

(Luiten, 2016)

(Rail) roads are not only barriers for people, Dutch biodiversity also suffers. Landscape fragmentation is one of the main reasons why species numbers in the Netherlands are declining (Alterra, 2001). Although the route of the Lely Line is not yet fixed, it is known that all variants will pass through high-value nature areas in the Northern Netherlands (Vos, 2021).

To counteract landscape fragmentation, railroads are placed along existing infrastructures when possible. In this way, infrastructural corridors are formed, which reduces the spatial impact and fragmentation caused by infrastructures. For sprinter and intercity trains this does not pose an immediate problem, but for trains that need to run at higher speeds (> 140 km/h), problems may arise. Looking at the map of the Netherlands, you can see that highways follow landscape structures, resulting in roads curving through our country. Those curves are not designed for high-speed trains to travel at 300 km/h. A winding route is also one of the reasons that the HSL South can only run at its top speed (300 km/h) for a minute and a half in the Netherlands, after which the train already has to slow down (NOS, 2018). Not only do curves in the tracks slow down, but these are also vulnerable parts of the track. More wear in curves requires more maintenance (Pals, 2015). Thus, the way train tracks are currently designed in the Netherlands has a negative impact on train speeds and hence travel times.



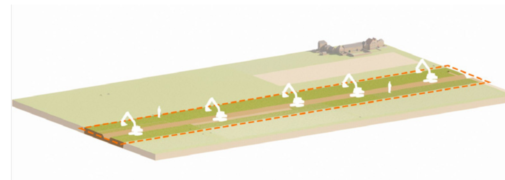
▶ 1.3 Train cuts through polder landscape, Purmerend. Photo: Swart (2012)

Chinese high-speed rail

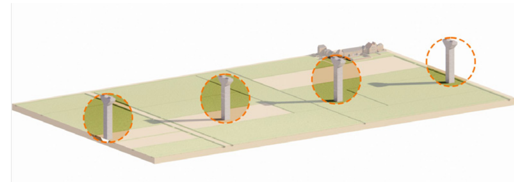
On the other side of the world, in China, a different strategy is being applied when it comes to rail construction. The focus is on fast train connections and efficient construction. This results in long and straight lines in the landscape. Because the routes often run through mountainous areas, many tunnels and viaducts are needed. To build the viaducts at a rapid pace, a gantry crane is used, which can lay down the next horizontal section from the already built railroad viaduct onto the next prefabricated column (Kun & Huiying, 2022).

The construction process of the railway viaduct is simplified into four steps (fig. 1.4). A modular construction technique is used. To apply this technique efficiently, the alignment of railroad tracks should be as straight as possible, so that there is maximum repetition of straight modules. Only a few curves in the train tracks are allowed.

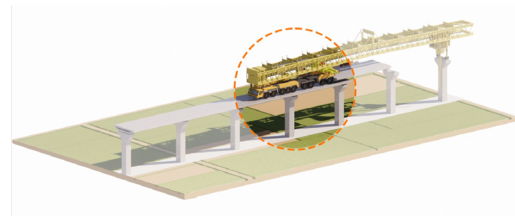
Although the image of the Fenhe railway (fig. 1.5) viaduct in China appears imposing and perhaps terrifying , the fascination for it also forms the basis for this design research. The Netherlands does not have height differences like China, yet building viaducts for high-speed trains can be a solution to the problems we encounter in the Dutch railroad network today.



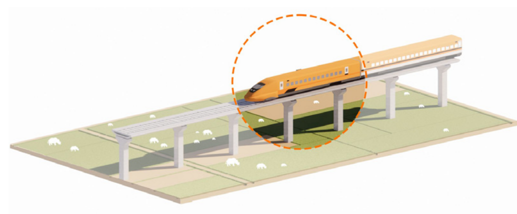
1/ Preparation with minimal surface impact



2/ Prefabricated colunms



3/ Installation of 40-60 meter long modular bridge components



4/ Completed high-speed train viaduct

▲ 1.4 Construction process of a self-extending modular railway viaduct. Images: Bai (2023)

▲ 1.5 Fenhe railway viaduct. Image: Reddit (n.d.)

Case-study

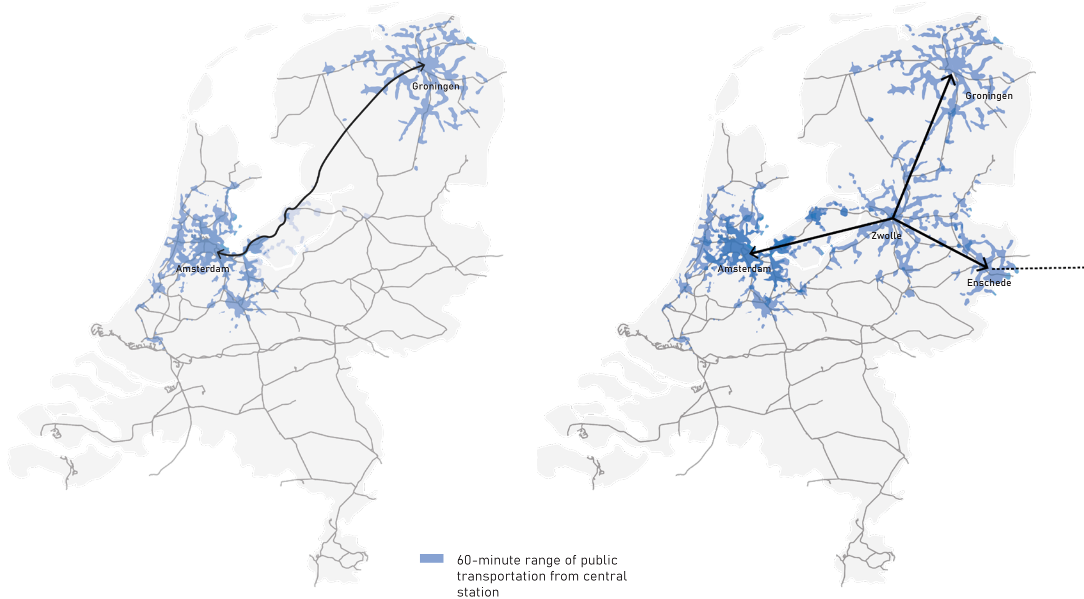
Back to the Lelyline. This new rail connection would make the northern Netherlands a more attractive location for people and businesses by connecting the two cities of Amsterdam and Groningen through a high-speed line. However, this would avoid a very valuable public transport hub located in the Netherlands: Zwolle. In fact, according to ProRail (2021), Zwolle is one of the most important rail hubs in the Netherlands. Moreover, the location of Zwolle is very suitable for an international train connection via Enschede to Germany. A connection between the cities of Amsterdam, Zwolle, Groningen and Enschede by means of an innovative high-speed line theoretically has a much greater driving range than the Lely Line offers (fig. 1.6).
In the graduation lab "Innovative Infrastructure Implementation" of the Flowscapes studio, three students are working together on an alternative Lelyline via Zwolle: a high-speed train connection, elevated as a viaduct, built according to the Chinese self-extending construction technique. This innovative railroad viaduct must be carefully and respectfully designed into the vulnerable Dutch cultural landscape, for which landscape architectural research and design is needed. The landscape interventions needed to implement the line in the cultural landscape between Amsterdam and Zwolle in a good way will be researched through this thesis.

“Zwolle is one of the most important railroad hubs in the Netherlands”

(ProRail, 2021)

Lelyline

Alternative Lelyline



► 1.6 Reach of the Lelyline (left) and reach of the alternative Lelyline via Zwolle and Enschede (right). Data: TravelTime plugin for QGIS. Images: author

Problem statement

The Lelyline is an inefficient rail link for a high-speed line between Amsterdam and Groningen due to its curvy route and barrier effect in the landscape. In China, high-speed tracks are built in straight-line alignment on viaducts, which reduces physical fragmentation and allows trains to reach higher speeds. The design and implementation of an alternative innovative Lely line between Amsterdam and Zwolle according to Chinese technology should be done with great attention to the Dutch cultural landscape to preserve and improve the quality of the landscape.

Research questions

Main question:
How can an innovative high-speed railroad between Amsterdam and Zwolle be superior to the Lelyline and how can this be implemented with collateral benefits through landscape architectural interventions respecting the Dutch cultural landscape?

Sub-questions:
► What are the current opportunities and constraints in the case study area that can be affected by the new high-speed alignment?

► What alignment for the innovative railroad between Amsterdam and Zwolle is most preferred to implement in the existing cultural landscape?

►What are the characteristics of the cultural landscape through which the alignment will pass?

► What design strategy can best be followed to respectfully implement the high-speed viaduct into the cultural landscape?

► In what way can the viaduct itself be best designed to integrate with the existing landscape according to the design strategy?

► How can collateral consequences of integrating the viaduct into the landscape create new land values?

► With what landscape architectural interventions can the innovative high-speed viaduct be implemented in the existing landscape, in which respect for the existing landscape and the creation of new land values are key?

02.RESEARCH FRAMEWORK

Theoretical framework

Train networks, like roads and energy networks, are often single-purpose infrastructures. Engineering infrastructures with a single purpose often results in disrupted landscapes and blurring of cultural and natural values in a landscape (Strang, 1996). The Fenhe railway viaduct (fig. 1.5) is an example of a train landscape, where the train network overshadows the existing landscape. Today, it is widely known that these single-purpose landscapes can have indelible negative effects on natural systems, but awareness about the importance of striving for a balanced landscape has grown (Nijhuis et al., 2015).

To this day, the responsibility of an infrastructural design has been divided between different disciplines such as architecture, civil engineering, urban design, landscape architecture and ecology (Strang, 1996). This causes poor integration because of the different starting points, leading to unexploited potentials of infrastructures (Nijhuis et al., 2015). As a result, fragmented landscapes and places are often ignored or marginilized in the planning and design process (fig. 1.7) (Lally & Moore, n.d.). Arup University has studied how these types of places under (train) overpasses can be put to a variety of productive uses. This study provides design principles, by which the lost places, non-places, under train viaducts are given back to society (fig. 1.8) (Lally & Moore, n.d.). This indicates that if more integrated consideration is given to function and landscaping at the front end of engineering train networks, the rail landscape can serve multiple purposes and perhaps enhance the existing landscape.

Train viaducts cannot possibly be hidden because of their scale, making them a prominent component in the landscape (Strang, 1996). This makes the challenge of integrating these structures into the landscape and culture even greater (Nijhuis et al., 2015). At the same time, it is beneficial for the growth of sustainable awareness among people if sustainable landscapes are visible (Thayer, 1993). Travelling by train is more sustainable than travelling by car or plane (Milieu Centraal, n.d.) and it is therefore good to encourage train travel. However, train landscapes are often hidden because they are aesthetically unsatisfactory (Thayer, 1993). Thayer advocates making sustainable landscapes transparent in order to make a difference in making the world more sustainable (1993).

In the design of the alternative Lelyline, the aim is to create a multi-purpose viaduct landscape that fits well into the cultural landscape

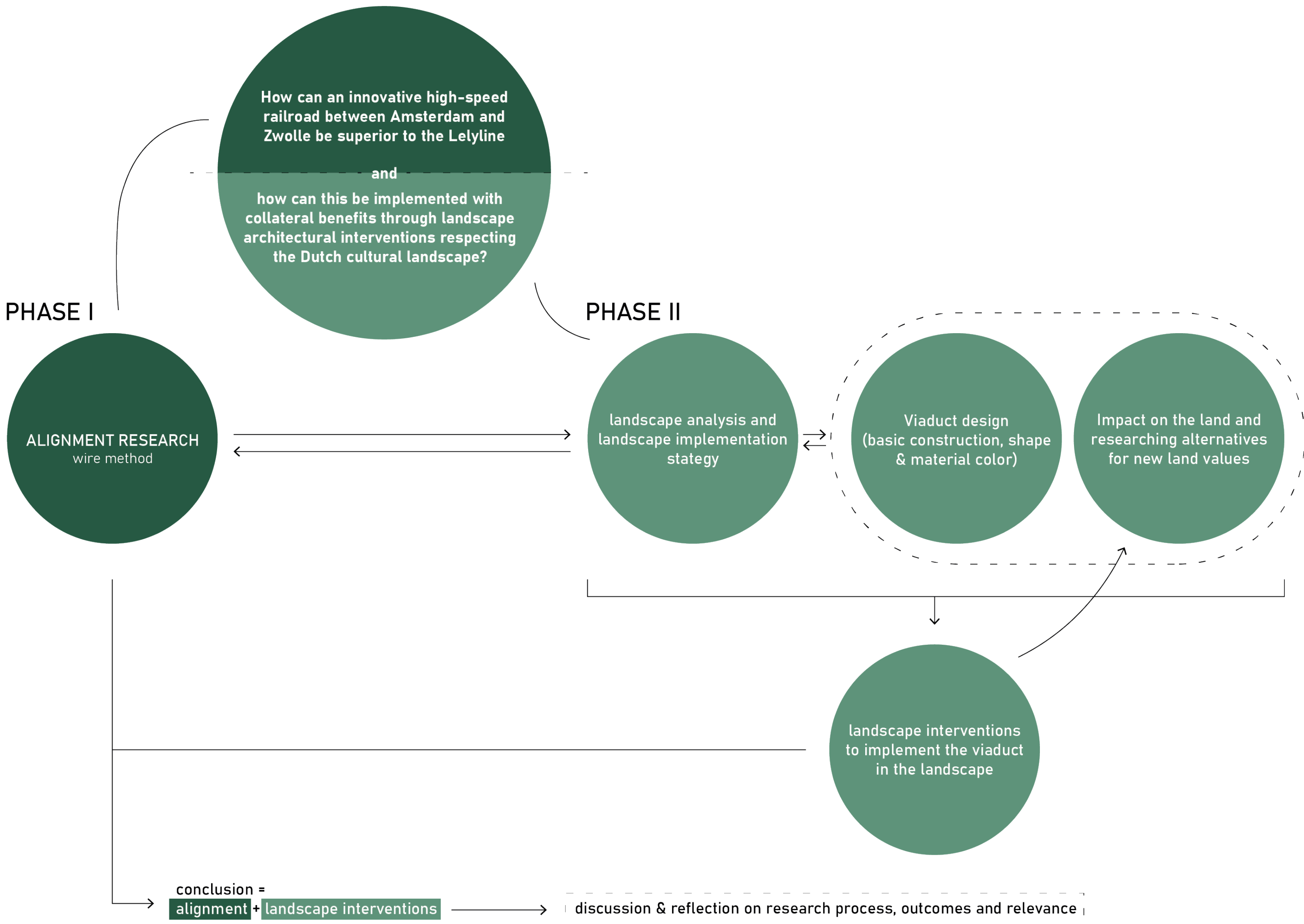
“An acceptance of sustainable techniques and technologies into our concept of nature and human nature is an essential part of the process toward sustainable landscapes”

(Thayer, 1993)

through landscape architecture, thereby increasing the acceptance of sustainable landscapes. To achieve that, infrastructure design can no longer belong to the single disciplines, but belongs to a multidiciplinary field (Shannon & Smets, 2011). The role of the landscape architect is challenging and essential in landscaping and creating collateral benefits in the landscape (Bélanger, 2010). This study presents the research-by-design design process of the alternative Lelyline viaduct through the Dutch landscape from the perspective of landscape architecture, with the disciplines of civil engineering and ecology also considered.

▲ 1.7 Images of the neglected spaces underneath the A40(M) motorway vaiduct in London. Photos: Westway Trust (n.d.)

► 1.8 Kleinpolderplein in Rotterdam is not only a space underneath atraffic junction, it is also an open air museum and it serves as a water buffer for the city (DIEKMAN landschapsarchitecten, 2022). Photo: Mesman (2022)


How can an innovative high-speed railroad between Amsterdam and Zwolle be superior to the Lelyline
and
how can this be implemented with collateral benefits through landscape architectural interventions respecting the Dutch cultural landscape?
PHASE I
ALIGNMENT RESEARCH
wire method
PHASE II
landscape analysis and landscape implementation stategy
Viaduct design (basic construction, shape & material color)
Impact on the land and researching alternatives for new land values
landscape interventions to implement the viaduct in the landscape
conclusion =
alignment + landscape interventions
discussion & reflection on research process, outcomes and relevance

Methodology

This research can be delineated into two distinct phases. In phase one, the primary objective is to address the initial component of the main research question: 'How can an innovative high-speed railroad between Amsterdam and Zwolle be superior to the Lelyline...' To examine the optimal alignment, a foundation of (basic) knowledge regarding the project area is indispensable. This knowledge has been acquired through the utilization of data from PDOK processed in QGIS, extensive literature studies, comprehensive precedent analyses such as the HSL-Zuid, and on-site visits. Literature and precedent studies have also been employed to determine the technical constraints associated with high-speed alignments. Various alignments have been sketched on a map created in QGIS, utilizing the TOP25NL dataset at a scale of 1:25,000 from the Nationaal Georegister (2022). Additionally, high-density urban areas have been examined at a smaller scale of 1:5,000 to identify the most suitable alignment.

An assessment has been conducted through a multi-criteria analysis (MCA), employing parameters specifically tailored to the context of this study. Each parameter has been assigned a unique weighting factor to account for priority discrepancies. The alignment that obtains the highest score in the MCA is deemed the preferred alignment option.

The preferred alignment model is further developed in phase two, which concentrates on the landscape implementation of the chosen alignment. This phase aims to address the second part of the main question: : 'How can an innovative high-speed railroad .... be implemented with collateral benefits through landscape architectural interventions respecting the Dutch cultural landscape?' This phase remains intricately linked to phase one, as adjustments to the preferred alignment can be made based on new discoveries. The decision was made to limit the design area to the agricultural landscape of Flevoland, as literature sources like "De Groene Horizon. Vijftig jaar bouwen aan het landschap van de Flevopolder" (Horlings et al., 2018) and site visits have indicated the substantial impact of an overpass on the Flevoland landscape, necessitating focused attention in this research.

Through the creation of maps (at a scale of 1:5,000) and sections (at scales of 1:50, 1:100, and 1:200), diverse landscape interventions have been sketched to develop a strategy that best harmonizes the existing landscape with the new high-speed viaduct. Subsequently, a design for the viaduct itself was generated, incorporating civil engineering information derived from literature provided by lecturers at Delft's Faculty of Civil Engineering. Multiple viaduct options were modeled using Rhinoceros software.

Integrating a new viaduct into agricultural land yields not only visual transformations in the landscape but also other collateral consequences for the agricultural areas, as revealed during the Drawing Time workshop of the Flowscapes studio. Research has been conducted to explore how the (negative) impacts of the viaduct could be leveraged to generate additional benefits within the landscape, resulting in a range of variants. The knowledge acquired about the design area's landscape, the viaduct design, and the potential collateral benefit variants serve as the basis for the landscape architectural interventions undertaken, culminating in the final design of this research.

Lastly, the research and design process are critically assessed. Additionally, the significance of this research within the problem field and the novel insights it has generated are thoroughly discussed.

PHASE I

03.ALIGNMENT STUDY

Current situation

To travel from Amsterdam South to Zwolle station by train, there are currently two options (fig. 3.2). From Amsterdam South, a traveler can travel to Zwolle via Amersfoort. In Amersfoort, one must transfer to another train, which goes to Zwolle via the Veluwelijn. This trip takes 1.07 hours excluding the 16-minute wait in Amersfoort (full trip 1.24 hours).
The second option is the route that crosses the Flevopolder. Since 1988, the line from Amsterdam to Lelystad Centraal has been active. This line runs on the western side of the Flevopolder and connects the various stations of the cities of Almere and Lelystad with each other and the southern mainland. Since 2012, the Hanzelijn has been in operation as a connection between Lelystad and Zwolle (Jacobs, 2013). With that connection, it has thus been made possible to travel between Amsterdam South and Zwolle via Flevoland as well. It is not necessary to change trains during this trip, which results in a shorter travel time of 1.01 hours (fig. 3.1).

❶

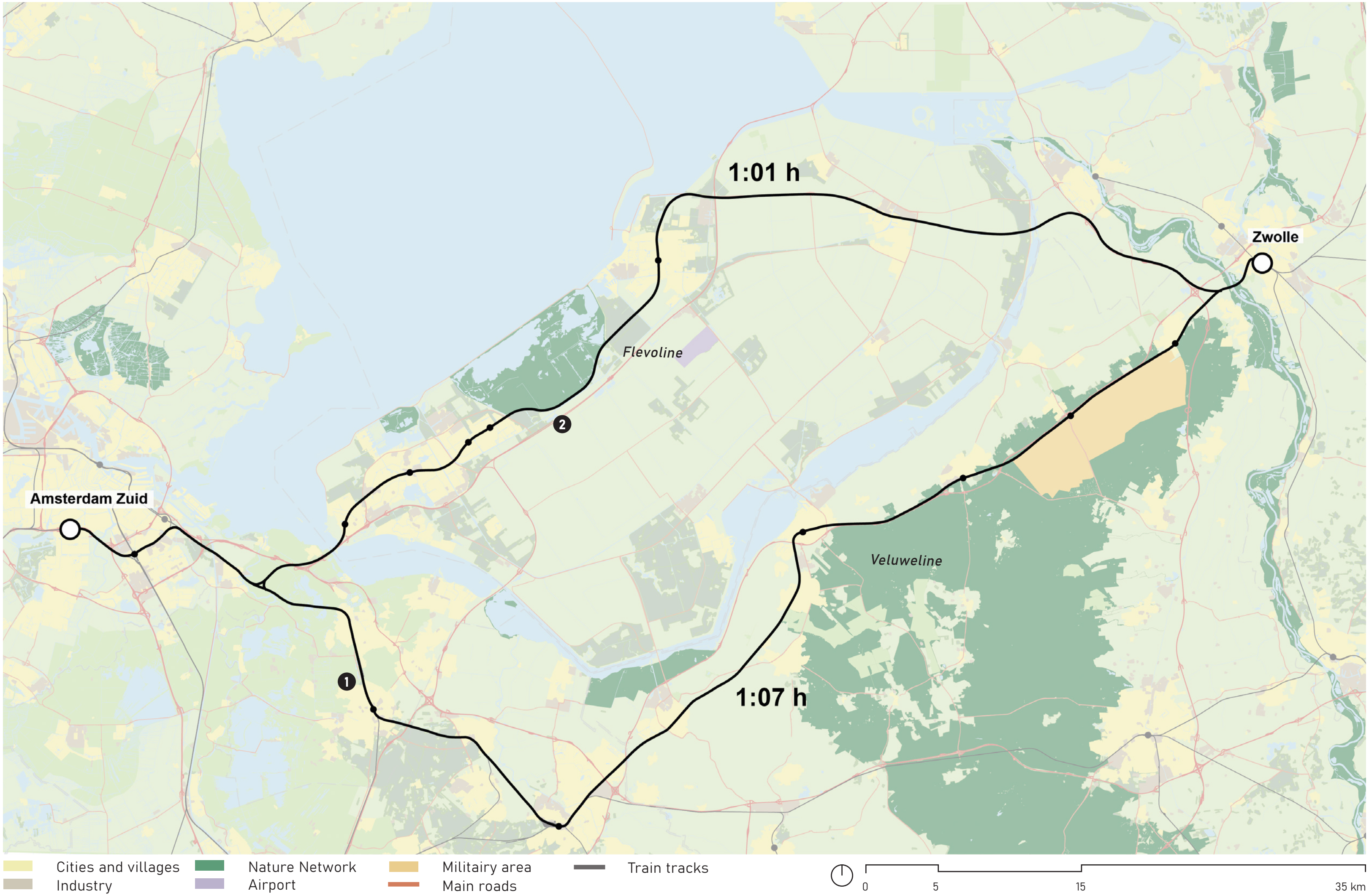
Track	Veluweline
Duration	1.07 h
Stops	Amsterdam South, Duivendrecht, Hilversum, Amersfoort Centraal, Zwolle
Design speed	140 km/h
Train type	Intercity

❷

Track	Flevoline
Duration	1.01 h
Stops	Amsterdam South, Almere Centrum, Lelystad Centrum, Zwolle
Design speed	140 km/h
Train type	Intercity

▲ 3.1 Train tracks between Amsterdam South and Zwolle. Data: NS Reisplanner

► 3.2 The current train connections between Amsterdam South and Zwolle in map. Image: author

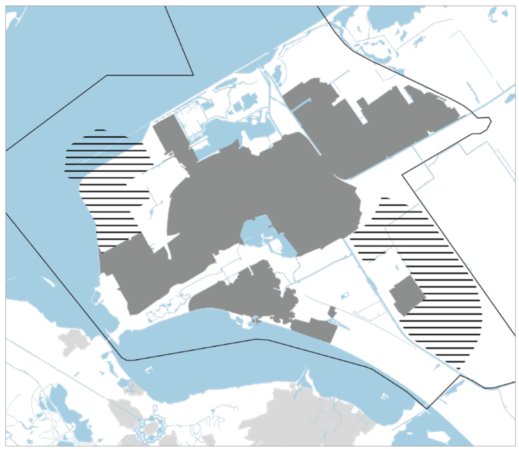

1:01 h
Zwolle
Flevoline
Amsterdam Zuid
2
1
Veluweline
1:07 h
Cities and villages
Industry
Nature Network
Airport
Military area
Main roads
Train tracks
0
5
15
35 km

Connecting Almere

A straight line between Amsterdam South to Zwolle passes right through the municipality of Almere (fig. 3.5), the youngest large city in the Netherlands. In the parcellation plan of Southern Flevoland, actualized in 1987 (Horling & Blom, 2018), possible urban expansion of Almere was already taken into account. Areas were reserved on the west side and on the east side that could be used as residential areas (fig. 3.3).

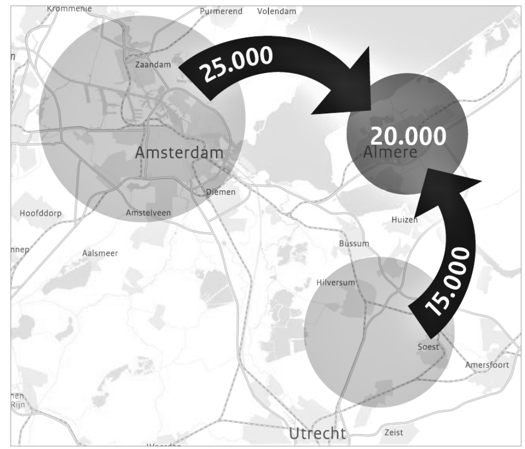
Almere is part of the North Wing of the Randstad. This area includes the coherent urban network from the Noordzeekanaal to Utrecht, Amersfoort and Almere, with Amsterdam at the center of the area. Because of its strategic location, Almere has an interesting business climate. However, the demand for housing in the North Wing is very high. According to the Rijksstructuurvisie Amsterdam - Almere - Markermeer (2016), around 440000 additional homes will be needed until 2040 (fig. 3.4). To preserve as much Dutch rural area as possible simultaneously with this demand, the task is to build as much as possible within urban areas. Because a large area in Almere is already reserved for urban expansion, the municipality possesses very good possibilities to accommodate a large part of this housing demand. In the Rijksstructuurvisie, the target is 60000 additional homes in Almere (Ministerie van Infrastructuur en Milieu, 2016).

Due to few connections between the mainland and Almere, the (rail) roads are overloaded during peak times. More homes in Almere will increase the load on roads and railroads and therefore investments in public transport and roads are necessary (Heinz et al., 2020). Because of this, people have been lobbying for a new infra connection between Amsterdam and Almere for several years: the IJmeer connection. A regional IJmeer connection and a role for Almere in the high-speed network create enormous development opportunities for Almere and contribute to economic strengthening of the North Wing. To seize these opportunities, the new high-speed train will also make a stop at Almere central station (Almere Centrum).

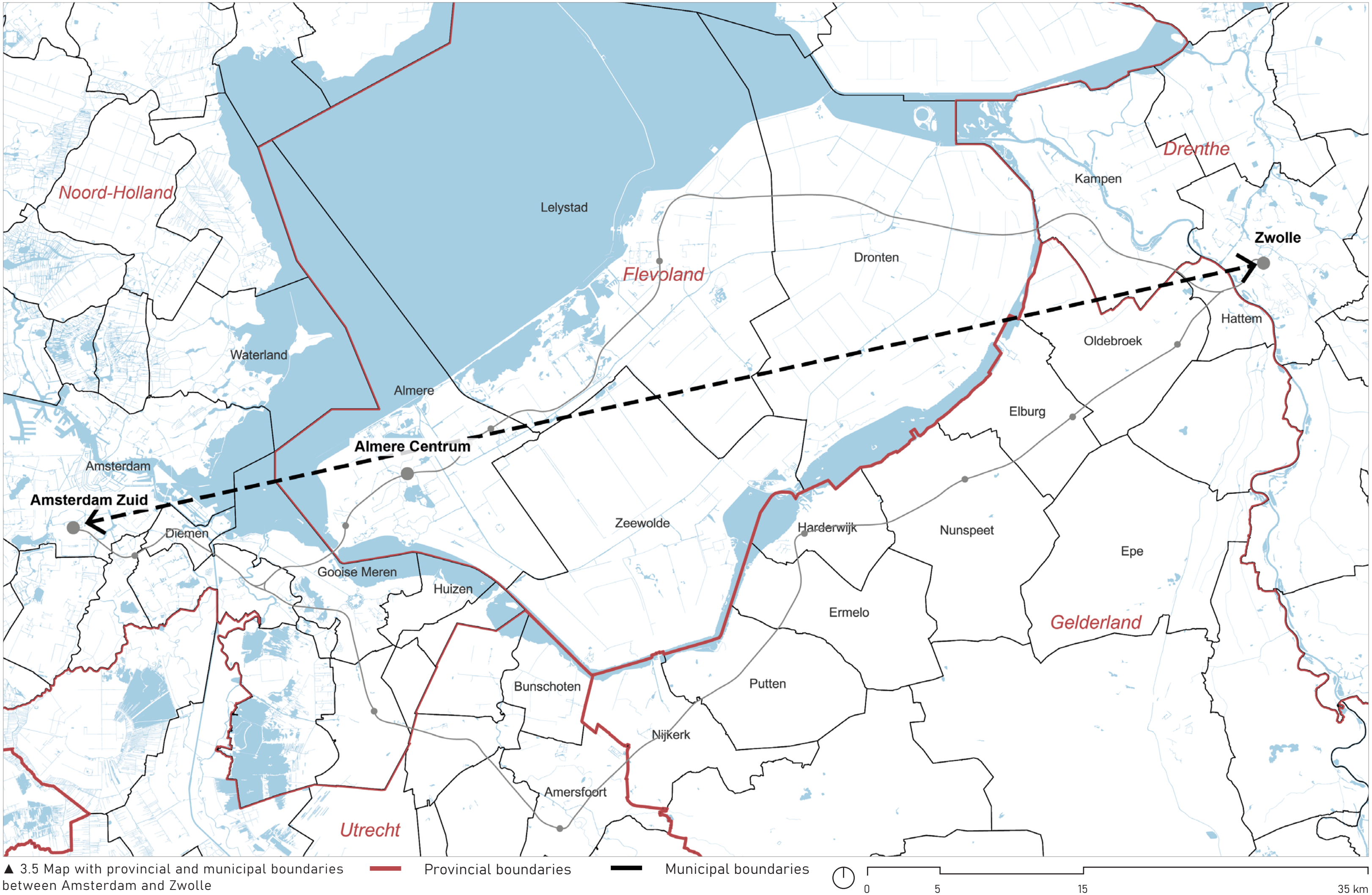


urban area — reservation urban area — municipality of Almere

▲ 3.3 For the municipality of Almere, urban expansions on the east side and on the west side near the IJmeer were already taken into account in the 1987 subdivision plan. Data: PDOK and *De Groene Horizon* (Horlings & Blom, 2018). Image: author



▲ 3.4 Origin of need for 60,000 housing units from the Noordvleugel (region Amterdam - Almere - Markermeer) in Almere. Part of *Rijksstructuurvisie Amsterdam-Almere-Markermeer* (Ministerie van Infrastructuur en Milieu, 2013). Image: Ministerie van Infrastructuur en Milieu.



▲ 3.5 Map with provincial and municipal boundaries between Amsterdam and Zwolle

About the IJmeer Connection

The IJmeer connection is a -yet unrealized- connection between the part of Amsterdam located on the IJmeer and Almere Pampus, the district on the southwest side of Almere (fig. 3.7). Pampus is so far only an empty reserved area for new housing development, but plans are ready to start building 25,000 homes in 2025 (Movares, 2011).

Both a bridge and a tunnel can form the IJmeer connection, but Movares (2011) has shown that a bridge is significantly cheaper. In addition, a bridge forms a strong visual link between Amsterdam and Almere, reinforcing the sense of proximity.
The plan for the IJmeer connection as a bridge is supported by several political parties. Due to the housing shortage in the Netherlands, the large number of new homes in Pampus is in huge demand and, CDA and D66 (2018) describe, so is the IJmeer connection.

Several agencies have already worked out their version of a modern subway bridge across the IJmeer. Figure 3.6 shows the impression by Movares (2011), with a view on the new Almere Pampus neighborhood.

► 3.6 Impression of IJmeer bridge connection in direction of Almere Pampus. Image: Movares (2011)

► 3.7 Vision map of the IJmeer connection by M55. A new subway line is connected in IJburg (Amsterdam) to the subwaynetwork. Image: M55.nl (2011)

Required curve radii high-speed track

There are two types of railroad constructions: ballasted and ballastless. Ballasted tracks are generally the most used in the Netherlands. However, these are not suitable for the modular construction technique to be applied for the alternative Lelyline, because this type can not be prefabricated. Ballastless tracks, on the other hand, are suitable for modular construction, because this type consists of prefab parts. On top of that this type is known for its lower noise production, more comfort at high speeds and longer life span than ballasted tracks (Agico Group, 2017). The recommended curve radii by construction type are shown below (fig. 3.8), relevant in this study are the numbers for ballastless tracks:

V_{max} (km/h)	Type of Track	R_{min} (m) Good	Normal	Special
250	Ballastless track	3500	3000	3000
	Ballasted track	4000	3500	3000
300	Ballastless track	5000	4500	4000
	Ballasted track	5500	5000	4500
350	Ballastless track	7000	6500	5500
	Ballasted track	7500	7000	6000

▲ 3.8 Recommended values of minimum curve radius of the high-speed railway for high-speed trains running on a single line (Yi, 2017).

For maximum travel time gains between Amsterdam and Zwolle, the alignment study aims for an alignment suitable for speeds up to at least 300 km/h. This includes for the ballastless tracks the recommended radii highlighted in the table. These radii or larger can also be seen in the HSL South track (fig. 3.10). However, when a high-speed train approaches a stop, and thus has to slow down anyway, smaller radii are allowed. Around Zwolle station, radii between 400 m and 1250 m occur (fig. 3.9).

▲3.9 Train tracks near the station of Zwolle with radii between 400 m and 1250 m. Data: PDOK. Image: author

▲ 3.10 The track of HSL-Zuid in the Netherlands, with a curve radius of 7000. Data: PDOK. Image: author

The wire method

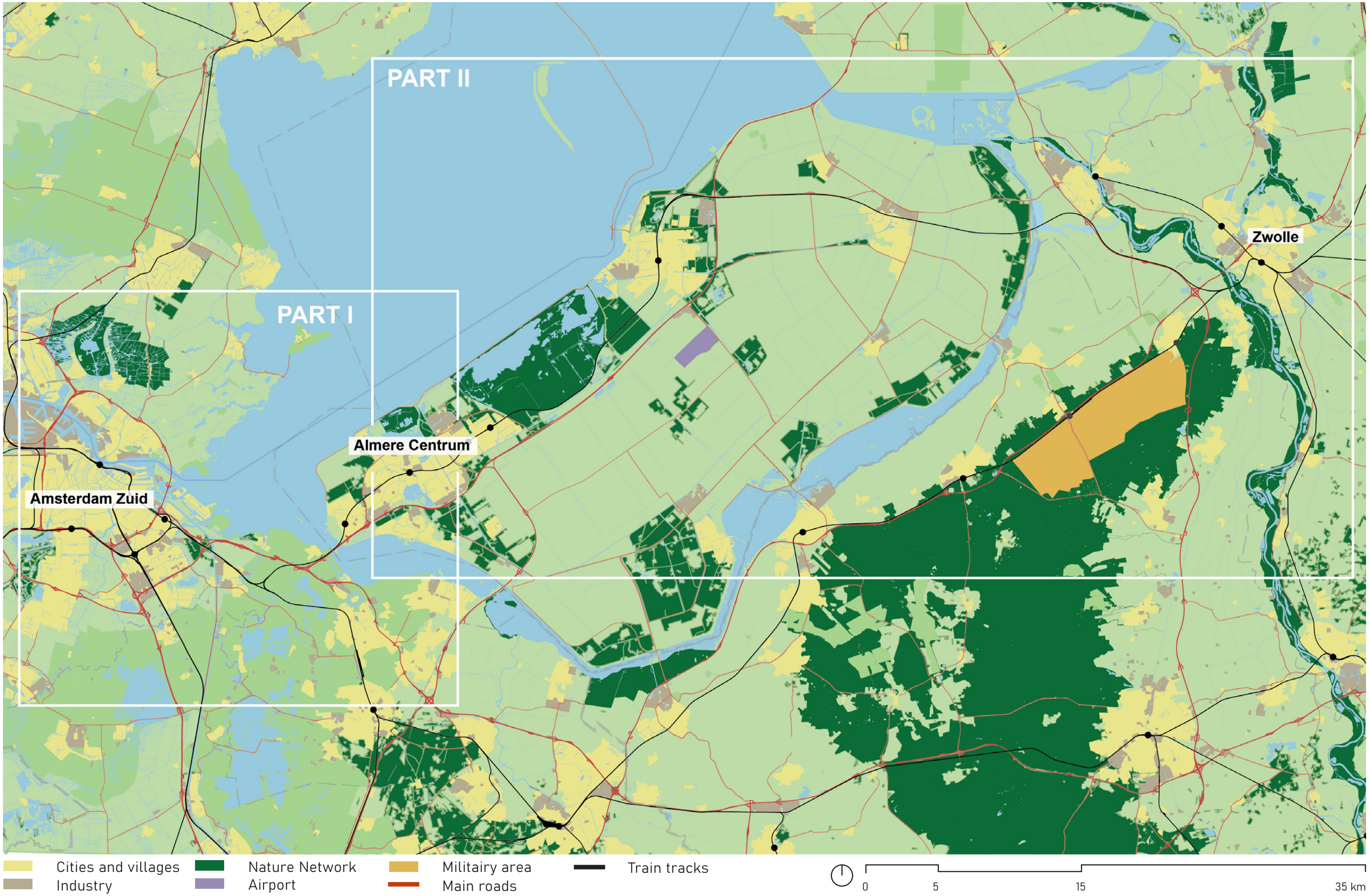
The alignment for the new high-speed track will make stops in Amsterdam South, Almere Centrum and Zwolle central station. The landscape between Amsterdam South and Almere is highly urban and is mainly the IJmeer. Between Almere and Zwolle the landscape is predominantly agricultural with scattered villages, industry and nature reserves. Because the (landscape) characteristics between the track sections differ so much, the project area for the alignment study was divided into two parts (fig. 3.12):

Part one: Amsterdam South – Almere Centrum
Part two: Almere Centrum - Zwolle station

For both sections, the 'wire method' was applied to outline line options (fig. 3.11). The wire method was developed collaboratively in the graduation lab Innovative Infrastructure Implementation. This method involves 'sketching' lines with string and a large topographic poster. By stretching rope across the poster, you always work with straight lines, untill a kink is made in between. Different colors of rope were used to group alternative alignments. For the poster, Top25NL from PDOK (2022) was used to represent topographic information. By printing the poster at 1:25000, there is both a good overview and sufficient detail.
Both parts have their own alignment goals and priorities. Therefore, the testing method of line options for part one and part two is different. The assessment method is explained for each subarea. For both part areas, a preferred alignment follows from the assessment. Joining the preferred alignments of part one and part two creates the complete preferred alignment for the new high-speed rail.

► 3.11 Using the technique with rope and large maps to create alignment options. Photos: Credendino (2023)

► 3.12 Topographic map of project area, showing sub-areas Part I and Part II. Image: author


PART II
PART I
Almere Centrum
Amsterdam Zuid
Zwolle
Cities and villages
Industry
Nature Network
Airport
Militairy area
Main roads
Train tracks
0
5
15
35 km

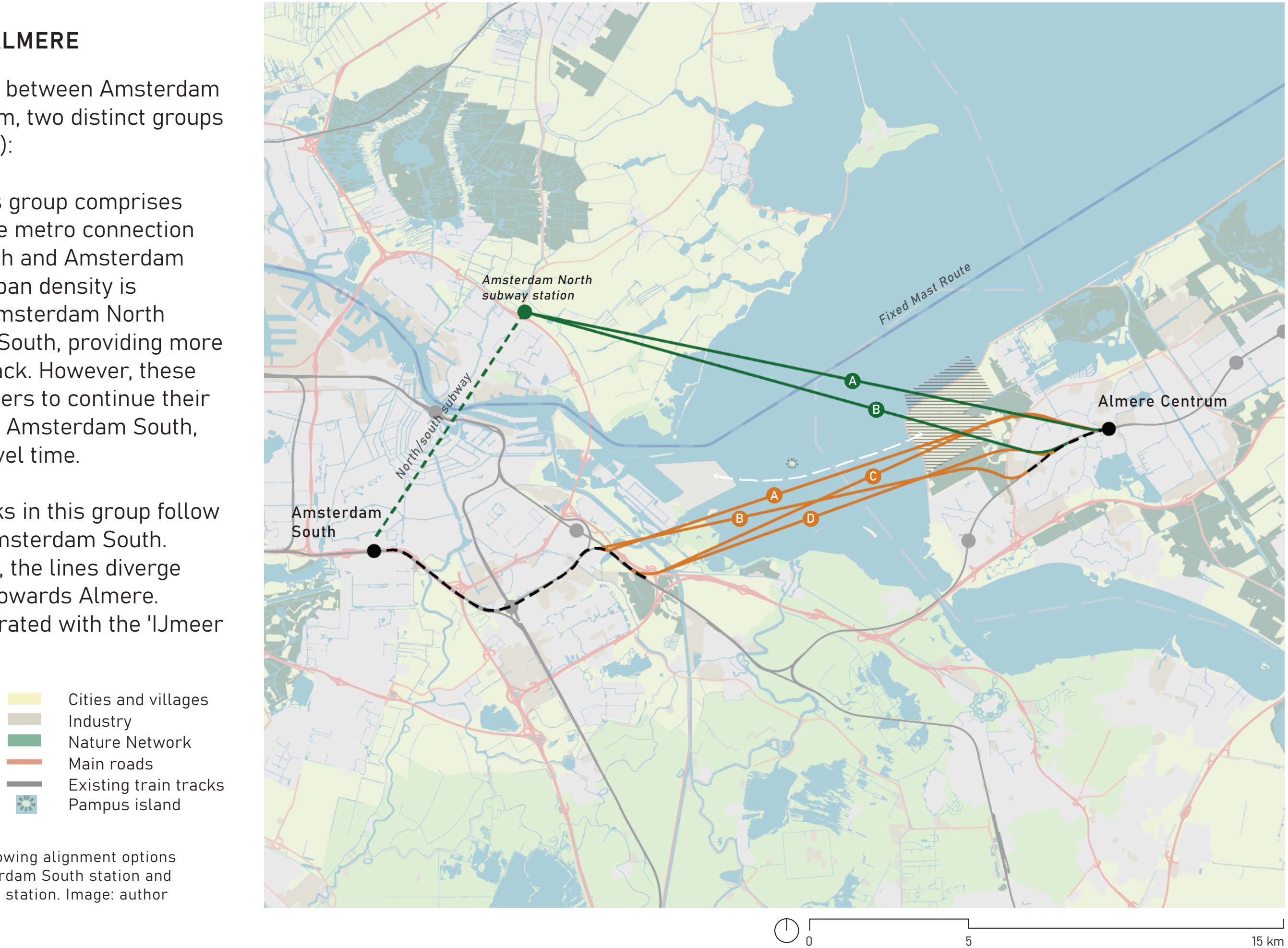
PART ONE

AMSTERDAM SOUTH - ALMERE

For the alignment options between Amsterdam South and Almere Centrum, two distinct groups were established (fig. 3.13):

● Group Markermeer: This group comprises line options that utilize the metro connection between Amsterdam North and Amsterdam South. In this area, the urban density is relatively lower around Amsterdam North compared to Amsterdam South, providing more available space for the track. However, these options necessitate travelers to continue their journey by metro to reach Amsterdam South, resulting in additional travel time.

● Group IJmeer: The tracks in this group follow the existing route from Amsterdam South. Upon reaching the iJmeer, the lines diverge and traverse the IJmeer towards Almere. These tracks can be integrated with the 'IJmeer subway Connection'.



► 3.13 Map showing alignment options between Amserdam South station and Almere central station. Image: author

The comparison of different alignment options involves considering four key parameters, outlined as follows:

Crossing the Fixed Mast Route (yes/no):
The Fixed Mast Route is a crucial shipping route in the Netherlands, requiring bridges to be openable for all passing ships. An openable bridge in a high-speed track may cause significant delays. Hence, a preference is given to options that do not intersect with the Fixed Mast Route.

Possibility to integrate with the 'IJmeer Connection' (low, medium, high):
Alignment options closer to the IJmeer subway Connection offer increased potential for merging both subway and high-speed line routes, leading to more efficient realization. The level of integration possibilities is categorized as low, medium, or high.

Impact on urban development (low, medium, high): Alignment options that align well with the planned urban development of Almere are more desirable. If a line passes directly through the designated area for Almere Pampus, it has a high impact on the development, which is considered unfavorable.

Travel time (minutes):
Minimizing travel time is a primary objective. Hence, options that result in fewer travel minutes are preferred.

The IJmeer alignment option, specifically option B, emerges as the most favorable choice based on the assessment conducted. As a result, further development will be focused on this line. The subsequent description delves into how this line option enters Almere and traverses through the city.

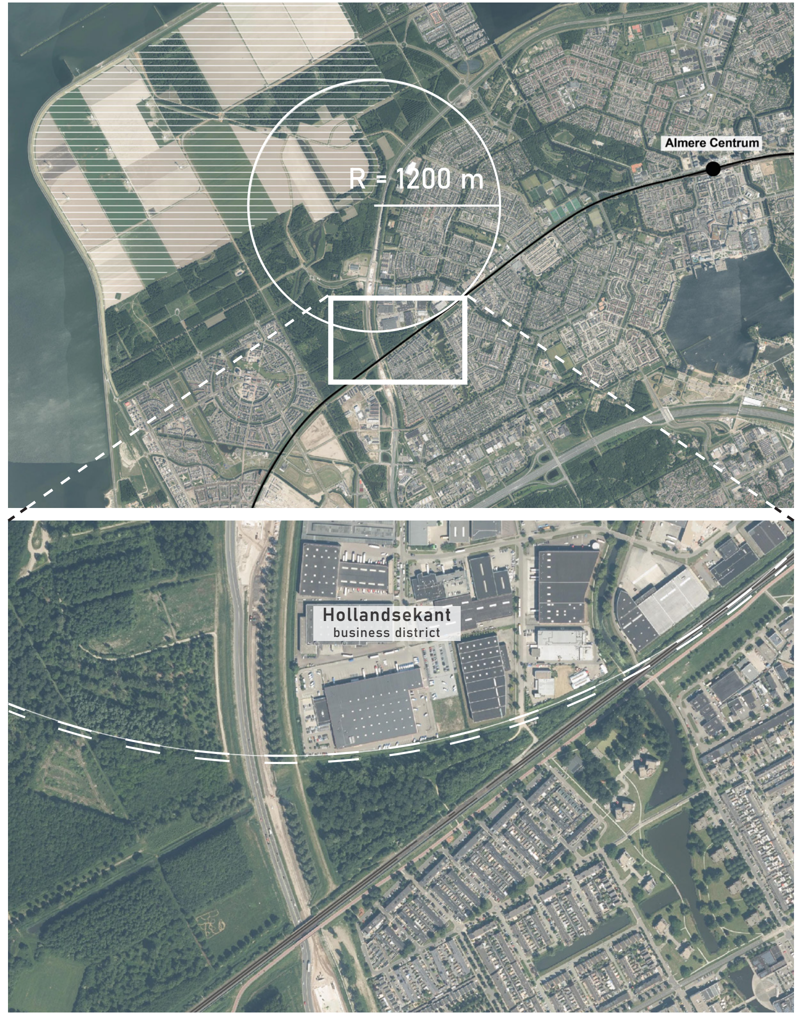
	Crossing Fixed Mast Route	Compatibility with IJmeer Connection	Impact on urban development	Travel time
Markermeer. A	yes	low	high	18
Markermeer. B	yes	low	high	18
IJmeer. A	no	high	medium	8
IJmeer. B	no	high	low	8
IJmeer. C	no	medium	medium	9
IJmeer. D	no	low	low	9

Alignment through Almere

The options in group 3 (IJmeer connection) show the fastest travel times with great difference, compared to groups 1 and 2. And because the alignments of group 3 can very well be realized together with a subway IJmeer connection, the support of the group is enormous. This is why we zoom in on the alignments of group 3 and the possible routes on the Almere side to connect to Almere Central Station.

In figure 3.14 you can see the western side of Almere, where the alignments from group 3 will arrive. Opportunities were sought to connect the new rail line to the existing track. A close-up of the search area (fig. 3.15) shows what appears to be a reserved alignment zone with a curve radius of 1200 m. This zone is 20 m wide and runs on the south side of the Hollandsekant business park, shown in figure 3.14. This radius is almost equal to the wide curve radius at Zwolle station and thus suitable for a route where the train must slow down because it is approaching a stop.

▼ 3.14 The curved area on the south side of business district *Hollandsekant*. Image: Google Street View.



▲ 3.15 Aerial picture of Almere (west) with a close-up of the curved zone along the business district. The curved zone connects to the existing rail track. Data: PDOK. Images: author

Alignment option IJmeer. B follows the curved zone adjacent to the Hollandsekant and connects to the existing rail network up to Almere Central station (fig. 316). Beyond Almere Central, a separate route is pursued due to the curvy and urban nature of the existing track. The optimal disconnection point occurs at the S104 regional road crossing, where the new HSL viaduct can form an infrastructural corridor with the road. The S104 and the railroad viaduct cross the highway together, and the new railroad line continues towards Zwolle via a 1600 m radius curve.

Part two of the study focuses on determining the most suitable alignment between Almere and Zwolle station.

▲ 3.16 Map of preferred HSL alignment through Almere. Image: author

ALMERE - ZWOLLE

The region between Almere and Zwolle encompasses a significantly larger area compared to the Amsterdam-Almere section, with distinct stakeholders to be considered. Predominantly characterized by agricultural land, this area also features scattered villages, protected nature areas such as Natuurnetwerk Nederland and Natura2000, as well as prominent infrastructural networks including Flevoland's Randmeren, the Reevediep, highways, and railways. The alignment planning for the new high-speed railway line necessitates careful consideration of these elements.
The line study has revealed three distinct groups (fig. 3.17), each offering a route between Almere and Zwolle with unique characteristics:

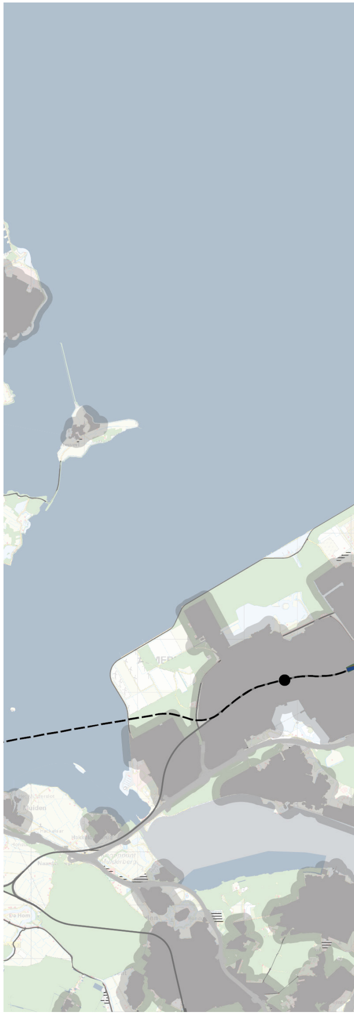
Group Veluwe: These two lines traverse the Flevopolder, forming a corridor that aligns with the existing Veluwe railroad line leading towards Zwolle. However, the availability of space for an HSL track is constrained in the western Veluwe area due to the presence of scattered villages and a military site.

Group Corridors: These lines utilize existing infrastructural networks within the Flevopolder. By integrating the new HSL with these networks, efforts are made to minimize disruption to the surrounding landscape.

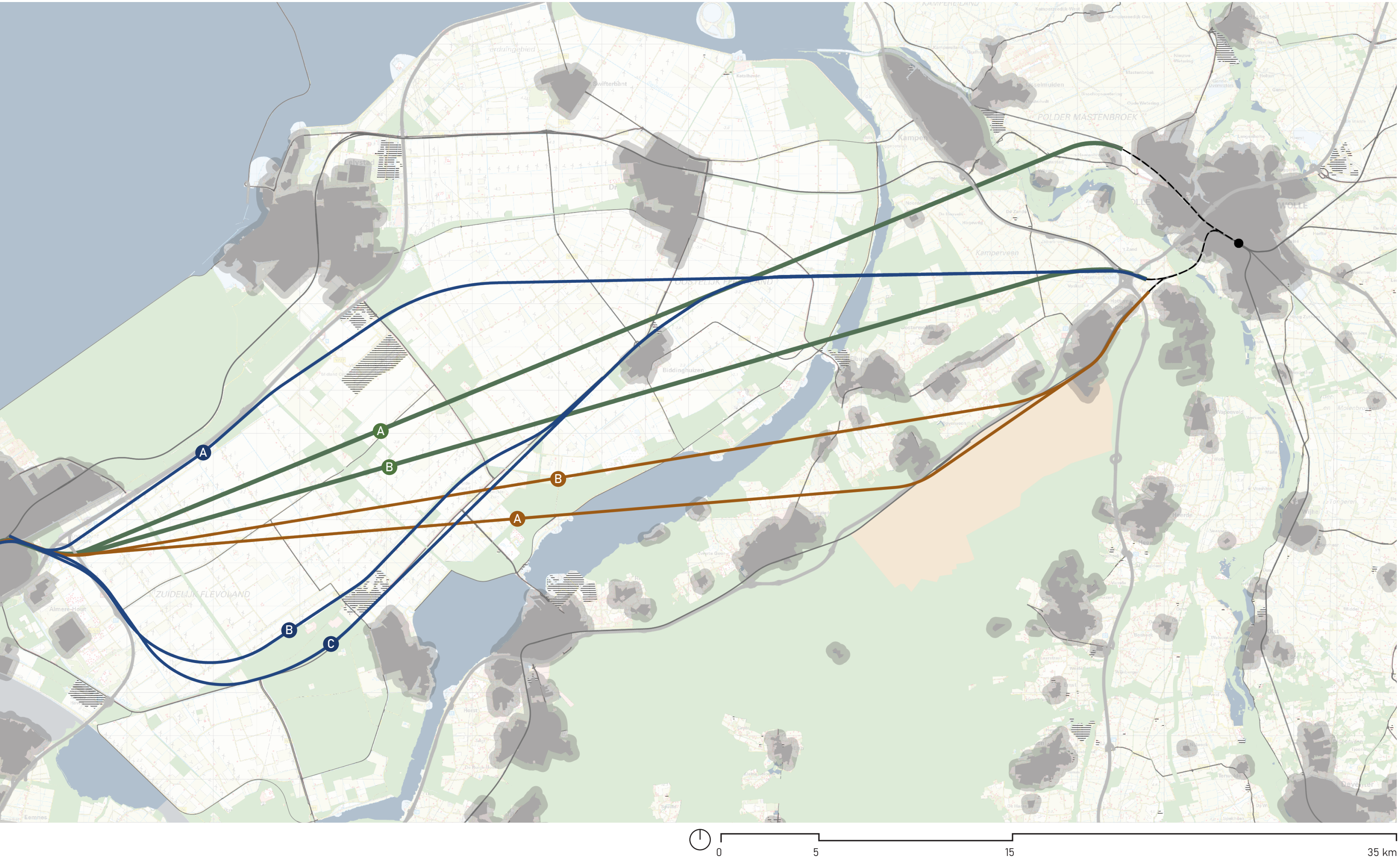
Group Straight through polder: Two line options have been identified, both offering an efficient straight route connecting Almere to Zwolle. These lines differ in their entry points into Zwolle.

In the subsequent analysis, the suitability of these three groups will be thoroughly examined to determine the most viable alignment between Almere and Zwolle station for the new high-speed rail project.

The alignment options under investigation underwent a comprehensive analysis and comparison through the utilization of a multi-criteria analysis (MCA). The MCA methodology entails a systematic evaluation process that enables the ranking of different options based on various criteria and priorities. The selection of criteria is contingent upon the specific context and stakeholders involved. Presented below are the crucial parameters employed in the assessment of alignments between Almere and Zwolle, categorized by theme:



► 3.17 Map showing alignment options between Almere central station and Zwolle station. Image: author



A
B
C
A
B
B
A
ZUIDELIJK FLEVOLAND
POLDER MASTENBROEK
Kampen
Swifterbant
Biddinghuizen
Kamperveen
0
5
15
35 km

Engineering Feasibility: This parameter appraises the technical feasibility of each alignment option. Factors such as track curvature, intersections with other infrastructure networks, and track gradients are considered to ascertain the efficiency and effectiveness of project execution.

Impact on Residents: The well-being and health of residents residing within a range of up to 300 meters can be influenced by noise and vibrations emitted by trains (Van Kamp et al., 2014). Consequently, alignments near residential areas, particularly villages and cities, are regarded as less preferable.

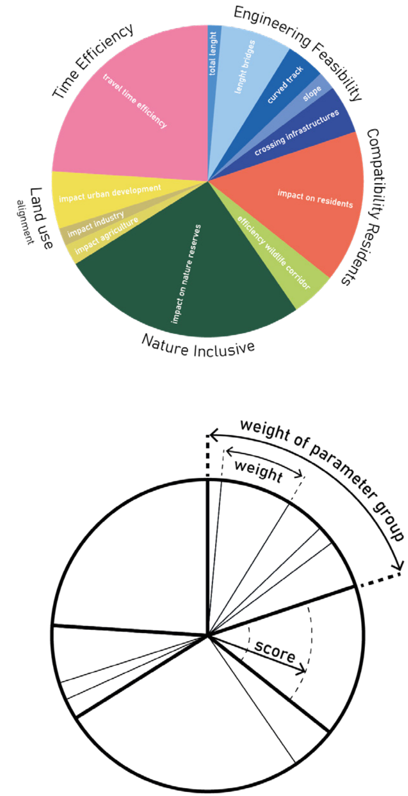
Impact on Nature: This parameter encompasses two aspects. Disrupting natural areas through the alignment route negatively impacts the desirability of a particular option. Conversely, the potential for enhancing nature in the vicinity of the track, either through the expansion of natural areas or the establishment of a natural corridor, exerts a positive influence.

Land Use and Urban Development: This parameter considers three primary land use categories: urban development, industrial areas, and agricultural land. The new high-speed rail line holds the potential to contribute to economic growth, provided it minimally interferes with other economic activities conducted on the land.

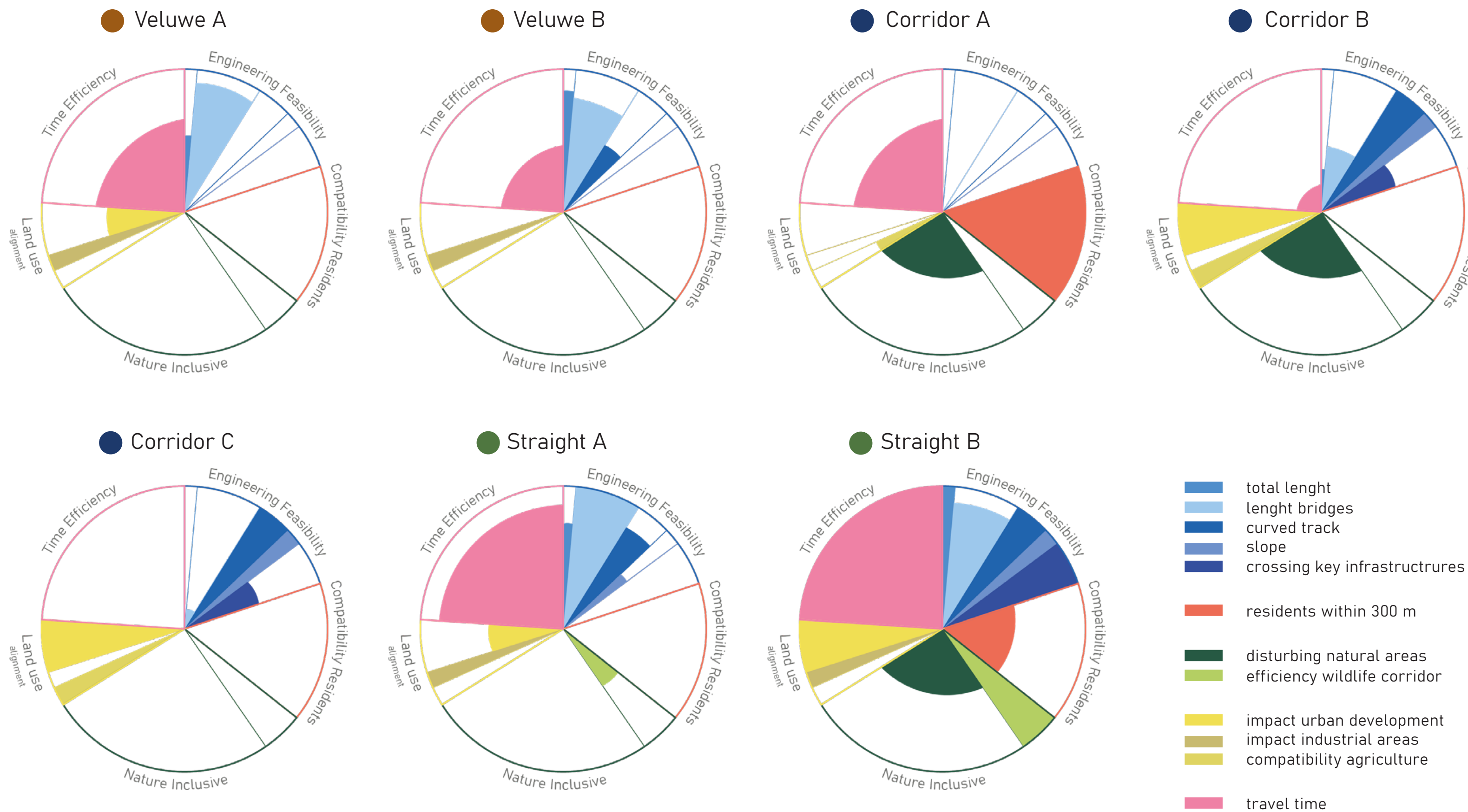
Time Efficiency: The optimization of travel time constitutes a fundamental objective. Consequently, alignment options resulting in reduced travel minutes are more preferred.

Hence, each parameter is assigned a specific weighting factor (fig. 3.18), which was determined, in part, based on the outcomes of the Lelylijn consultation (Mouter et al., 2023). In recent months, all residents of the Netherlands were given the opportunity to contribute to the Lelylijn plans and express the degree of importance they ascribed to design choices such as travel time, inconvenience, and impact on nature. The analysis revealed the following prioritized design objectives, listed in descending order of importance:

· Minimizing the ecological impact of the Lelylijn.
· Minimizing travel time between the northern Netherlands and the Randstad.
· Ensuring cost-effective implementation of the Lelylijn project.
· Minimizing disruptions experienced by residents.
· Facilitating a more balanced distribution of new housing developments across the country.



▲ 3.18 The MCA diagram shows the weight of parameters and relative score of alignment on the parameter. A fully coloured diagram represents the highest possible score. Image: author

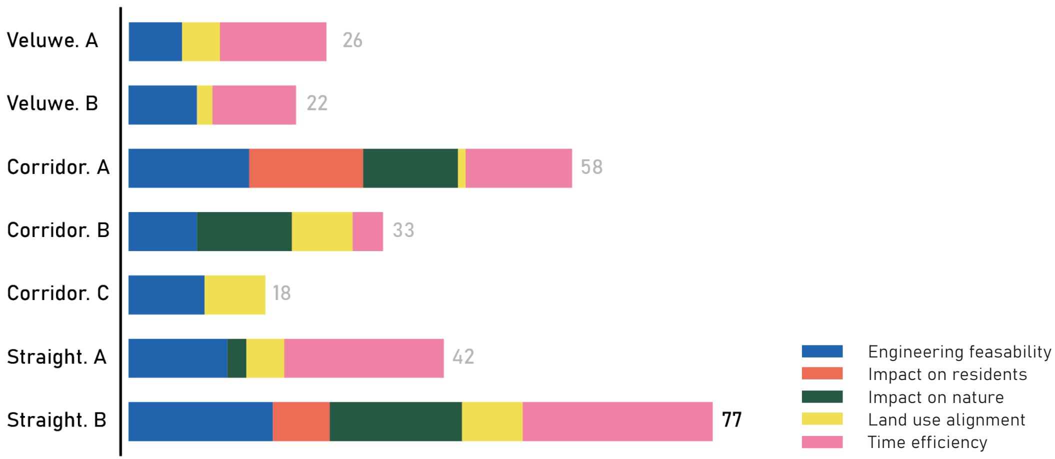


▲ 3.19 The scores of all the alignment options between Almere and Zwolle. Straight. The highest score and would be represented by a fylly completed diagram. Image: author

These priorities were taken into account when assigning the weighting factors for the parameters used in the multi-criteria analysis (MCA). A total of 100 points were allocated among all the parameters. To facilitate comparisons, all values were standardized and multiplied by their respective weighting factors. A higher score indicates a stronger preference for a particular alignment. The results of the MCA are shown in the diagrams in figure 3.19, detailed results of the assessment can be found in Appendix I

Notably, alignment Straight. B emerged as the preferred choice (fig. 3.20) due to its short travel time, suitable technical characteristics, and minimal impact on natural areas. However, the compatibility with agriculture of this alignment is very low. Because the line passes diagonally across agricultural land, the efficiency of agricultural activities may come under pressure. It is necessary to pay close attention to this during the elaboration phase.

After combining this preferred alignment with the one between Amsterdam South and Almere, the lines represent the preferred alignment for the new high-speed rail viaduct.



▲ 3.20 The sum of all the scores are shown in this diagram. Alignment option Straight. B has the heighest score on this MCA with 77 points out of 100. Image: author


OVER THE FLEVOPOLDER
▶ 22 minutes ride
▶ Time win of 35 minutes
▶ 65 kilometers of straight track
▶ 80 % modular, self-extending construction
▶ Boosting ubran development Almere
Almere Centrum
IJmeer line
Amsterdam South
8 min


Groningen
50 km straight track
Zwolle
14 min

PHASE II

04.THE DIAGONAL OVER THE FLEVOPOLDER

The creation of Flevoland

For centuries, the Dutch have been reclaiming land from the water. In 1918, reclamation was not a new concept, but in this year the starting signal was given for the largest reclamation project known. The Zuiderzee Act was enacted and the Wieringermeer was the first polder to be reclaimed. Now, some 55 years ago, Southern Flevoland fell dry as the last polder of this mega-project (Horlings et al., 2018) . The reclamation meant endless empty plains. The Flevopolder was created entirely on the drawing board. Planners, administrators and landscape architects hunched over this table and figured everything out in detail.

The realization of the Flevopolder happened mostly after the reconstruction period. Eastern Flevoland was reclaimed in 1957 and Southern

“The reclamation and creation of the polders not only brought new land, an entirely new landscape was realized.”
(Horlings et al., 2018)

Flevoland after that, in 1968. The major social issues of the time, such as housing shortage and a great need for food production, were translated into spatial solutions. Designing this large-scale new landscape was one big cultural, forestry and spatial experiment (Horlings et al., 2018).

Construction of Lelystad began in 1967. Ten years later, the first house was completed in Almere (Horlings et al., 2018). The first residents of Flevoland were real polder pioneers. They went to inhabit the "land of promise" (Luiten, 2016). The pioneers sought a new existence in the polder. Some because they were looking for better than the rundown Amsterdam neighborhoods, where a large proportion of the new residents came from (Hoffmann et al., 2016). Others to be allocated farmland after rigorous selection and build a new farming life (Rijk, 2018).

The Flevopolder stands out as a truly unique landscape, representing a remarkable feat of human engineering and planning. How the polder was created, its huge scale and the pioneers have created a new cultural landscape. Because this landscape is so special and distinctive, the full focus of the landscape implementation of the new high-speed line will be on the landscape of the Flevoland polder.

▲ 4.1 Reclamation eastern Flevoland. Photo: retrieved from Visit Flevoland (n.d.)

▲ 4.2 Harbour of Almere. Photo: Bart Hofmeester / Aerocamera (1973)

▲ 4.3 First habitants of Almere. Photo: retrieved from Andere Tijden (n.d)

A functional landscape

The entire Zuiderzee project was focused on water safety and food production. What came as collateral benefits were an increase in the Dutch freshwater supply and a better connection between the western Netherlands and the north. That did not take away from the fact that all the new land also had to become pretty and livable (Horlings et al., 2018). In 1928, a comprehensive advice on the design of the new polders was published: Het toekomstig landschap der Zuiderzeepolders, prepared by Het Nederlands Instituut voor Volkshuisvesting en Stedebouw (Hudig et al., 1928). The main message of the advice was "that modern man should be able to experience the beauty of the agricultural landscape ... this could be achieved by designing functional landscaping elements in such a way that they would naturally evoke the experience of beauty" (Horlings et al., 2018). To experience that functional beauty, "variation for the sake of variation" must be avoided (Hudig et al., 1928).

“No variety for the sake of variety”

(Hudigs et al., 1928)

The realization that a purely functional landscape was too austere came after the completion of the Wieringermeer. After this, making landscape architectural plans for the other polders took on a greater role.
In the landscape design of the Flevopolder, combining practicality and beauty was the guiding principle throughout the design and construction period. This resulted in a landscape with great contrasts between up and closed spaces, consisting of a number of spatial components (fig. 4.4) (Horlings et al., 2018).

Dikes and canals

Necessary elements for a polder are dikes and canals. The Flevopolder is completely surrounded by water, with the Randmeren (edge lakes) on the east side. These lakes are made recreationally attractive by varying widths and space for bays. The visibility of the open water has been increased by the occasional road over the top of the dike at the edge of Flevoland. The Knardijk in the middle of Flevoland was once a sea dike, but now separates Eastern and Southern Flevoland as a sleeping dike. This dike is now a strong landscape carrier. The internal water management, consisting of the Hoge and Lage Vaart, is rigid and functional to create as many equal conditions for agriculture as possible (Horlings et al., 2018).

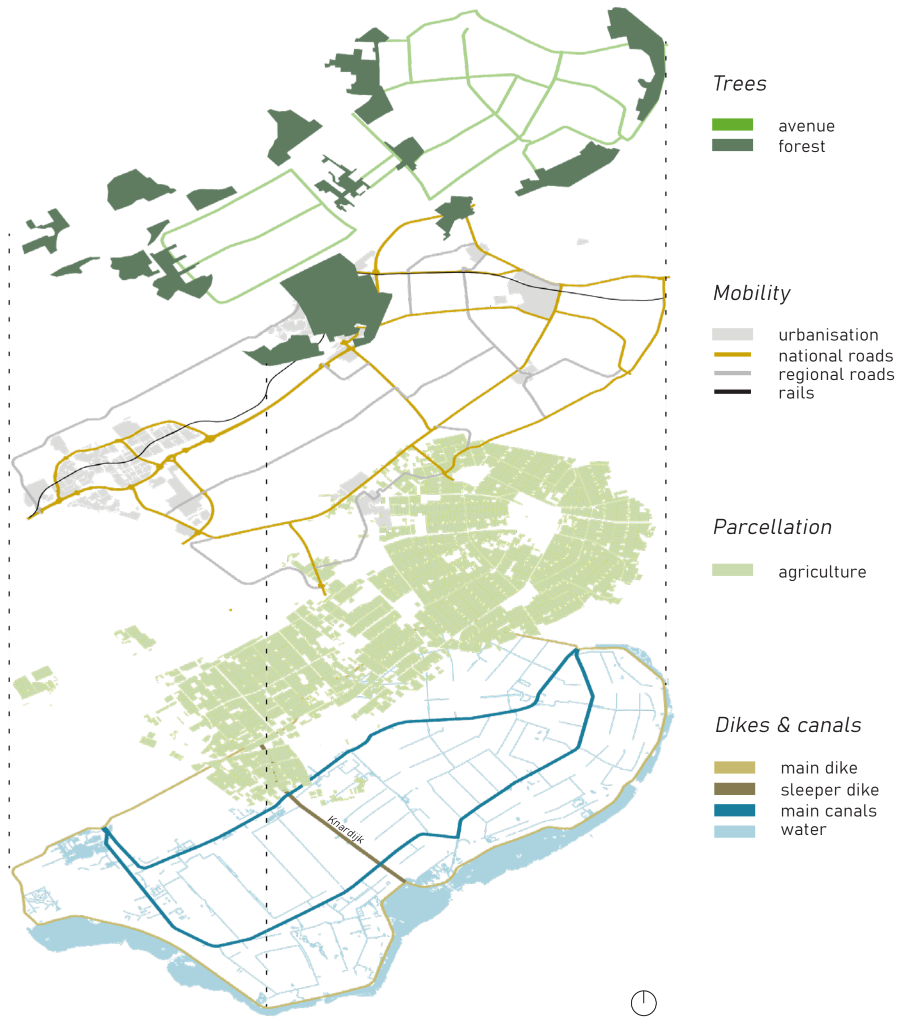
Parcellation

Agricultural allotment is hugely influential in the layout of the Flevopolder. Here too, the aim was to create as many equal conditions as possible for the benefit of agriculture.
With the development in mechanization and consequently larger agricultural machinery, the arable land became increasingly larger. Because there was a number of years between the layout of Eastern and Southern Flevoland, the plots in Southern Flevoland are larger.
The farmyards in the south are always four clustered together, where in Eastern Flevoland two yards face each other. Tree belts surround the farmyards, providing wind protection. As a result, the farmyards appear as islands in the polder (Horlings et al., 2018).

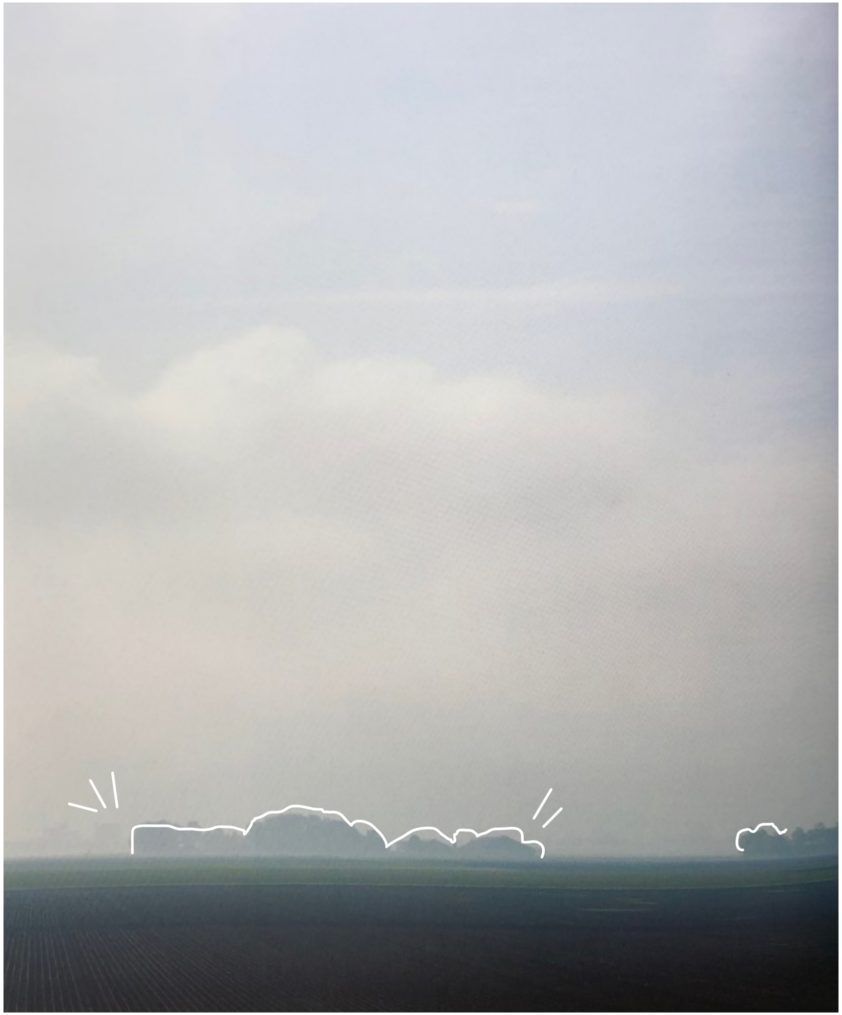
Mobility

Agricultural roads in Flevoland are generous in design due to their wide profile. With the exception of the major N roads, the roads are unplanted. The practical reason for this is so that minimal shadow falls on the arable land. The major roads (N-road) form continuous, slightly curved lines in the landscape. This is where the landscape plan has been given a greater role than the functionality of the croplands (Horlings et al., 2018).

Trees
The Flevopolder has a strong green structure that is fixed in the tree avenue pattern, especially in Southern Flevoland, and vigorous forest strips along the curved main roads. Perpendicular to this lie broad forest belts along the Hoge and Lage Vaart. In the middle of the polder there are two forests. The Knarbos was created during the reclamation. The Larserbos was once planned as a village, but those plans changed. Along the edge lake on the eastern side of Flevoland, recreational forests have been created. These form the green horizon of Flevoland. The Flevoland polder is mainly distinguished from the other Zuiderzee projects by the generous forest strips along the major roads and the edge forests along the edge lake on the eastern side (Horlings et al., 2018).

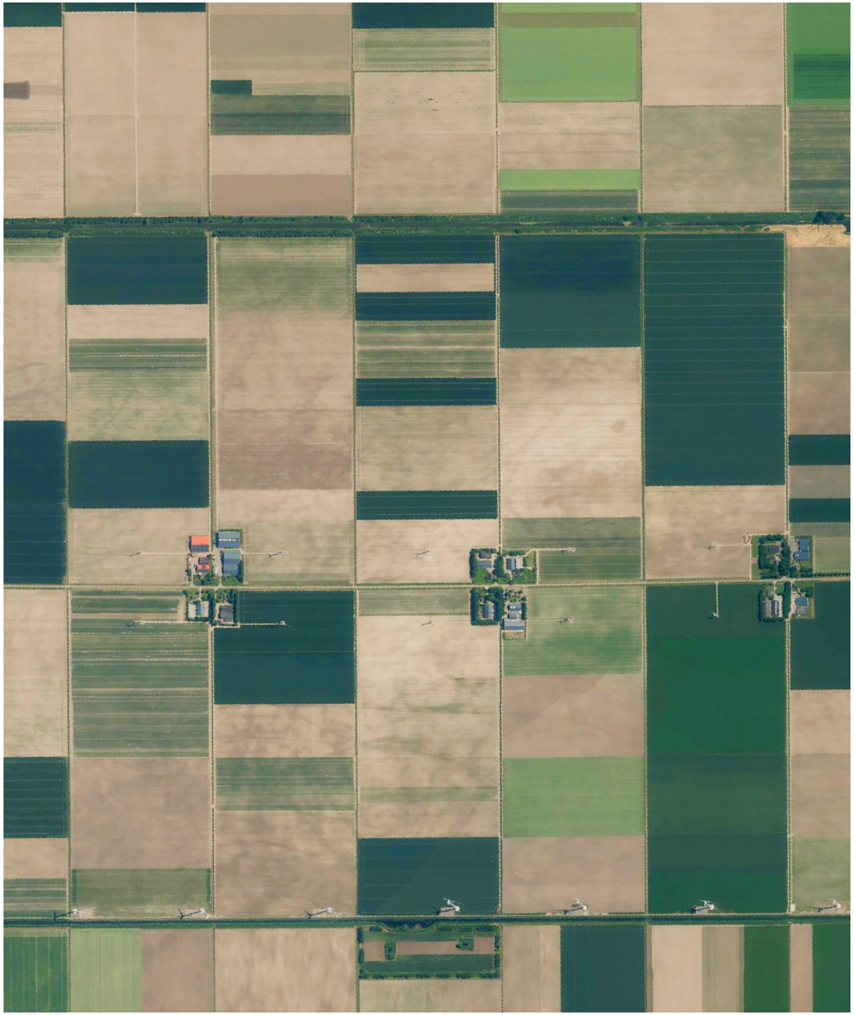


▶ 4.4 The layered Flevoland landscape. Image: author

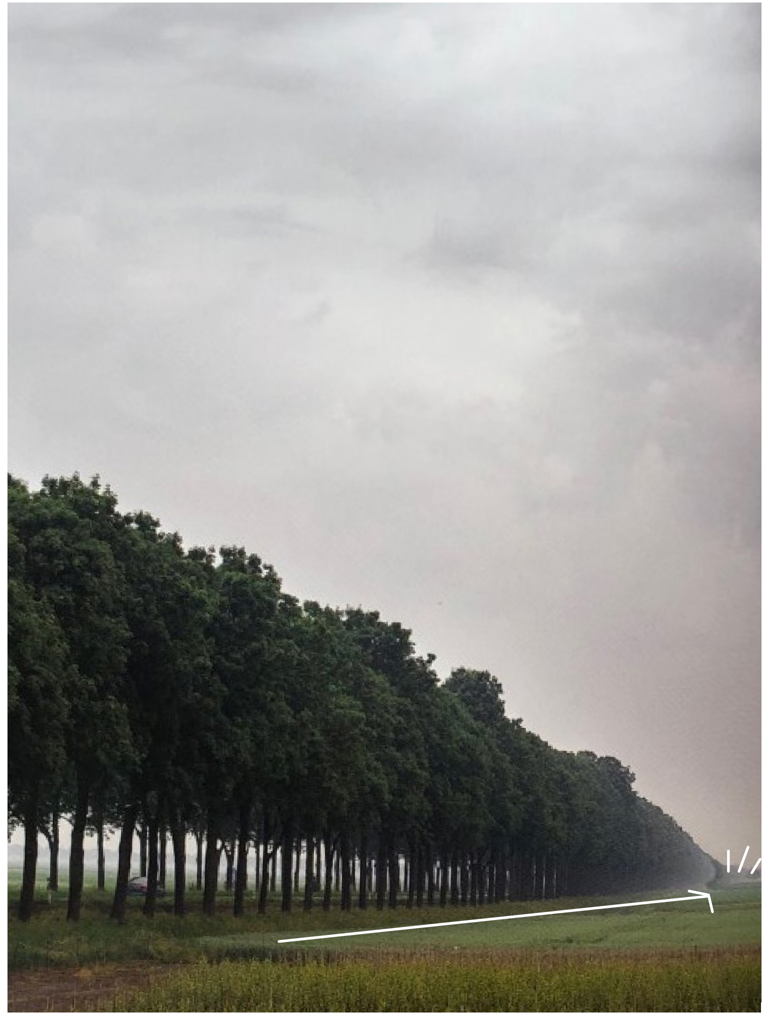


▲ 4.5 Yards in the open space. Photo: Hendrickx (2018)

▲ 4.6 Wide, long ditches. Photo: retrieved from *Programma Landschap van de Toekomst* (Provincie Flevoland, 2021)



▲ 4.7 Rythm and direction due to the polder pattern. Image: Google Earth (2023)



▲ 4.8 Long sightlines along tree lanes. Photo: Hendrickx (2018)

Wind turbines

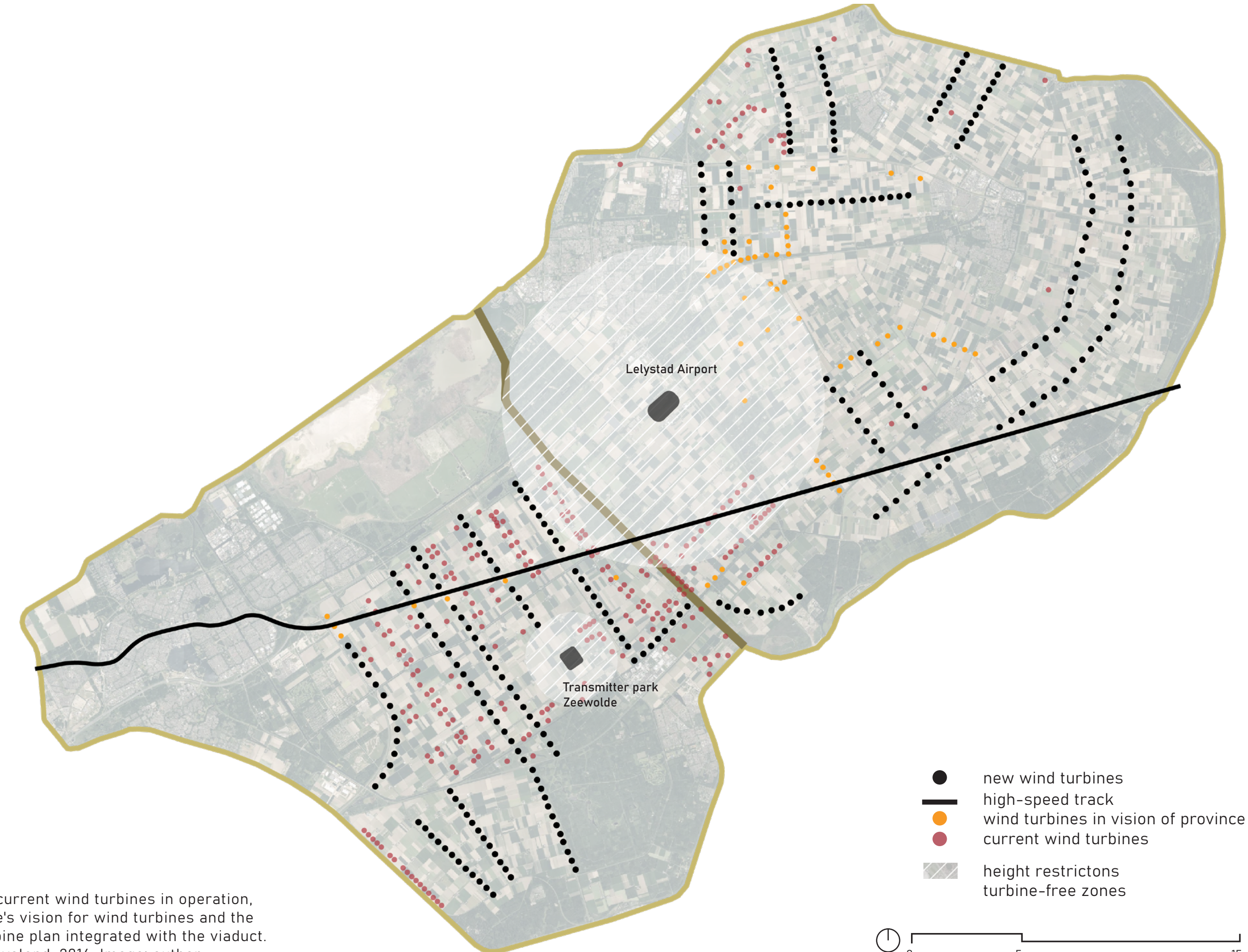
On top of the four layers (dikes and canals, parcellation, mobility and trees), a new layer has emerged since the 1990s: wind turbines. Because of Flevoland's openness, wind turbines provide power, and therefore income, all year round. Farmers discovered this too and were given free rein to place wind turbines on their land. This resulted in hundreds of wind turbines scattered throughout the polder, some larger than others (fig. 4.9 & 4.10) (Provincie Flevoland, 2016). The wind turbines have become part of the Flevoland landscape, but they have affected the systematic and rational design. The wind turbines have greatly cluttered Flevoland's structured landscape. The province and municipalities also realized this and they instituted a construction freeze on wind turbines in 2005. A plan was made for a new wind turbine landscape (fig. 4.11), which should enhance the character of the polder landscape (Provincie Flevoland, 2016).

However, the province's vision for the new wind turbine landscape could be more ambitious. There are still solitary wind turbines, line arrangements are very different from each other, and turbines stand together in clusters. Because the alignment of the new high-speed train runs diagonally across the polder and thus does not follow the landscape framework, a it is necessary to additionally strengthen the existing landscape in its own form. Therefore, a new proposal has been developed for the future wind turbine landscape.

The new proposal is an adaptation of the provincial plan and fully cooperates with the alignment of the new high-speed train. The new plan consists only of rows of wind turbines, so no solitary turbines. Lines have been made as long as possible, just like the continuous lines in the low landscape. Clusters have been removed to create a calmer appearance. In the polder lie Lelystad Airport and transmitter park Zeewolde, which both do not accept wind turbines within a certain radius.

The wind turbines together enhance the landscape and add a new functional layer to the Flevopolder: the energy landscape. By letting the energy landscape, the polder and the train viaduct come together in the rational framework of the polder, a unique modern polder landscape can be created with the three main themes of agriculture, energy and mobility.

▲▲ 4.9 Turbines create chaotic horizon. Photo: author (2023)
▲ 4.10 Scattered turbines in the landscape. Photo: Van Lonkhuijsen/ANP (n.d.)



► 4.11 Map of the current wind turbines in operation, Flevoland Province's vision for wind turbines and the modified wind turbine plan integrated with the viaduct. Data: Provincie Flevoland, 2016. Image: author

Integration with the Flevopolder

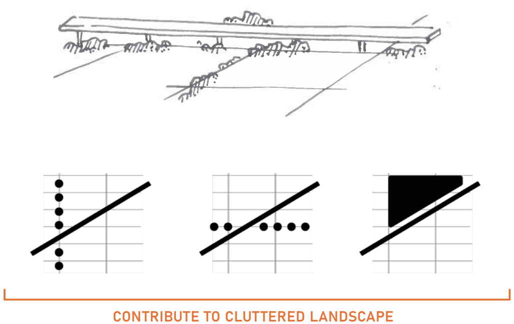
The integration of the high-speed viaduct with the open polder landscape has undergone extensive testing through various sketches, aiming to achieve optimal cohesion. These interventions primarily involve the strategic addition of trees, as they contribute to creating spatiality within the polder landscape.
The landscape interventions within the viaduct landscape can be classified into two principles: those guided by the polder grid and those guided by the viaduct itself. However, caution must be exercised to avoid introducing additional clutter into the landscape.

Valuable insights can be drawn from the development of the wind turbine landscape, where the inclusion of landscape elements within the Flevopolder is best approached as part of a larger network. The placement of isolated wind turbines creates visual chaos, while establishing long lines of turbines fosters a harmonious relationship with the landscape.

Similarly, the viaduct, as a continuous line, can coexist with the openness and straightness of the polder landscape without necessitating further landscape interventions: *no variety for the sake of variety*.

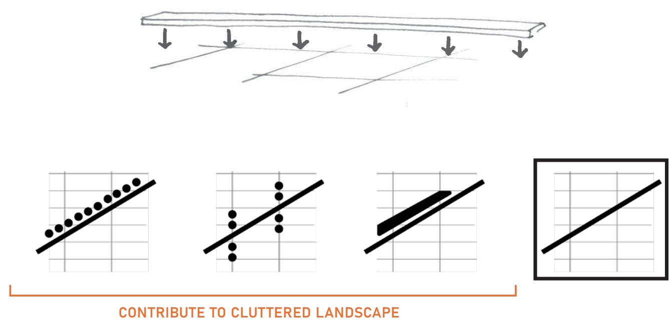
Implementing a viaduct in the Flevoland landscape entails practical considerations. Evaluation of various alignment options reveals that the chosen alignment does not score optimally in terms of Impact on Residents,

Polder is leading:



▲ Interventions follow the grid of the polder landscape

Viaduct is leading:



▲ Interventions follow the direction of the viaduct.

● tree ■ group of trees ▬ viaduct

Compatibility with Agriculture, and Impact on Nature.

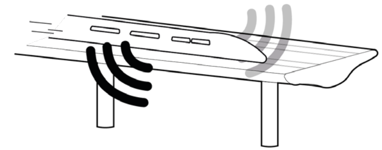
Within a 100-meter proximity to the viaduct, 14 farmyards are situated, causing significant disturbances for residents due to their proximity to railway tracks, leading to adverse health effects (Van Kamp et al., 2014). As a result, the decision has been made to relocate all farmyards with residential dwellings within 100 meters of the viaduct to a minimum distance of 300 meters.

Farmyards located between 100 and 300 meters from the viaduct, totalling 27 in number, may still experience some disturbance from the high-speed train. However, due to the uncertainty surrounding the effects and level of disruption within this range (Van Kamp et al., 2014), immediate relocation of these farmyards is not warranted. Nevertheless, the viaduct's design incorporates measures to minimize noise impact, thereby mitigating its effects on the surrounding natural environment.

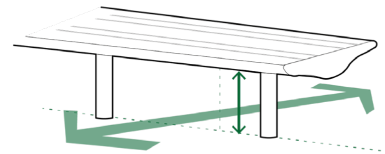
Repositioning of 14 farmyards; 27 farmyards within a 300m radius of the viaduct

In an agricultural landscape that prioritizes efficiency, ensuring the harmonious coexistence of the viaduct and agriculture is vital. Maintaining accessibility (fig. 4.12) to the viaduct's surroundings and the underlying landscape is crucial, with the viaduct's height playing a significant role in achieving this objective. Attention must also be given to the viaduct's impact on the land, including reduced precipitation and shading on agricultural areas (fig. 4.12) . Although the integration of a suitable water management system within the viaduct structure is beyond the scope of this report, thoughtful attention is dedicated to evaluating the impact of viaduct shadows on agricultural practices, ensuring smart design and effective mitigation strategies.

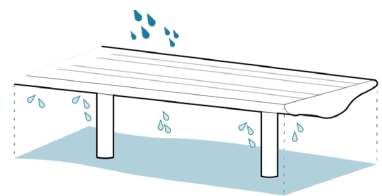
► 4.12 Design parameters that require explicit attention in the design process. Images: author



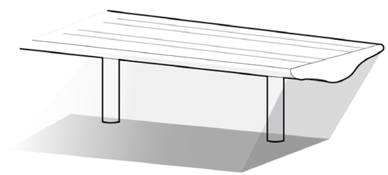
1/ Reducing noise impact



2/ Maintaining accessability



3/ Integrating suitable water management



4/ Designing with shadow effects

PHASE II

05.THE VIADUCT

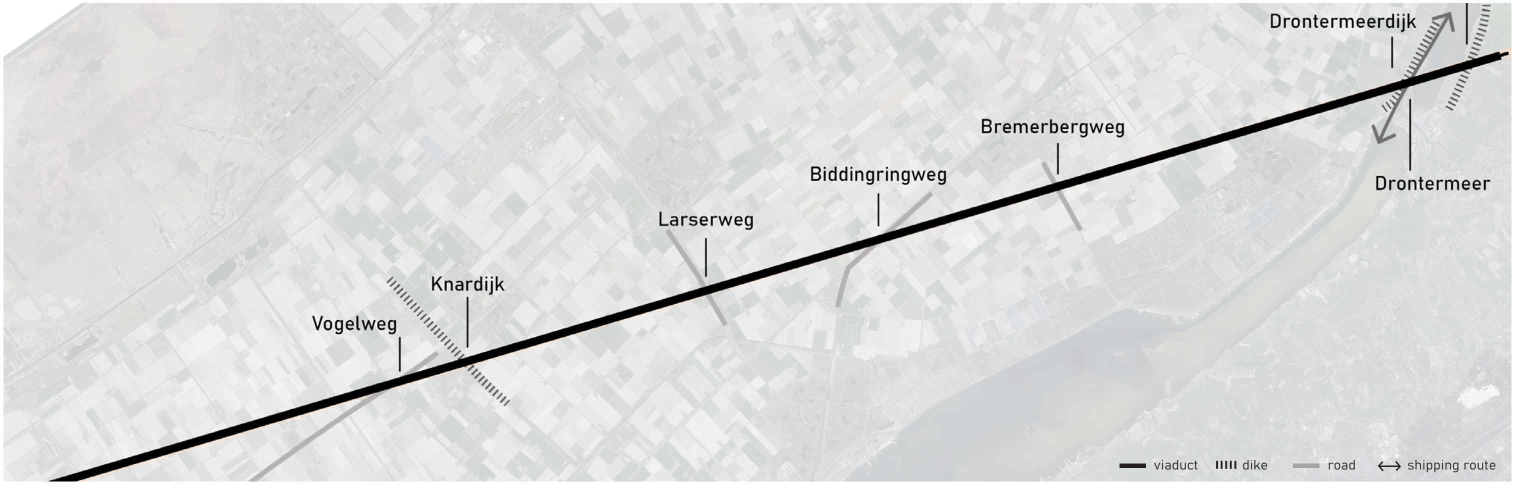
Height profile

The determination of minimum clearance heights for infrastructures is regulated by law. According to the regulations set by the Dutch government (Nederlandse Overheid, 2017), a minimum clearance height of 4.50 meters is mandated for (car) roads, which has also been adopted as the required clearance height above agricultural areas. In the case of bicycle paths, a clearance height of 2.50 meters is deemed sufficient.

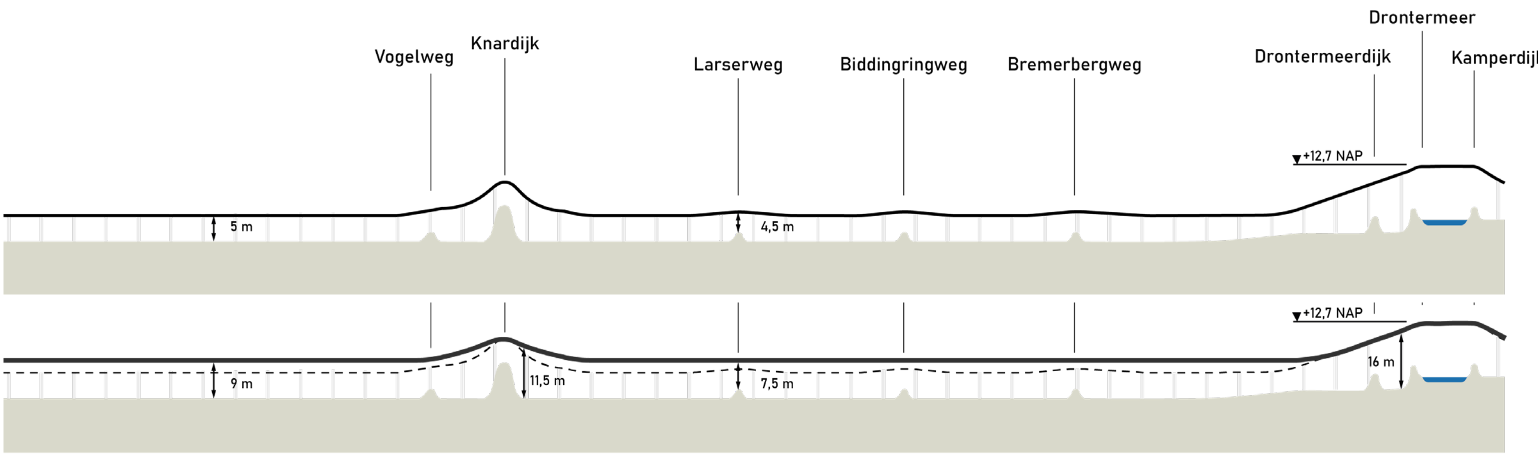
The viaduct traverses various landscapes, including dikes with roads on top, main roads that are elevated above agricultural land, and the Drontermeer channel. Consequently, the height profile of the viaduct fluctuates, with its highest point reaching +12.7 meters NAP to provide ample clearance above the Drontermeer channel (fig. 4.13). The determination of this clearance is influenced by the height of other bridges spanning the Randmeren.

It is important to note that a viaduct positioned at 4.5 meters above ground level has a significantly different impact on the surrounding landscape compared to viaducts at heights of 9 or 16 meters. Furthermore, the perception of height varies depending on the observer's viewpoint within the field. To visualize the effects of different viaduct heights (5m, 9m, and 16m) on the landscape, a simplified 3D model was employed (page 52). The study revealed that a viaduct height of 9 meters integrates most harmoniously with the Flevoland landscape. Consequently, the height profile of the viaduct across the Flevopolder has been adjusted, resulting in an almost constant horizontal alignment.

► 4.13 The minimum and desired height profile of the high-speed rail viaduct over the Flevopolder. Images: author



Drontermeerdijk
Bremerbergweg
Drontermeer
Biddingringweg
Larserweg
Knardijk
Vogelweg
viaduct
dike
road
shipping route



Drontermeer
Vogelweg
Knardijk
Larserweg
Biddingringweg
Bremerbergweg
Drontermeerdijk
Kamperdijk
+12,7 NAP
5 m
4,5 m
+12,7 NAP
16 m
9 m
11,5 m
7,5 m

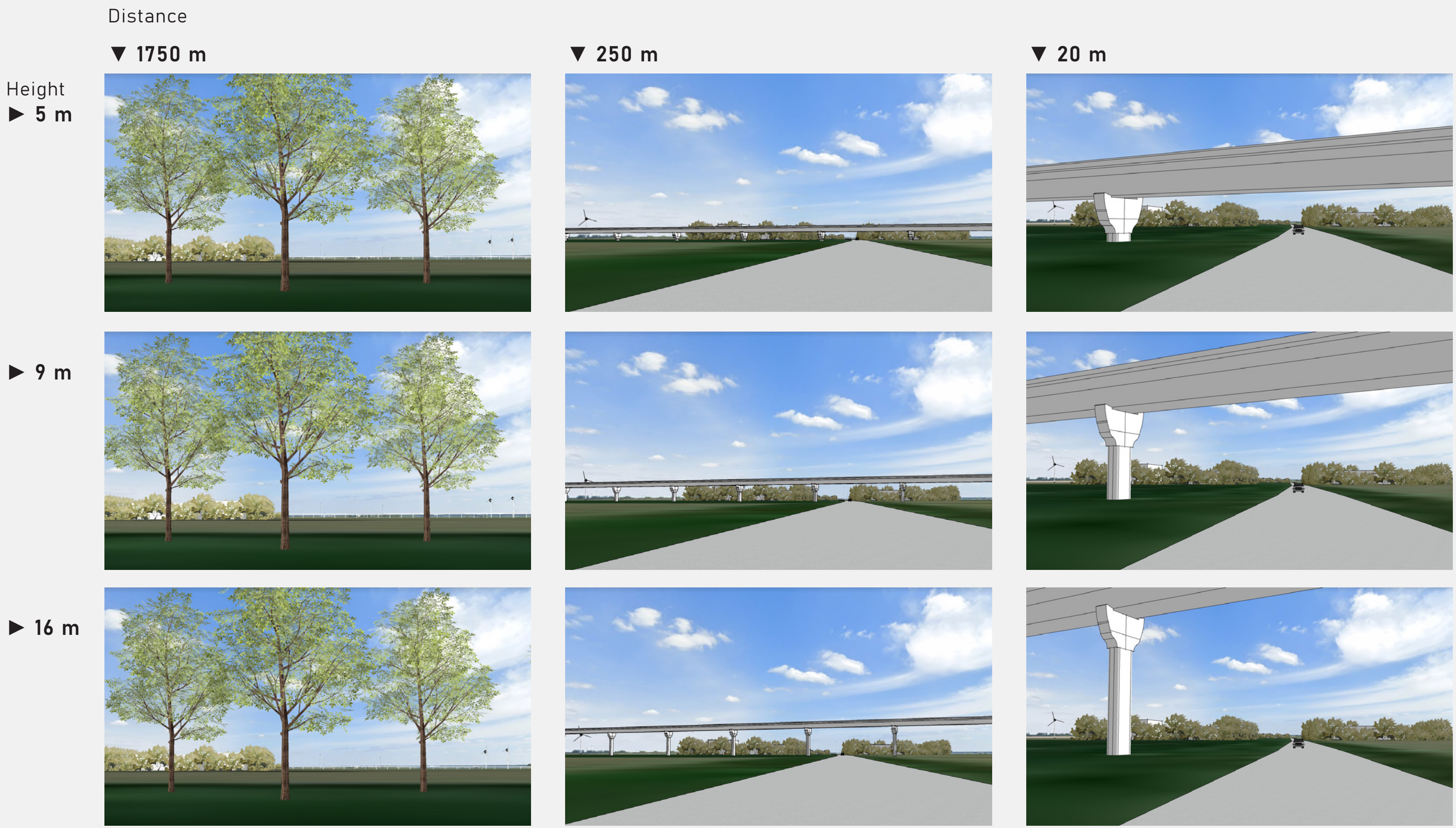
Height & perspective

When the viaduct is at a great distance, one can hardly see a difference in height between the three viaducts. All three viaducts are a thin line on the horizon.

At a smaller distance from the viaduct (250 m), a significant change is seen. The 5 m high viaduct takes the view away from the horizon, demanding all the attention. At a height of 9 m, the landscape passes under the viaduct and provides a freer horizon. The 16 m viaduct opens up the whole landscape image, but this version is so high above ground level that proportions disappear and the viaduct takes a lot of attention.

Close to the viaduct, the lowest version creates a very narrow space. As a result, the viaduct looks massive. The 9 m height does frame the space, but does not form a visual blockage. The 16 m high version is barely visible, it quickly falls out of the field of vision due to its height.

The 9 m viaduct fits best into the landscape due to its proportions. It is higher than necessary (4.5 m), but because of this the height profile is a more constant line (fig. 4.13) and more equal modules can be applied in construction. It is expected that in this way some of the additional material costs due to higher columns will be compensated.


Distance
▼ 1750 m
▼ 250 m
▼ 20 m
Height
▶ 5 m
▶ 9 m
▶ 16 m

Construction

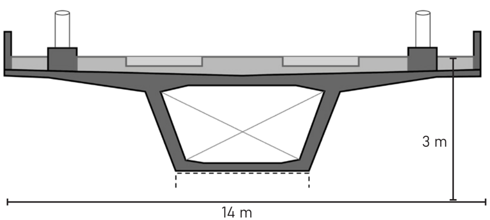
The high-speed viaduct must, of course, adhere to the necessary structural requirements. In this study, the determination of the required dimensions is based on established rules of thumb and reference projects. A design manual released by the California High Speed Rail Authority (Wagonner et al., 2009) serves as a valuable resource, providing guidelines for a fundamental high-speed train aerial structure that is well-suited for modular construction. By minimizing the use of material in the aerial structure through the inclusion of a void in the middle, the overall structure becomes lighter, resulting in cost savings.

The primary dimensions that are visually prominent include the overall structural height, set at 3 meters, and the cross-section width, which measures 14 meters (fig. 4.14). These key dimensions play a crucial role in defining the visual appearance and functionality of the viaduct.

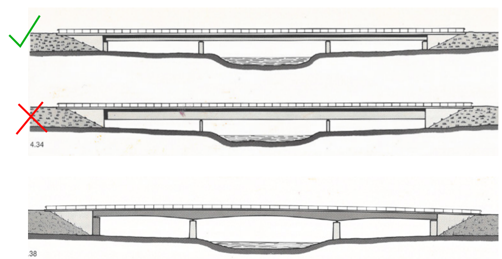
Shape & appearance

In the context of the well-organized and modern Flevopolder, as well as the functionally designed wind turbines, the integration of a contemporary and slender viaduct becomes imperative. Achieving this aesthetic objective requires careful consideration of the proportions between the structural height of the horizontal section and the thickness of the columns. Notably, the work of Leonhardt (1984) highlights that unfavorable proportions occur when employing a deep beam on small columns, while a slender beam on thick pillars yields a more desirable outcome (fig. 4.15).

Introducing a haunched beam design allows for a lower structural height at the midpoint between two columns, thereby facilitating efficient force distribution and enhancing the overall elegance of the viaduct (4.16) (Leonhardt, 1984). An exemplification of this design language can be observed in the



▲ 4.14 Section of high-speed train aerial structure recommended by California High Speed Rail Authority. Image: author, inspired by Wagonner et al. (2009)

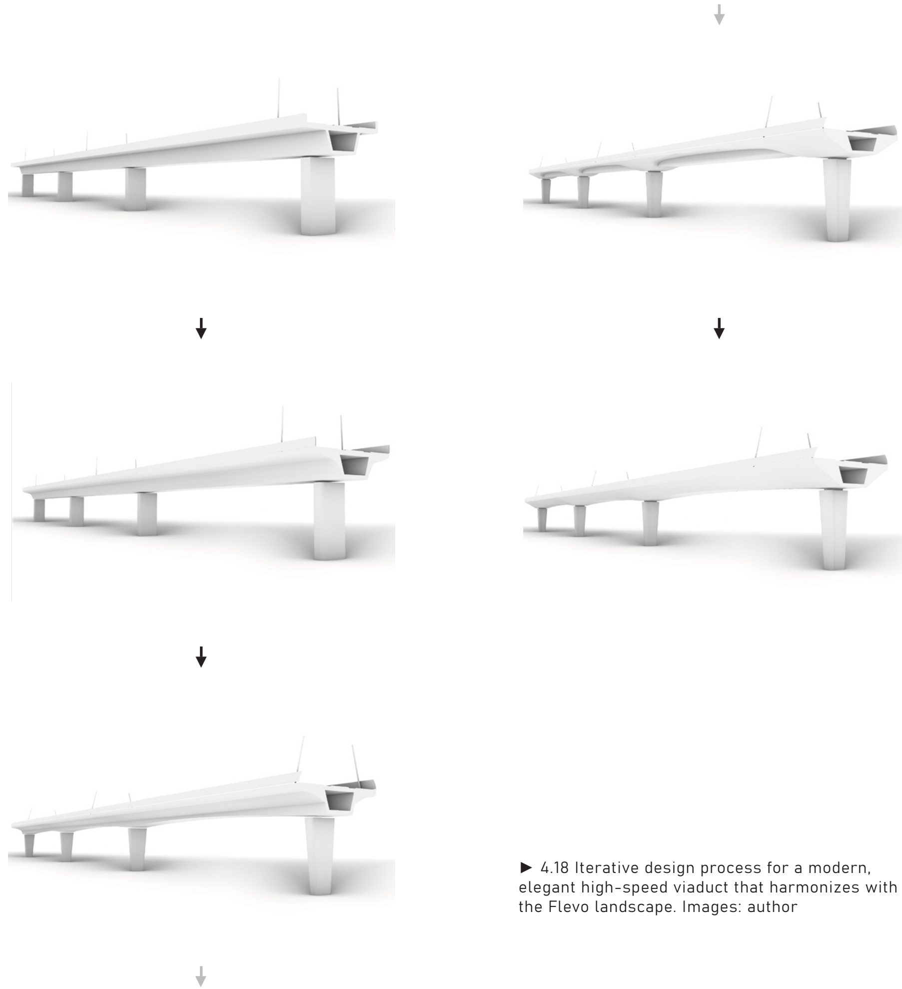


▲▲ 4.15 Good: thin beam, thicker columns; Bad: Thick beam, thin columns
▲ 4.16 Haunched beam for less construction height & elegance. Images: Leonhardt (1984)

▲ 4.17 Colne Valley viaduct. Image: Arup (2016) modern Colne Valley Viaduct of the UK's high-speed track, HS2, as executed by Arup and AECOM (2016). The sleekness, tapered edges, and meticulous selection of materials and colors in this viaduct (fig. 4.17) serve as a reference for the new high-speed viaduct planned over the Flevopolder.

To develop the optimal design for the new viaduct, various models were constructed, building upon the fundamental structural form (fig. 4.18). Each iteration involved refining the design by smoothing corners, sloping the sides, and tapering the columns. An initial attempt to incorporate the curvature of wind turbine blades into the viaduct resulted in a model that appeared overly futuristic (fig. 4.18). Consequently, a more simplified model characterized by continuous lines emerged as a better fit for the polder landscape, maintaining a harmonious visual integration with the surroundings.

Moreover, an additional element of visual cohesion was considered by aligning the color scheme of the viaduct with the existing wind turbines in the landscape. This harmonization, achieved through color matching, further enhances the integration of the viaduct with the surrounding environment, creating a unified and visually pleasing composition in the Flevopolder.



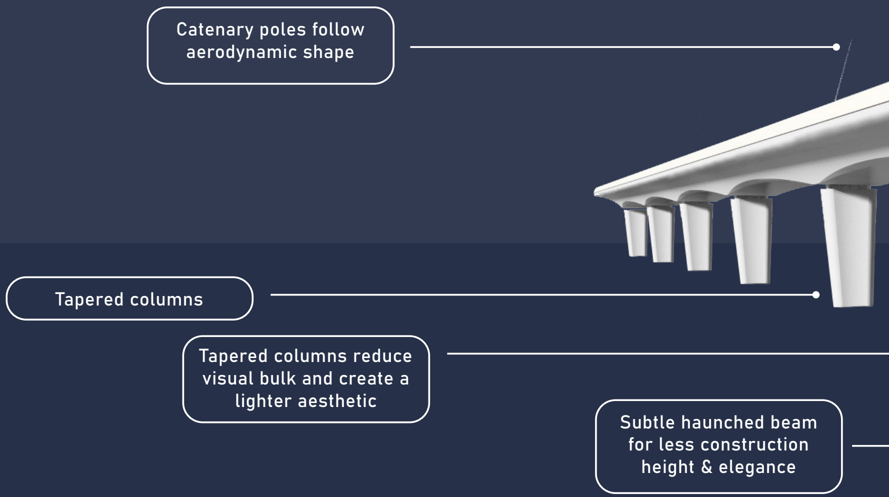
► 4.18 Iterative design process for a modern, elegant high-speed viaduct that harmonizes with the Flevo landscape. Images: author

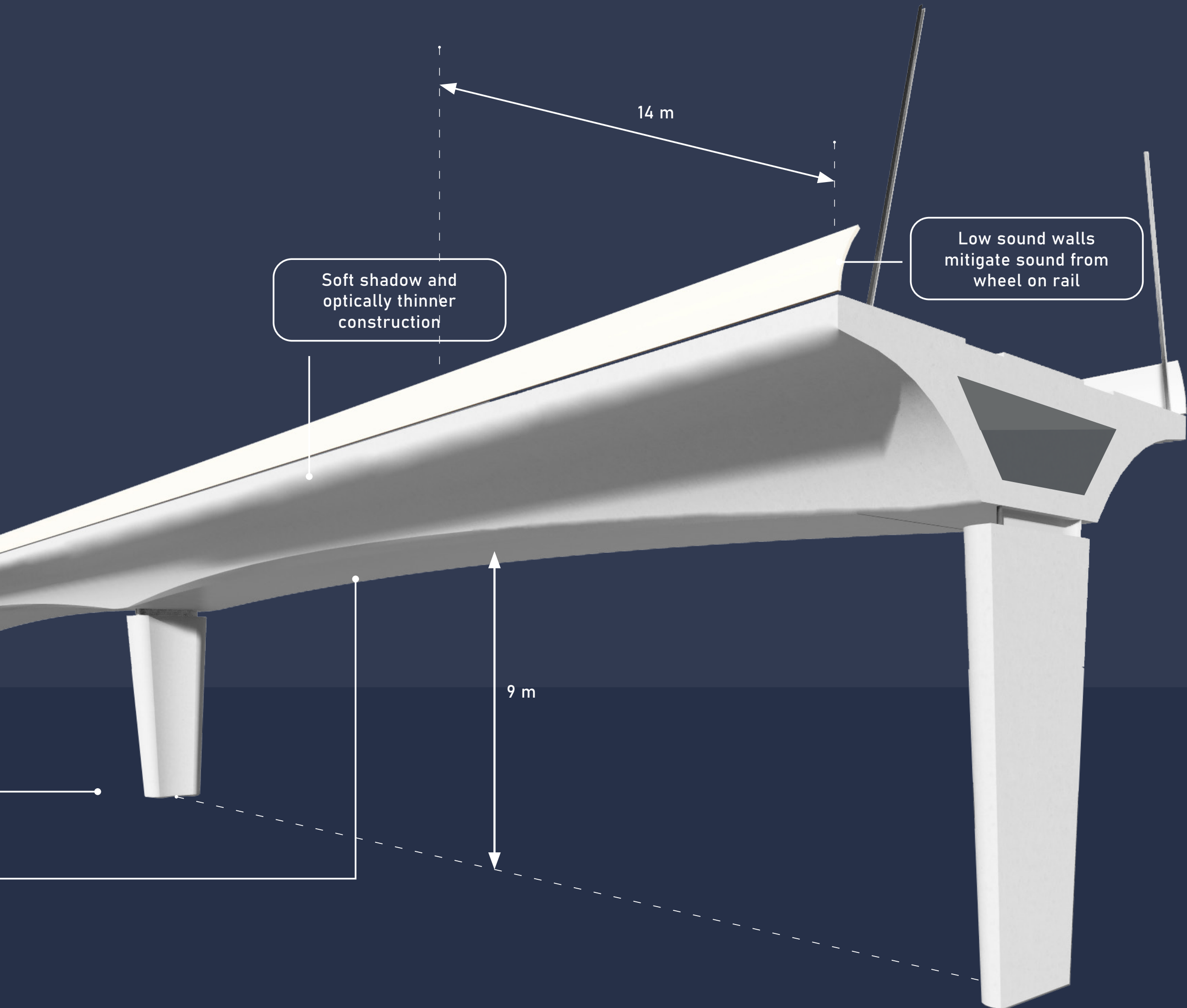
THE VIADUCT

The viaduct design embodies sleekness, modernity, and speed. Its tapered columns, complementing the white color of nearby wind turbines, create an aesthetic harmony within the landscape. The slight haunching of the viaduct's beam adds an elegant touch, reducing its overall height while maintaining visual appeal.

Catenary poles seamlessly integrate into the design, further enhancing the overall aesthetic of the viaduct. Rounded edges ensure that no harsh shadows mar the structure, lending it a softer and more inviting appearance.

Functionality is also prioritized in the design. Low sound walls effectively mitigate the noise generated by the train wheels, ensuring a pleasant acoustic experience for passengers. Importantly, these sound walls are strategically positioned to avoid obstructing the views from the train. Passengers can enjoy uninterrupted panoramas of the surrounding landscape as they travel, as the low sound walls preserve the scenic vistas.




14 m
Low sound walls mitigate sound from wheel on rail
Soft shadow and optically thinner construction
9 m

PHASE II

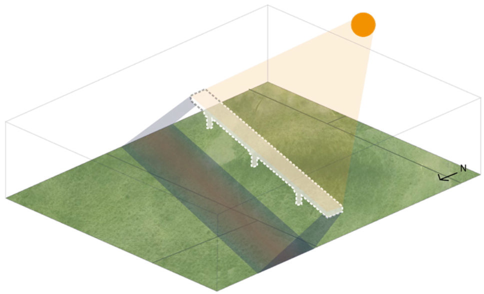
06.IN THE SHADOW

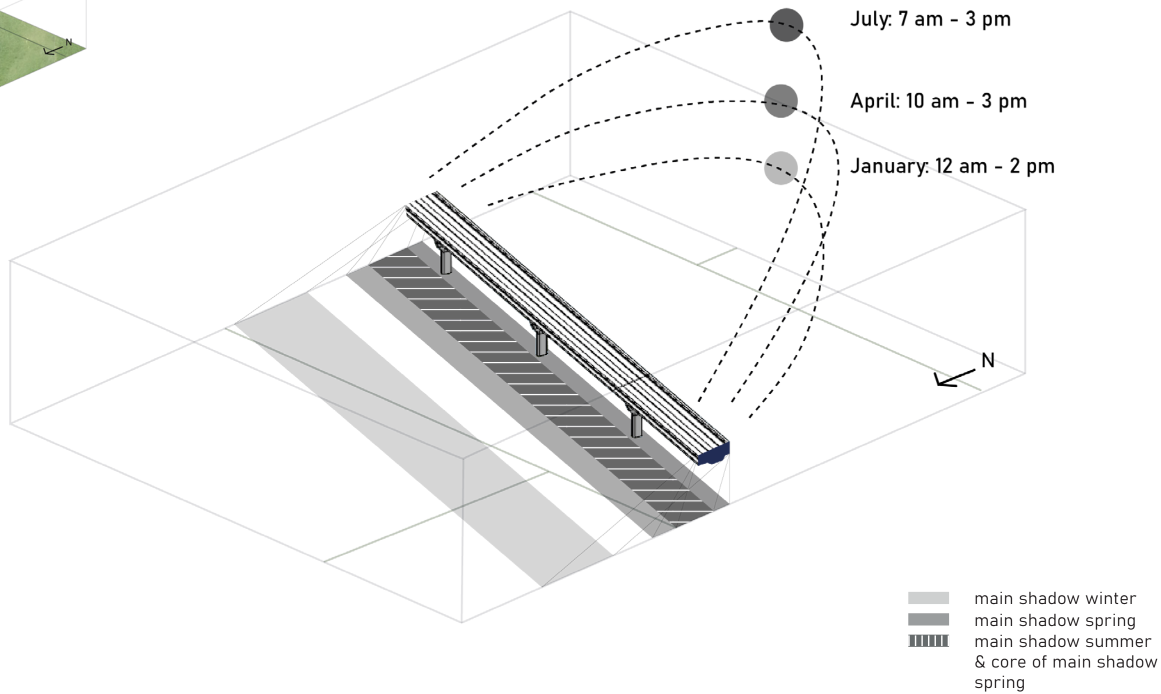
Shadow study

The limited presence of avenue planting on major roads in Flevoland serves a practical purpose: trees offer shade, which creates varying conditions for agricultural activities. Ensuring consistent sunlight exposure across farmland is crucial for reliable crop yields. Although the high-speed viaduct is elevated, its presence still affects the land and its functioning. Spanning the Flevopolder in a southwest-northeast direction, the viaduct casts a consistent shadow throughout the day. A shadow study was conducted to analyse the extent and location of the viaduct's shadow during different seasons (fig. 5.1): winter (January 1), spring (April 1), and summer (July 1). Given the significance of the flowering season in spring, reduced sunlight on specific areas of land can have a substantial impact.

On April 1 the sun rises at 7:15 and sets at 20:15 (KNMI, 2021), providing a total of 13 hours of sunlight. The study reveals that, on a sunny April 1, a 14-meter-wide strip on the north side of the viaduct experiences 6.5 hours of shade per day. The morning and evening shadows are further away from the viaduct due to the lower position of the sun. However, during the afternoon, when the sun is higher and should benefit the land the most, the same strip of land is consistently shaded. The edges of the 14-meter-wide strip receive more sunlight hours on average compared to the core zone, creating a gradient of sunlight (edges) and shade (core) within the shaded area.

The presence of the viaduct and its shadow strip raises concerns regarding the ability of affected farmers to achieve optimal harvests in the shaded areas. Given the functional nature of the Flevopolder landscape, a meaningful and practical approach is necessary to address this shadow strip and ensure its compatibility with agricultural practices.



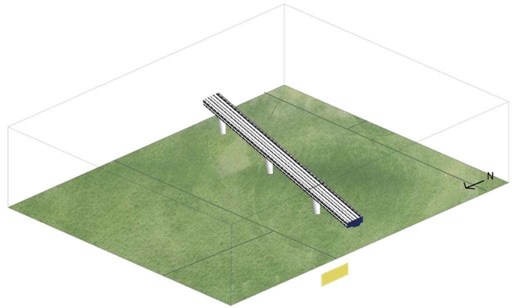


► 5.1 Diagram showingn the range of the drop shadow on the land created by the viaduct on three days in a year. Images: author

Alternatives shadow

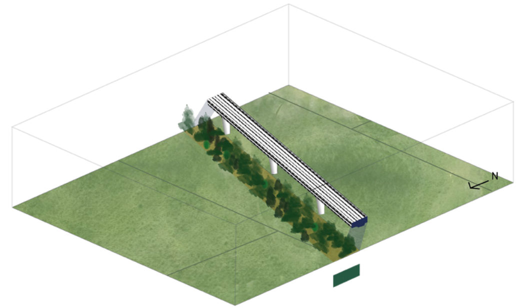
There are of course countless ways to use the shadow strip. The most logical ones, which can actually add something to the landscape, are given as shadow alternatives. Alternatives also include keeping the shadow zone open and letting the agricultural land continue. That way the land is poetically untouched. The other alternatives can be roughly divided into two groups: ecological and mobility purposes.

Each alternative has been given its own color. Those colors come back later to show which alternatives were applied where.



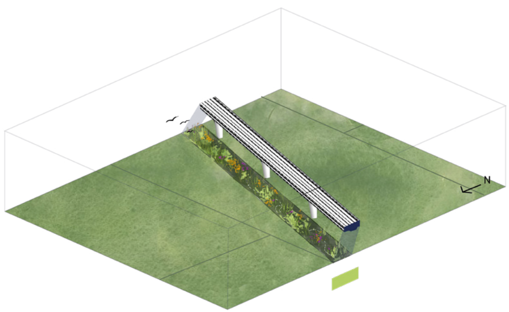
Not touching the land

Let the landscape continue completely under the viaduct, so that the train in no way forms a barrier in the land. By disconnecting the diagonal of the viaduct and the orthogonal system of the polder, there are two layers of landscape that poetically do not touch, but are linked.



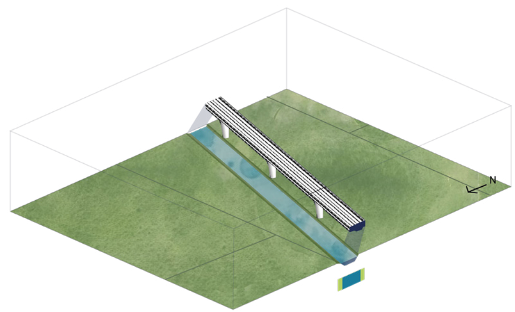
Forest strip

A robust use can be made of the shadow strip by planting and maintaining it as a forest strip. This is very suitable for the shade zone, as the forest plantings find their own way to sunlight by growing upward. A continuous forest strip is a convenient corridor for many different flora and fauna, as it provides protection for larger mammals. The high vegetation of the forest zone itself creates shade, which is a drawback to this alternative.



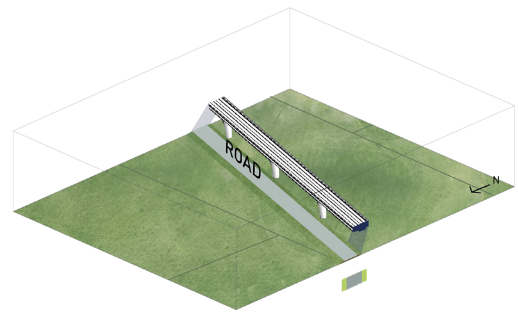
Forest vegetation

Planting the shade strip with low vegetation creates minimal additional shade. Forest undergrowth, which normally blooms in the shade of trees, is well suited for this. With a diversity of shade plants and herbs, the strip along the viaduct can provide shelter for small mammals and birds. At the edges of the strip, where there is more sun, more floral planting can be applied, which will also attract various insects.



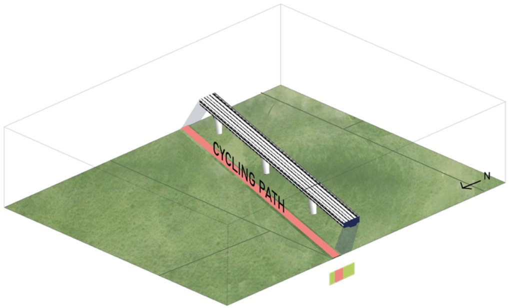
Wet zone

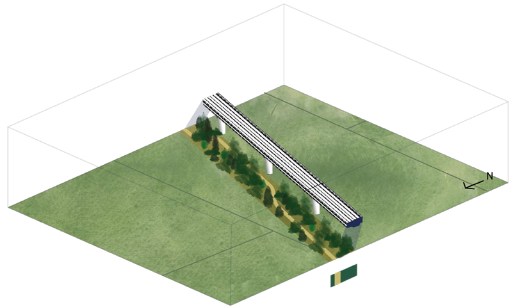
If the shade strip is further excavated, it can become a water passage through the polder. This can be a continuous line, connected to the existing water system, thus providing a route for various fish, aquatic animals and plants. Especially in combination with ecological banks, this alternative is of great value in Flevoland's nature network, as it would also provide shelter for small mammals.

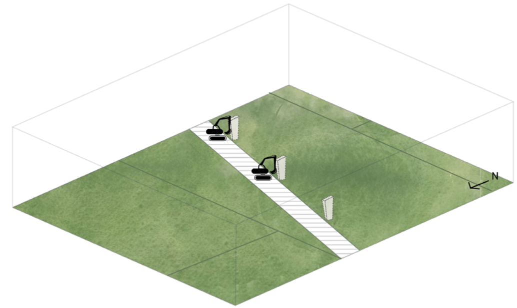


Motorway

Due to its width of 14 meters, the shaded area offers sufficient space to build a road of two lanes wide. However, due to the good access in the Flevopolder, especially for cars, it is doubtful that a road along the viaduct would really make a difference.







Bike path

Because the viaduct runs straight through the polder, giving a new perspective on the land, it may be very interesting from a recreational point of view to lay a bicycle path along (part of) the viaduct. The Flevopolder is primarily designed for motorized vehicles. For cyclists, therefore, distances can be very long. Providing a faster route through the polder may therefore be very welcome.

Footpath

It is obvious that if a road and a bicycle path are among the alternatives, a footpath can also be realized in the shadow zone. The footpath can of course be combined very well with the forest strip, for example, as shown in the figure.

Construction road

In order to build the viaduct, a construction road will be needed to move all the equipment in and out. The road will carry heavy vehicles, which will put considerable strain on the land. With the idea that the -in that phase future-shadow zone will have a different function than agricultural land, this strip can be used as a route during construction. The construction road can later function as another type of road, or the land will be used in an ecological way.

Some alternatives are not so interesting on their own, but can be very well combined with other alternatives. For example, the combinations of water and an ecological bank and footpath through the forest strip have already been mentioned. Also the bicycle path, due to the small space needed for the path, lends itself very well to be combined with ecological alternatives.

All these options are focused on giving a function to the landscape along the viaduct. These new uses can create opportunities in the landscape to make recreational, ecological or experiential improvements to the landscape. The next chapter explores what opportunities exist in the landscape and, through site-specific designs, shows, among other things, how some shadow alternatives can contribute to improving and enhancing the Flevopolder.

PHASE II

07.BOOSTING THE FLEVOPOLDER

Creating a cohesive network

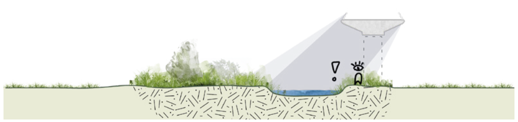
This chapter brings together key elements: the distinct characteristics of the Flevopolder, the organized energy layer, and the high-speed viaduct with its shadow zone. The aim was to harmonize these landscape layers, guided by the design principles of the Flevoland landscape itself. Factors like openness, orderly patterns, long lines, and functionality were crucial to maintain throughout the landscape design process.

Based on these principles, the design strategy outlined in chapter 3 was developed, including determining the height of the viaduct to ensure a continuous landscape underneath. However, certain shade variants within the ecological group did not align with these design goals, as illustrated in figure 7.1.

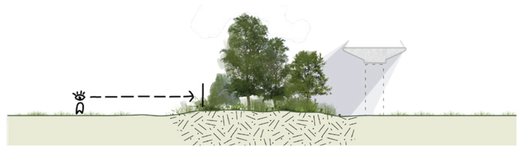
A water corridor in the shadow zone creates challenges, such as limiting access to fields for farmers and disrupting efficient agriculture - a significant concern in an area deeply rooted in agricultural practices.
Similarly, planting a forest strip along the entire viaduct would visually disrupt the openness of the Flevopolder landscape, which is highly valued.

On the other hand, incorporating low forest vegetation along the viaduct preserves openness and allows for well-designed passages on farmland. This approach, if implemented properly, can enhance biodiversity in the agricultural landscape.

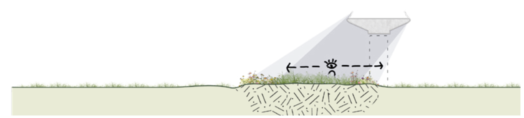
The Flevopolder, like many other regions in the Netherlands, has experienced a decline in biodiversity over the years, particularly affecting bird and insect populations. Insects play a crucial role in crop health, serving as pollinators and natural pest controllers. Therefore, enhancing biodiversity in agricultural landscapes can positively impact productivity and the overall appeal of the region. Some farmers in Flevoland have already adopted nature-friendly



1/ Wet & dry corridor: physical barrier



2/ Forest coridor: visual & physical barrier

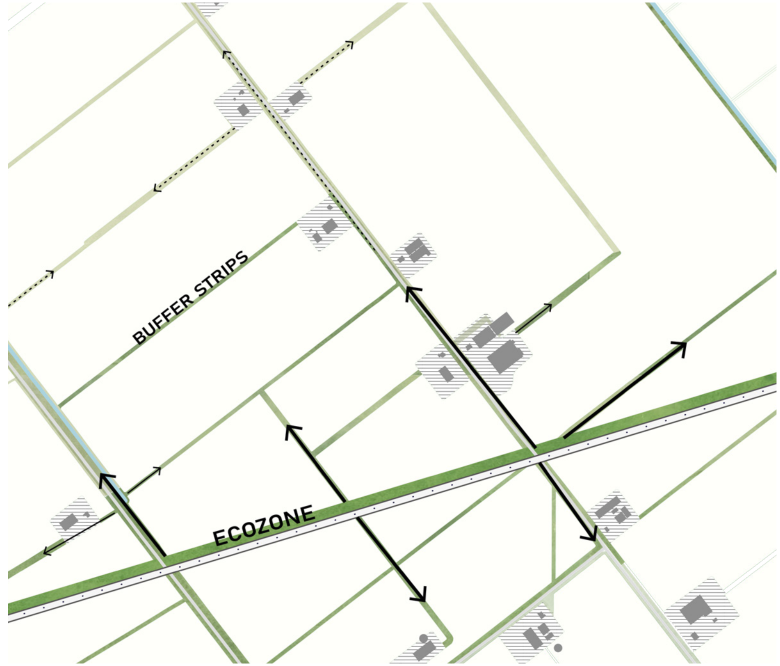


3/ Low (forest) vegetation corridor: preserves open landscape

▲ 7.1 The spatial characteristics of the landscape are influenced differently by three types of ecological shadow alternatives. Image:

practices, such as establishing field edges that support sustainability (fig. 7.3). This growing enthusiasm among Flevoland farmers to promote biodiversity is evident in an open letter by LTO Noord and the Flevolands Agrarisch Collectief, highlighting the importance of boosting insect populations and involving farmers in nature management to increase biodiversity in the region (Provincie Flevoland, 2021).

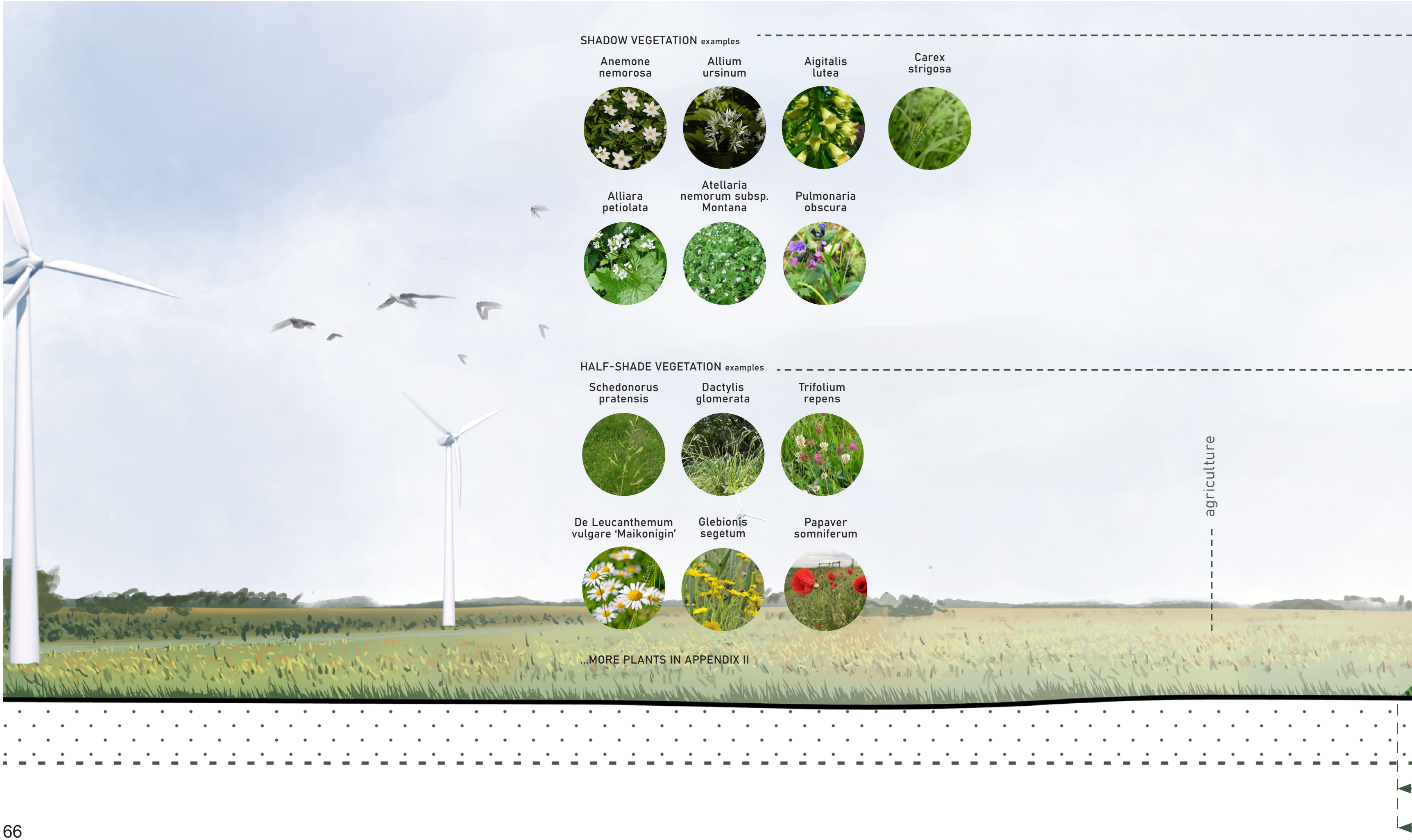
The shadow zone of the viaduct presents a significant opportunity to greatly enhance biodiversity in Flevoland. When farmers actively contribute to these efforts, a strong and cohesive network of ecological field edges can be created throughout the entire Flevopolder (fig. 7.2). A 14-meter wide ecological zone will replace intensive agriculture along the entire viaduct, with exceptions where necessary. This ecological strip will feature at least two passages per field to ensure minimal disruption to agricultural operations. In the core area, shade-tolerant plants will provide shelter for small mammals and birds, while the sunnier edges with more flowers attract butterflies, hoverflies, bees, and other pollinating insects. This sheltered zone will also support the presence of beetles, parasitic wasps, spiders, and other beneficial organisms that help control pest insects (Flevolands Agrarisch

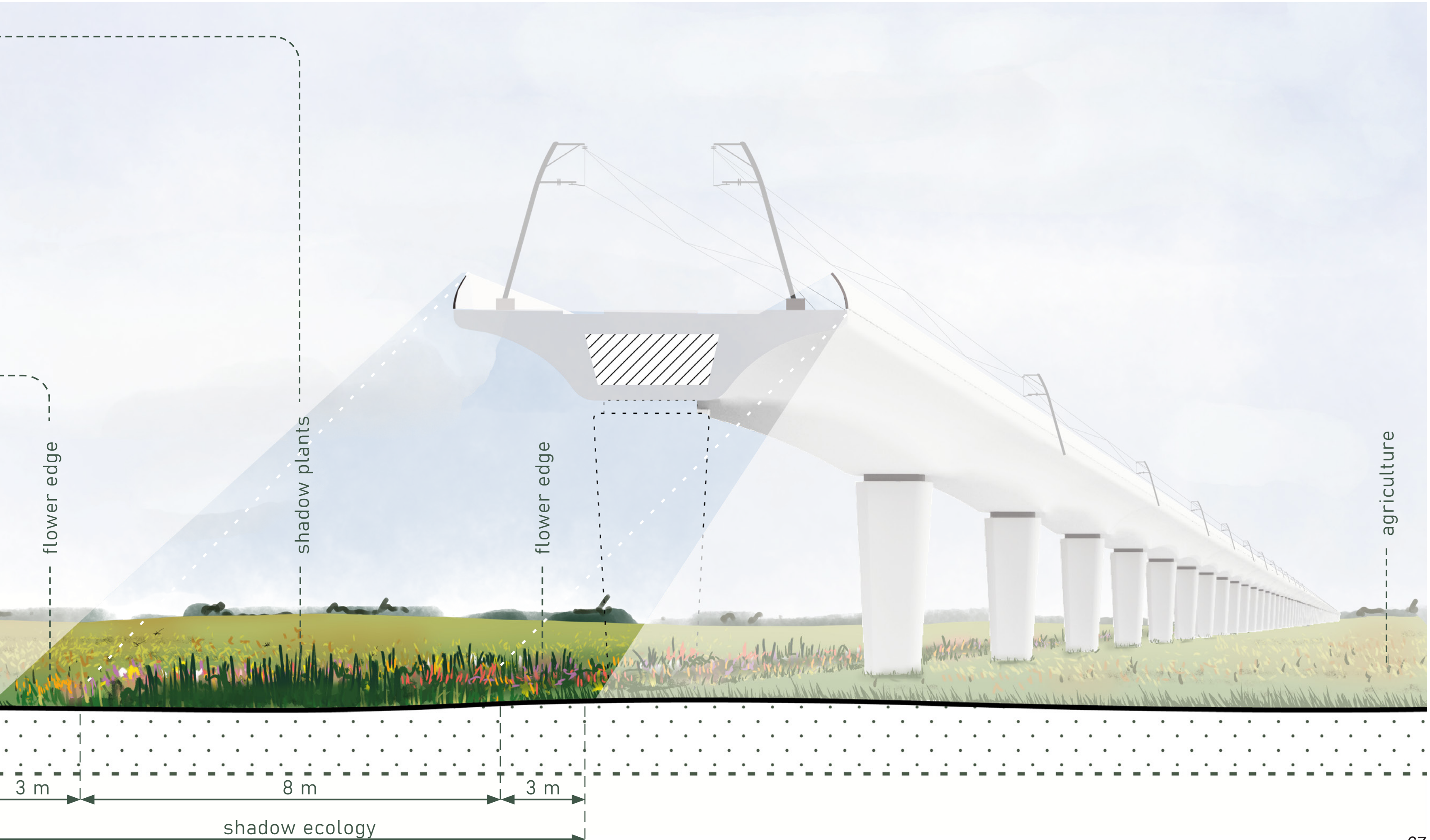


croplands
ecological buffer strips
buildings
farm yards
viaduct

► 7.2 Through collaboration with farmers, a robust and interconnected network of natural field edges can be established, originating from the ecological shade zone. Image: author

► 7.3 Flowers and herbs as buffer strips along the agricultural lands of Flevoland. Photo: Flevolands Agrarisch Collectief


SHADOW VEGETATION examples
Anemone nemorosa
Allium ursinum
Aigitalis lutea
Carex strigosa
Alliara petiolata
Atellaria nemorum subsp. Montana
Pulmonaria obscura
HALF-SHADE VEGETATION examples
Schedonorus pratensis
Dactylis glomerata
Trifolium repens
De Leucanthemum vulgare 'Maikonigin'
Glebionis segetum
Papaver somniferum
...MORE PLANTS IN APPENDIX II
agriculture


flower edge
shadow plants
flower edge
agriculture
3 m
8 m
3 m
shadow ecology

Masterplan

The ecological shadow zone of the viaduct creates a continuous low line across the landscape, except for specific areas where additional interventions are required to enhance landscape cohesion and serve nature better. These exceptions are outlined below and depicted in the master plan (fig. 7.4) The following four sub-areas deviate from the standard design and are discussed in detail in this chapter:

- I Reconnecting: Wildlife Corridor
- II Panoramic view from Biddinghuizen
- III The Cycling Experience
- IV Ode to the Knardijk

These design areas together with the continuous ecological zone complete this implementation design of the innovative high-speed train in the Flevoland landscape.

► 7.4 Masterplan showing ecological zone along the viaduct in the Flevopolder and four sub-areas. Image: author

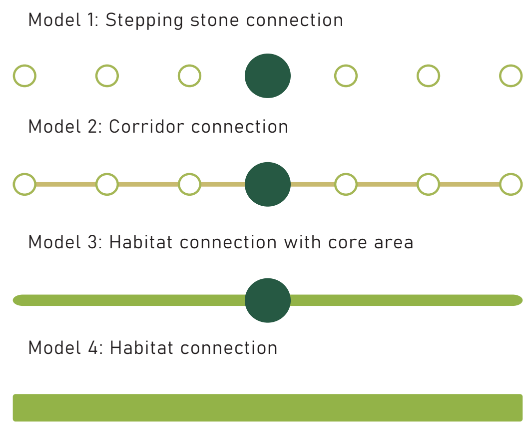

I
II
III
IV
0
5
15 km

The Flevoland Nature Network is an integral part of the broader Nature Network Netherlands (NNN), and its assessment plays a crucial role in exploring how the design of the viaduct landscape can contribute to the preservation and enhancement of nature in the province. The primary objective of the NNN is to safeguard and strengthen the natural networks by establishing effective connections between different habitats. These connections are vital for maintaining ecological balance and promoting biodiversity (Provincie Flevoland, 2023). However, one challenge facing the Flevoland Nature Network is the fragmentation of habitats caused by the absence of ecological connections between the key areas Het Spijk, the Greppelveld, and Reve-Abbert (fig. 7.6). A new corridor within the viaduct landscape can contribute to connecting these key areas.

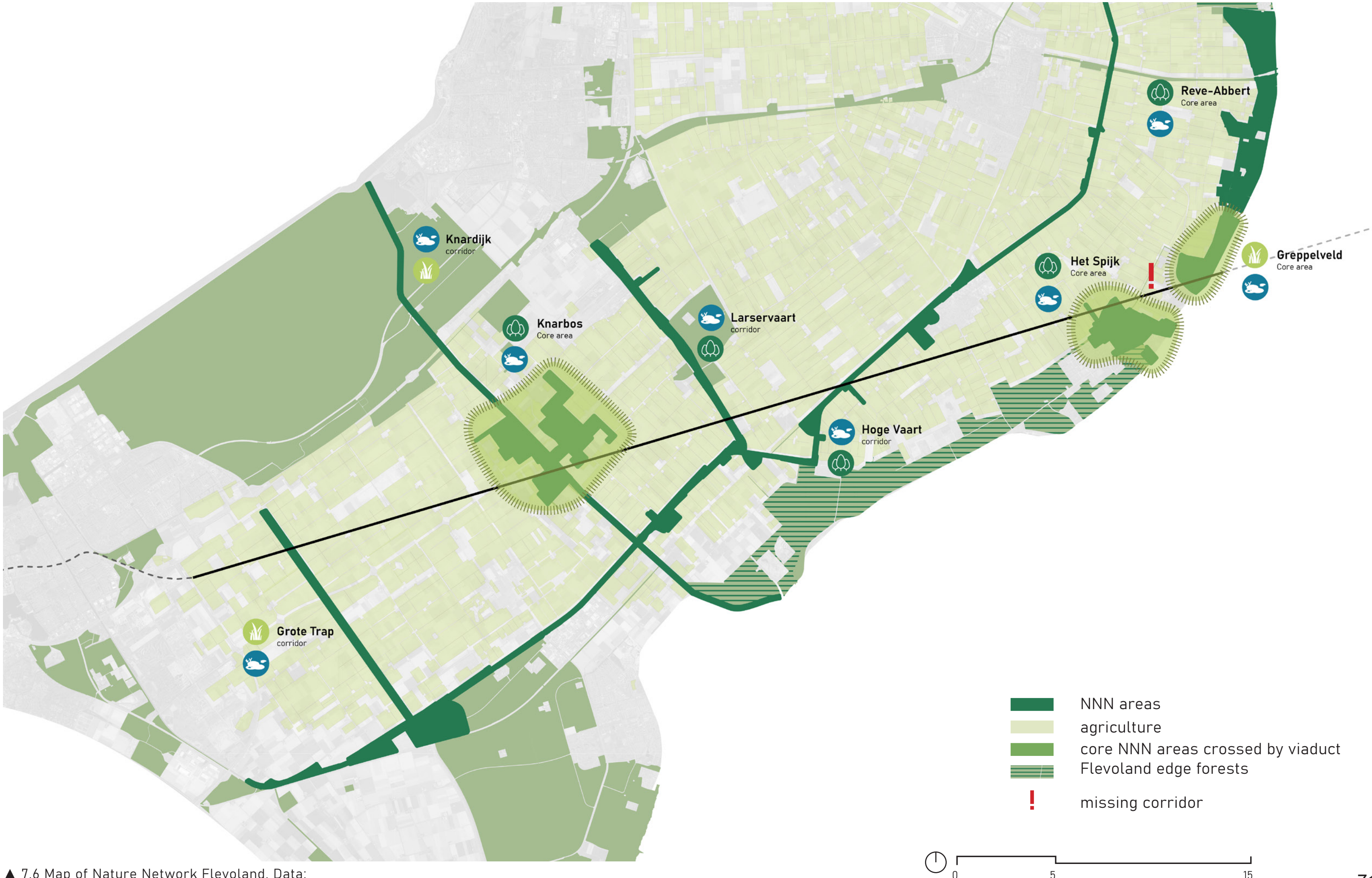
The corridor's primary target species is the pine marten, living in Het Spijk and Reve-Abbert. This mammal is listed as threatened on the Red List in the Netherlands due to its declining population (Zoogdiervereniging, n.d.). By focusing on the pine marten as the target animal for the corridor, we prioritize the conservation and sustainability of this specific species. With only 400-500 adults remaining in the country, providing a suitable habitat and facilitating its movement is crucial for its long-term survival. The corridor will be designed to meet the specific requirements outlined in the pine marten's ecoprofile (Appendix III), which includes factors such as the need for higher vegetation and safe crossing of barriers like highways (Broekmeyer & Steingröver, 2001).

The creation of an ecological corridor involves considering various models for its design. Four basic corridor models exist (fig. 7.5) (Broekmeyer & Steingröver, 2001):
1. Stepping Stone Connection: Suitable for species that move through the air, utilizing patches of suitable habitat (stepping stones) connected by key areas.
2. Corridor Connection: Incorporates stepping stones and key areas interconnected by a corridor, enabling movement across fragmented landscapes.
3. Habitat Connection with core area: Provides continuous habitat for species that require larger distances to cover.
4. Habitat Connection (Fish-Specific): Designed for fish species, focusing on creating suitable aquatic habitats and connections.

For the pine marten corridor, model 2 (Corridor Connection) is most suitable. However, it is important to note that the corridor's benefits extend beyond the pine marten. An effective ecological corridor design will create a favorable habitat and promote connectivity for other wildlife species as well (Broekmeyer & Steingröver, 2001). This inclusive approach ensures that the corridor serves as a vital ecological link for various fauna, facilitating their movement, dispersal, and access to suitable habitats.



▲ 7.5 The 4 models for ecoprofile connections with their elements. Image from Broekmeyer & Steingröver (2001) edited by author



▲ 7.6 Map of Nature Network Flevoland. Data: Provincie Flevoland (2023). Image: author

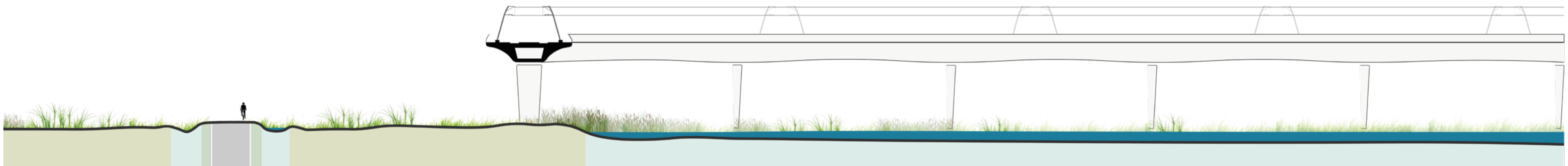
The integration of a forest strip as a shadow alternative along the viaduct offers a potential corridor solution for the pine marten. Within figure 7.7, this alternative, referred to as option 1, is depicted by a green arrow. Presently, the corridor aligns with the road edge leading to the forest strip on the north side of the Greppelveld. However, an alternative corridor route between Het Spijk and Reve-Abbert presents itself. From Het Spijk, a wide northeast-running ditch, known as the Ellertocht, connects to the waterway alongside the forest strip on the north side of the Greppelveld, named the Oosterwoldetocht. This alternative route not only facilitates the establishment of a pine marten corridor but also serves as a viable habitat for other species requiring wet or moister environments, such as dragonflies. Therefore, when appropriately implemented, route option 2 exhibits greater multifunctionality as an ecological corridor between Het Spijk and Reve-Abbert.

In addition to its ecological significance, route 2 offers enhanced landscape connectivity between the two nature reserves. By incorporating dense vegetation within the corridor to accommodate the pine marten, an easily discernible ecological line is established within the landscape, visible from a distance. The introduction of a diagonal line of high vegetation across the straight-lined polder, however, presents a potential challenge in terms of visual clutter, something which is tried to mitigate. Conversely, a forest strip adhering to the principles of the polder landscape entails a lesser risk of visual clutter. This advantage holds particular relevance in the eastern section of the Flevopolder, where edge forests are densely concentrated. Consequently, the forest strip along route 2 forms a logical and harmonious landscape connection within this area (fig. 7.7).

Within this design area, the Flevoland Nature Network experiences an enhancement through the establishment of a new corridor, suitable for the pine marten and other (water-loving) flora and fauna. To ensure the preservation of the landscape's tranquility and clarity (fig. 7.9), no additional landscape interventions are conducted within the shadow zone of the viaduct, thereby maintaining its designation as farmland.

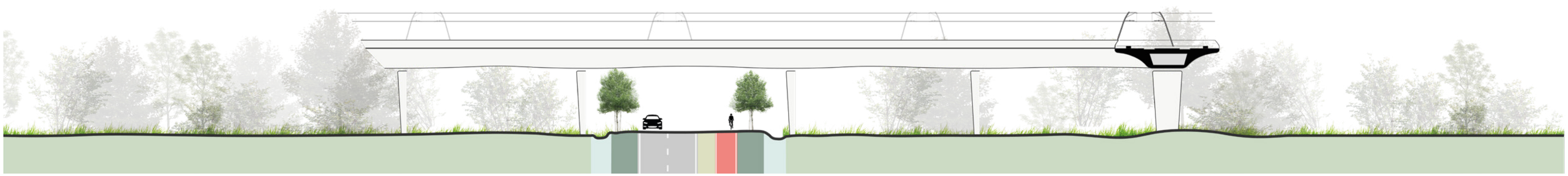
► 7.7 Optional routes for an ecological corridor between NNN areas Het Spijk and Reve-Abbert. Image: author


Reve-Abbert
Oosterwoldetocht
Greppelveld
2
Ellertocht
1
Elburg
Drontermeer
Het Spijk
pine marten habitat
wet meadow
ditch
0
100
300
700 m



SECTION A

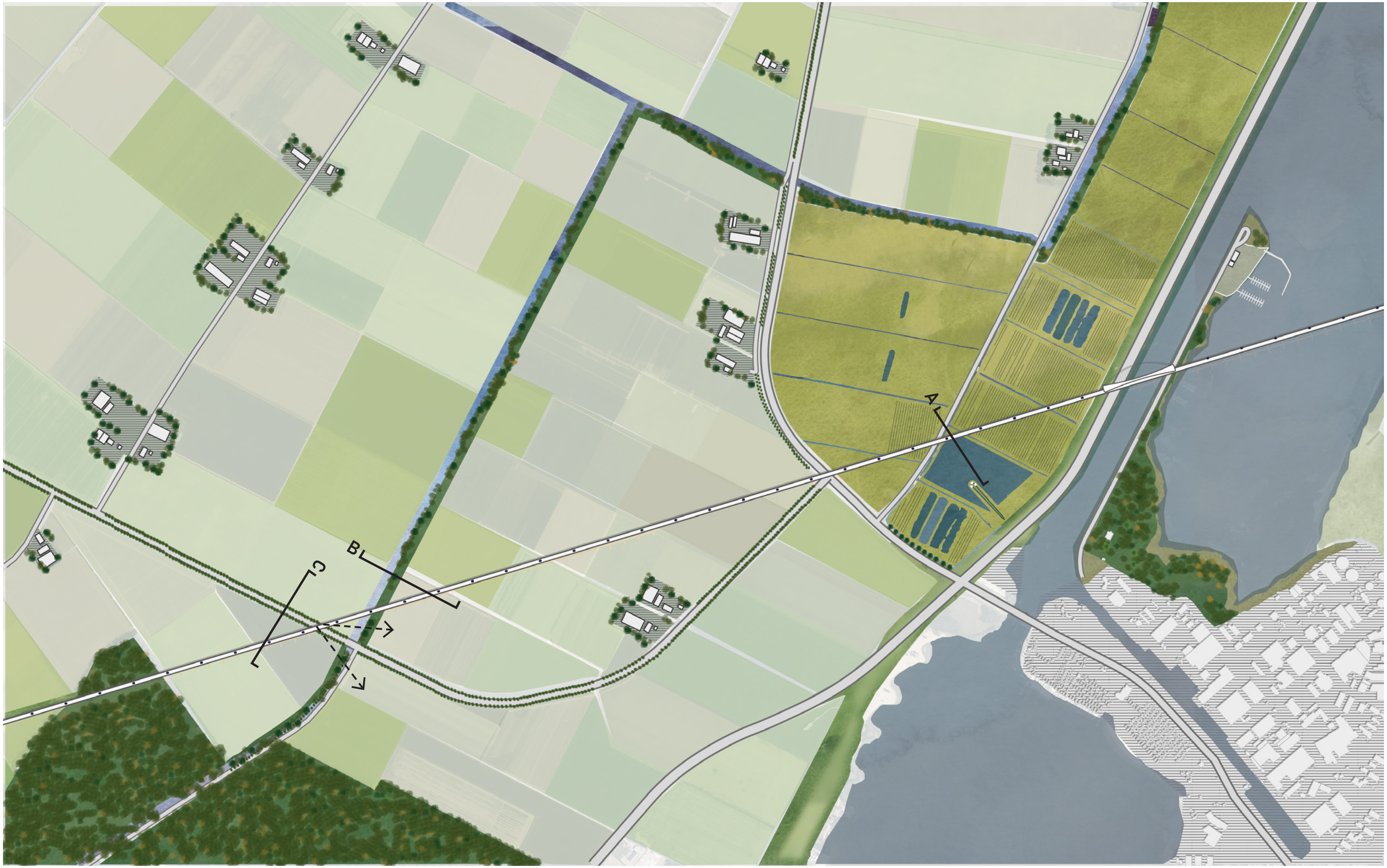
SECTION B



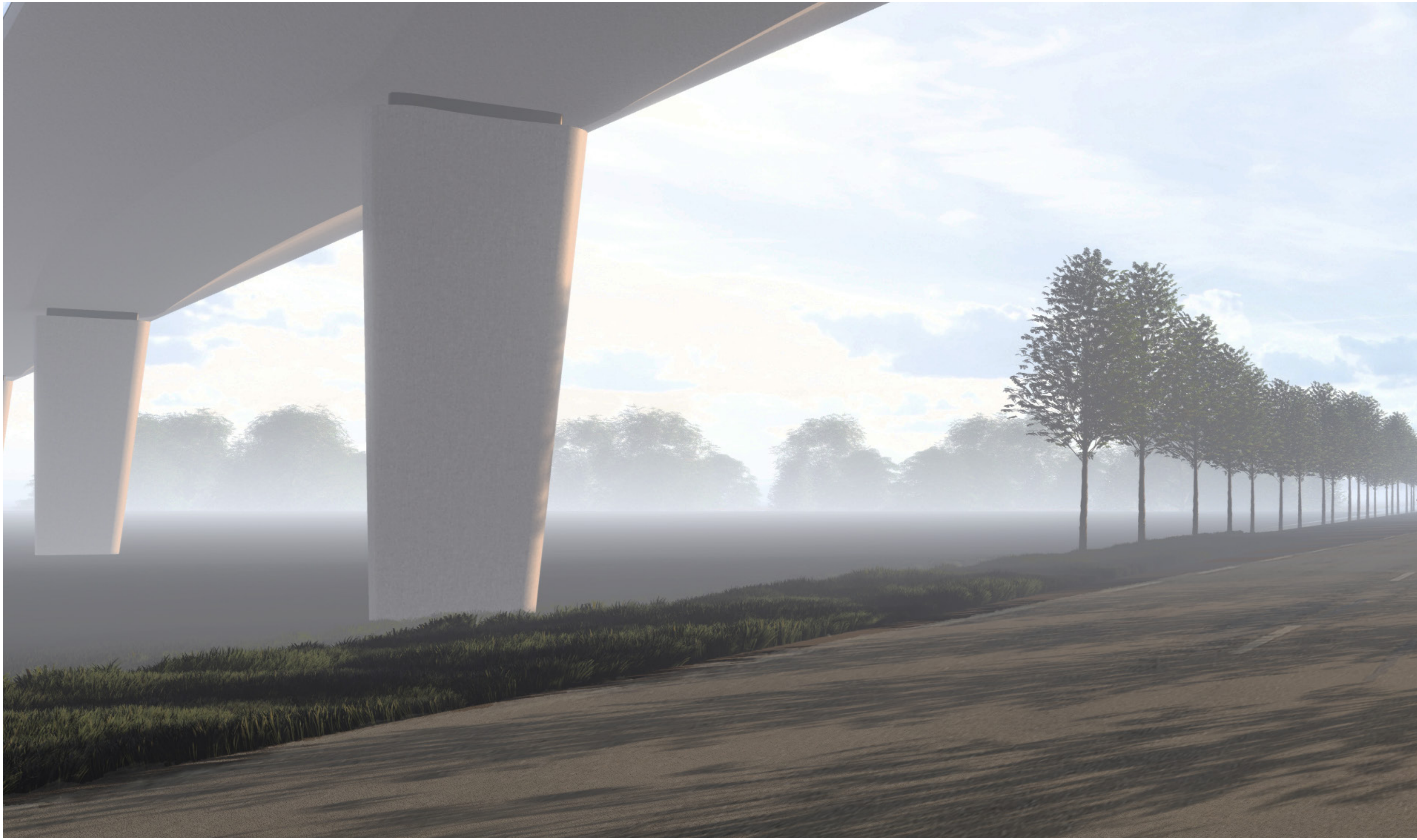
SECTION C

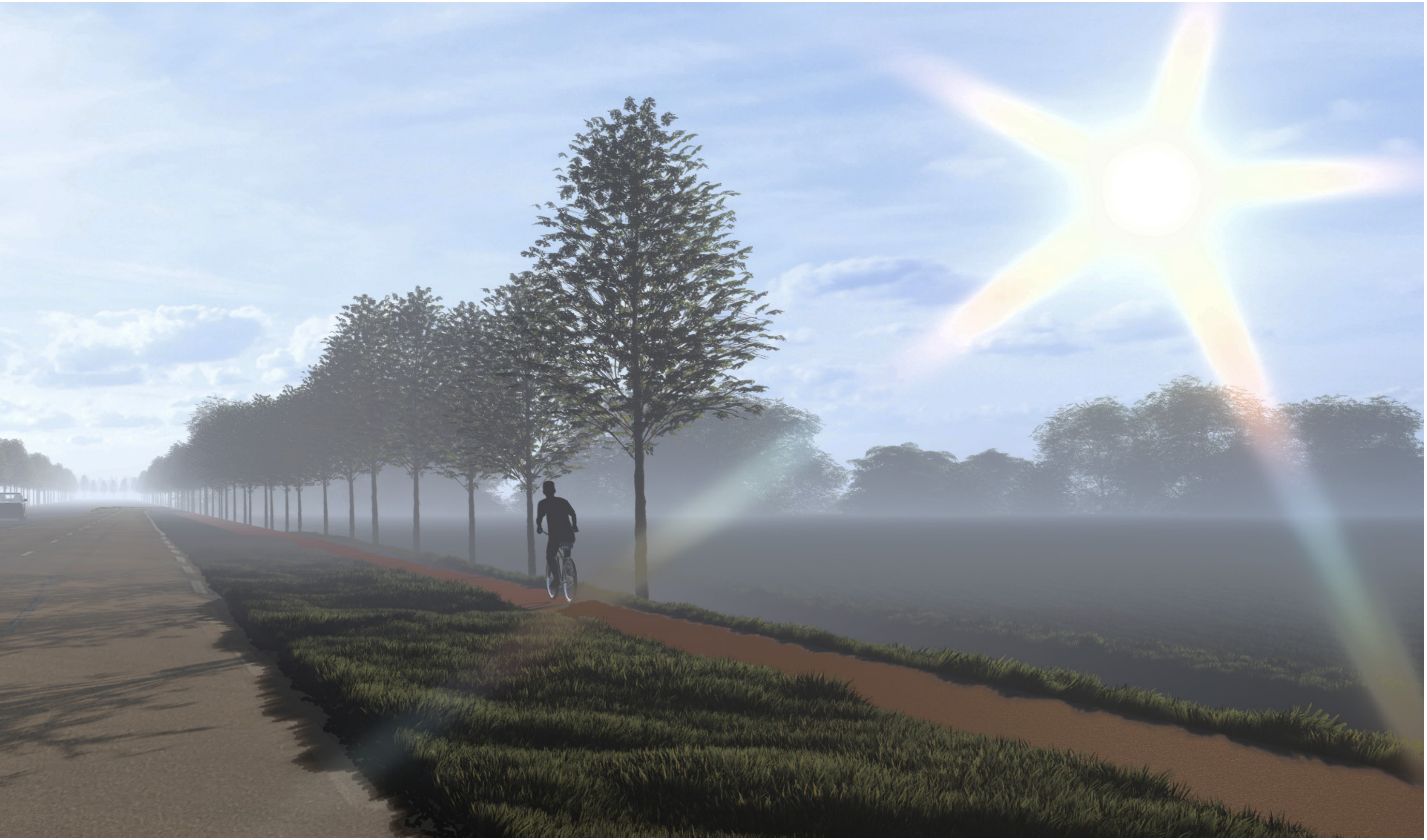
wet meadow
agricultural land
ditch & pond
forest vegetation
road
bike path

0 3 10 m



▲ 7.8 Masterplan ecological corridor between Het Spijk and Reve-Abbert.
The viaduct is crossing different types of landscapes. Image: author





▲ 7.9 View from under the viaduct on a foggy morning, with the ecological zone in the background. Image: author

II \ PANORAMIC VIEW FROM BIDDINGHUIZEN

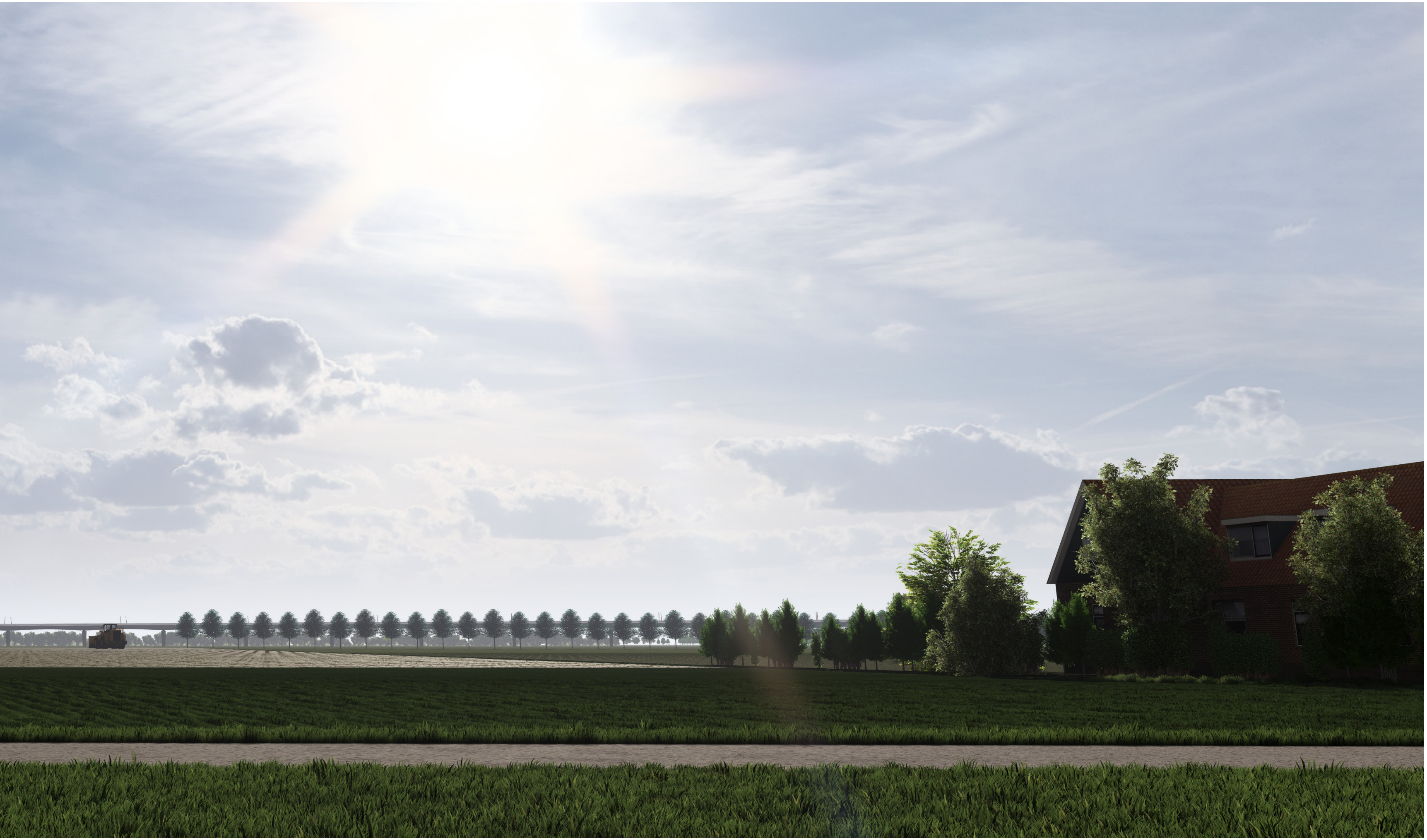
From the village of Biddinghuizen, in the middle of the Flevopolder, there will be an open view of the high-speed viaduct (fig. 7.10). Although most homes are turned inward, more and more new homes are being built on the border of Biddinghuizen overlooking the open polder landscape. The train viaduct will completely change the view of the Flevopolder. Without any other landscape changes, the viaduct will claim all the attention and be very dominant in the view. In this design intervention, a more varied view was sought, where the polder, turbine landscape and high-speed viaduct combine to make a scenic view. Through the subtle addition of a row of poplars (30 trees in total), an exciting, layered view is created, with agriculture and the viaduct as the main characters. As the train approaches the village, it disappears behind the trees in the foreground (fig. 7.12). The new row of trees is an extension of the Alikruiktocht (fig. 7.11), forming a continuous landscape line, which is taken up by wind turbines further on.

▲ 7.10 View from the eastside of Biddinghuizen on the open agricultural landscape. Image: Google Street View (2023), edited by author

► 7.11 Masterplan of Biddinghuizen area. The high-speed train is passing Biddinghuizen. When coming closer to the village, poplar trees provide shelter. Image: author

SECTION D

Biddinghuizen
Alikruiktocht
Poplar trees
D
0
100
300



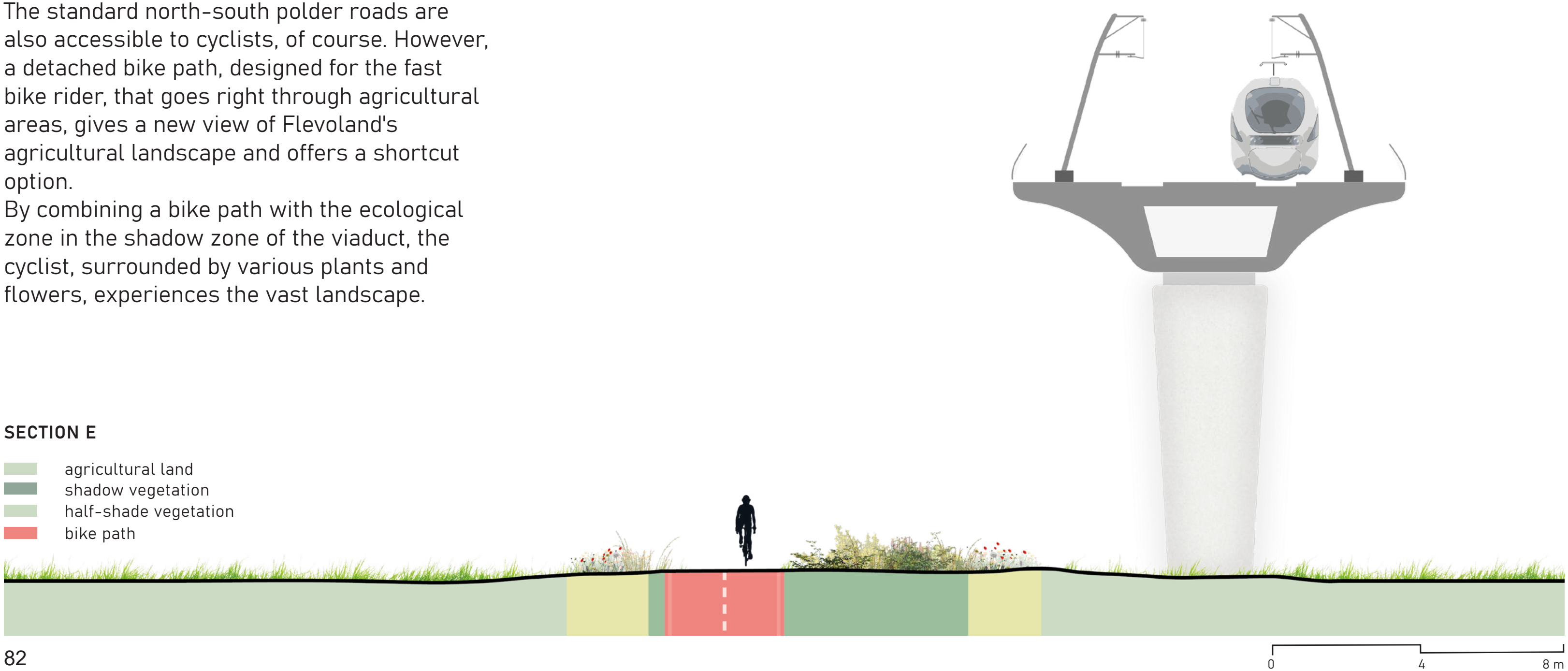
▲ 7.12 The panoramic view from Biddinghuizen. Image: author

III \ THE CYCLING EXPERIENCE

Centrally in Flevoland, the Larservaart forest and the Knardijk with the Knarbos both form attractive recreational areas for cyclists (Appendix IV). A new bicycle path along the viaduct can connect the recreational routes of these areas, creating a special bicycle tour through the heart of the Flevopolder (fig. 7.13). The standard north-south polder roads are also accessible to cyclists, of course. However, a detached bike path, designed for the fast bike rider, that goes right through agricultural areas, gives a new view of Flevoland's agricultural landscape and offers a shortcut option.
By combining a bike path with the ecological zone in the shadow zone of the viaduct, the cyclist, surrounded by various plants and flowers, experiences the vast landscape.

Where the bike path crosses farm roads, the concrete road for agricultural vehicles continues and the bike path is interrupted. This keeps the bicycle path as clean as possible, and clarifies the right of way for farmers.

SECTION E



▲ 7.13 Map showing the cycling path along the viauct in the shadow zone. The new path is connected to existing routes. Image: author

▲ 7.14 The new cycling route opens up new perspectives on the polder, guided by the high-speed line. Image: author

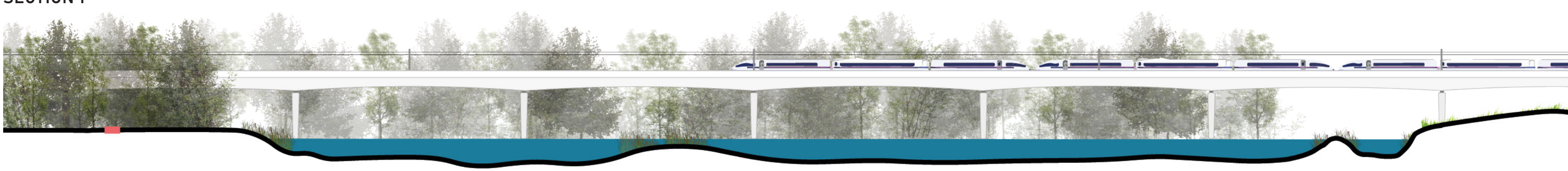
IV \ ODE TO THE KNARDIJK

The Knardijk holds a unique position as both a division and connector between Eastern and Southern Flevoland. Initially constructed as a sea dike during the reclamation of Eastern Flevoland (fig. 7.16), its purpose evolved to that of a sleeper dike as the entirety of Flevoland became dry. This dike offers an uninterrupted view towards the east and west (fig. 7.17), adding to its spatial significance.

In light of the Knardijk's rich history and distinctive spatial experience, particular attention will be given to enhancing its prominence. The view of the Knardijk will be intentionally opened up, emphasizing its unique features. On the southern side, the pond will be expanded significantly, integrating it into the train passenger experience and highlighting the contrasting elements of the dike's height and the surrounding low-lying landscape.

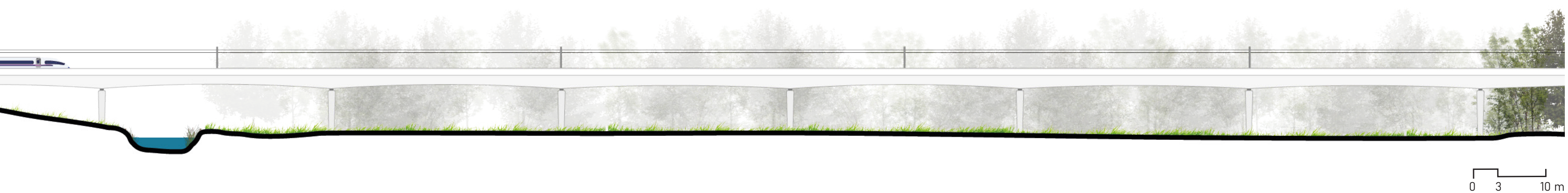
On the northern side, the Knarbos forest will provide an opening as the train passes, allowing a visual connection with the dike. Agricultural land will extend beneath the viaduct, eliminating the presence of an ecologically shaded zone. However, the shape of the Knarbos forest facilitates a detour that connects the ecological shadow zones on the western and eastern sides, enriching the overall ecological connectivity of the area.

SECTION F



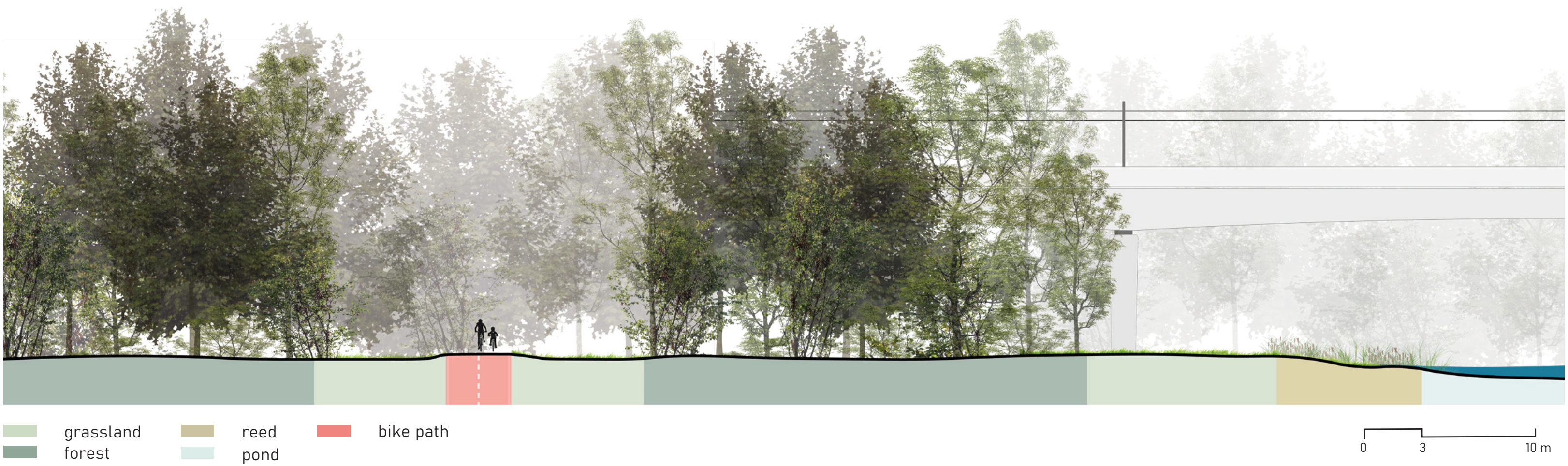
▲ 7.16 A line bus on the Knardike, when it was a primary dike protecting Eastern Flevoland. Photo: Potuyt (1956)

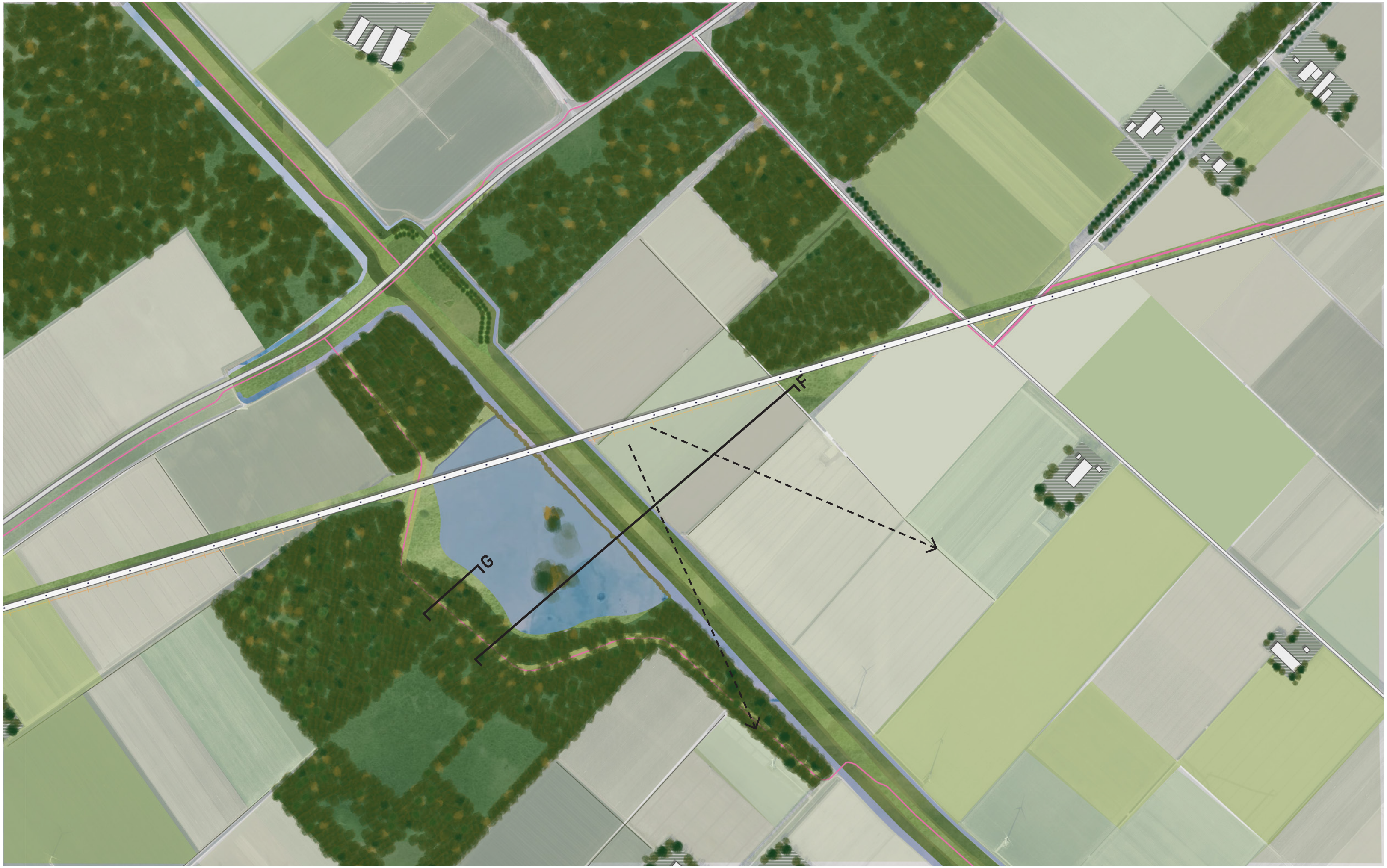
▲ 7.17 The Knardijk today: a green connector providing a long open view. Photo: author



The Knardijk features a dedicated route for cyclists and pedestrians, which has been thoughtfully realigned to accommodate the expanded water reservoir. This redesign offers a varied and engaging experience, allowing visitors to enjoy the open dike and the dense forested areas. The new pathways seamlessly connect with existing routes, ensuring continuity and accessibility. The enhanced cycling path provides an enriched journey along the Knardijk, allowing individuals to appreciate the contrasting landscapes and panoramic views of the open dike and dense woodland. This integration of pathways enhances the connection between visitors and the diverse environments found along the Knardijk.

SECTION G





▲ 7.15 Where the high-speed viaduct crosses the Knardijk, the land is opened up to create an open view on this historical dike. Image: author

08.CONCLUSION & REFLECTION

Conclusion

This research consists of two research phases, which together answer the main question of the design research: How can an innovative high-speed railroad between Amsterdam and Zwolle be superior to the Lelyline and how can this be implemented with collateral benefits through landscape architectural interventions respecting the Dutch cultural landscape?

Phase one studied the best alignment for the innovative high-speed railroad between Amsterdam and Zwolle. By connecting the alignment to the main stations Amsterdam South and Zwolle station, a significantly larger reach is achieved than the Lelyline. By also connecting the new alignment to Almere central station, the new track contributes to healthy urban growth and attractive urban sprawl in Almere.
Between Amsterdam and Almere, the high-speed train and an IJmeer subway connection can cross the IJmeer together.
Between Almere and Zwolle, the alignment crosses the Flevopolder in one straight line towards Zwolle, where it connects to the existing train network. The complete preferred alignment between Amsterdam South - Almere - Zwolle has an expected travel time of 22 minutes, which is one-third of the current travel time between Amsterdam and Zwolle.

The preferred alignment has as its largest implementation area the Flevopolder. This modern polder has an exceptional cultural landscape due to its openness, strong grid, focus on functionality and the prominent wind turbines. Because the train alignment crosses the polder diagonally and the viaduct will rise fiercely above the flat landscape, the impact of the train on the polder is significant and very special. Therefore, the focus of the landscape implementation in phase two of the study is fully on the functional land of the Flevopolder.

"No variation for the sake of variation" was the guiding principle for the designers of the Flevopolder, and it is also the guiding principle for the viaduct's integration. The viaduct lies naked in the landscape and is therefore highly visible. There is a strong relationship between the open Flevopolder the newly designed wind turbine landscape and the viaduct through use of color, functionality and clarity.

The shadow that the viaduct places on agriculture negatively affects crops. Through ecological strips or a road along the viaduct, a new function can be given to the shadow strip. In order to preserve the openness of the landscape, give biodiversity a huge boost and fit within the functional culture of Flevoland, the entire shadow strip along the viaduct, with some minor exceptions, forms an ecological zone with low shade planting and flowery edges. By means of a new bicycle route, enhancing the vista in the polder and improving the Nature Network Flevoland with an ecological corridor, valuable collateral benefits will be realized.

The alignment design resulting from this design research is thus significantly faster than the current Amsterdam - Zwolle connection with a wider reach, allowing more people to benefit from the alternative Lelyline. Collateral benefits of the alignment of the viaduct and the Flevoland landscape are de-cluttering, nature enhancement and new landscape experiences.

Reflection

The Flowscapes lab Innovative Infrastructure Implementation was a new lab in the Flowscapes studio this graduation year. Although designing at large scale, small scale and through all scales is the guiding principle in the Landscape Architecture master track, designing with Innovative Infrastructures was a completely new challenge for me.

Throughout the year, I worked closely with my groupmates. At the beginning, we helped each other build basic knowledge about the Dutch train system, a completely new topic for all three of us. Together we devised, tried and tested research methods several times, until we found a very effective and innovative sketching method to investigate alignments. Although graduation from our master track is basically an individual task, it was of great value to my process and end result to work with a group on the same goal. Because even though everyone worked on their own project, the starting point of this study on the implementation of innovative rail infrastructure is above all to show the potentials of high-speed train infrastructures in the Dutch landscape.

In this thesis it has been discussed, that train landscapes of today are often abandoned, closed and disrupted single-use landscapes. Places you'd rather not visit. On the one hand we want to enjoy our layered cultural landscape, and on the other hand we destroy it by constructing systems that fragment the landscape and give places a poor image. By means of the landscape design for the high-speed line through the Flevopolder, it has been demonstrated which opportunities are released when an innovative train infrastructure is designed with full attention to the layered landscape. Predicting the effect of the new train viaduct on other systems in the landscape has led to the potential for creating collateral benefits. In my opinion, that is what Flowscapes is: the relationships between different systems and the way systems affect each other across scales. Thus, the Flowscapes Workshops have repeatedly given me new insights within my project.

In principle, the intent of our graduation lab was that we would work closely with graduation students from Civil Engineering. However, close collaboration did not get off the ground due to various study agendas. As a small group, we did get to ask our civil questions at a number of meetings with civil engineering teachers. In retrospect, I doubt that civil engineering student involvement was a miss for this landscape architectural design research. Yes, a rail expert would have been of great value during the alignment research and expertise is also needed from other disciplines to properly realize a project like this. However, now I had the opportunity to make choices based on landscape improvement. That perspective is not common in design processes of large infrastructures. With my groupmates, this research has given me a new perspective on how infrastructural landscapes can be better designed in the valuable landscape.

I experienced difficulty during the second phase of this research, the landscape implementation, because of the large scale of the project. The alignment came through all kinds of different landscapes and each landscape needed a lot of attention to really respectfully implement the viaduct. There is just not enough time in a graduation year to do a complete study and design for each landscape type. That is why I started focusing on the Flevoland landscape. I feel that this focus has allowed me to get much more out of this study. My design and design elements, such as the shadow alternatives, are very specific to the Flevopolder and cannot be applied one-to-one in any other place. However, I do believe that this research method can be applied to other landscapes.

As long as trains have a negative image and prefer to be hidden away in our landscape, nothing is going to change their disruptive effect on landscapes; the Lelyline is an example of this. Designing a train track on columns required courage, something for which I also have to thank my supervisor, as well as a prominent role in the design process of infrastructures for the landscape architect. The last one in particular is something that could cause change in the professional field. The landscape architect is an indispensable connector between all the disciplines needed to build a new railroad track; after all, with the landscape architectural perspective, a rich cultural landscape and a sustainable landscape can very well be brought together and lead to improvements of the landscape.

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APPENDIX I

Table 1

	Engineering Feasability					Impact residents	Impact on nature	Land use and urban development			Transport efficiency
	Total length track	Total length bridges	Curved track	Slope	Crossing key infrastructures	Residents within 300 m	Efficiency	Impact on urban development	Impact on industrial areas	Compatibility with agricultural land	Travel time
	km	*m*	*% of total track*	*consistent, irregular,*	*open question*	*low, medium, high*	*highly effective, effective,*	*low, medium, high*	*low, medium, high*	*compatible, partially*	*minutes*
Veluwe.A	58	6600	19%	challenging	high complexity	high	insignificant	medium	low	incompatible	17
Veluwe.B	56,3	3400	23%	challenging	high complexity	high	insignificant	high	low	incompatible	18
Corridors.A	56,4	370	33%	consistent	low complexity	low	insignificant	high	high	partially compatible	17
Corridors.B	60	370	52%	consistent	medium complexity	high	insignificant	low	high	compatible	20
Corridors.C	61,5	370	44%	consistent	medium complexity	high	insignificant	low	high	compatible	21
Straight lines.A	56,5	1300	13%	irregular	high complexity	high	effective	medium	low	incompatible	15
Straight lines.B	54,2	420	18%	consistent	low complexity	medium	highly effective	low	low	incompatible	14

Table 2

STANDARDISED	*standardised value = (value - min_value) / (max_value - min_value)*											
	Engineering Feasability 20 pt					**Impact residents** 15 pt	**Impact on nature** 30 pt		**Land use and urban development** 10 pt			**Transport efficiency** 25 pt
	Total length track	Total length bridges	Curved track	Slope	Crossing key infrastructures	Residents within 300 m	Disturbance to natural areas	Efficiency possible wildlife corridor	Impact on urban development	Impact on industrial areas	Compatibility with agricultural land	Travel time
	km	*m*	*% of total track*	*consistent (0), irregular (0,5), challenging (1)*	*low complexity (0), medium complexity (0,5), high complexity (1)*	*low (0), medium (0,5), high (1)*	*low (0), medium (0,5), high (1)*	*highly effective (0), effective (0,5), insignificant (1)*	*low (0), medium (0,5), high (1)*	*low (0), medium (0,5), high (1)*	*compatible (0), partially compatible (0,5), incompatible (1)*	*minutes*
Veluwe.A	0,52	1,00	0,16	1	1	1	1	1	0,5	0	1	0,43
Veluwe.B	0,14	0,49	0,26	1	1	1	1	1	1	0	1	0,57
Corridors.A	0,30	0,00	0,53	0	0	0	0,5	1	1	1	0,5	0,43
Corridors.B	0,79	0,00	1,00	0	0,5	1	0,5	1	0	1	0	0,86
Corridors.C	1,00	0,00	0,80	0	0,5	1	1	1	0	1	0	1,00
Straight lines.A	0,32	0,15	0,00	0,5	1	1	1	0,5	0,5	0	1	0,14
Straight lines.B	0,00	0,01	0,13	0	0	0,5	0,5	0	0	0	1	0,00
weight	2	4	7	2	5	15	25	5	6	2	2	25

Table 3

STANDARDISED, INVERTED (ANS - 1), SCORED																					
	Engineering Feasability		total: 20 pt				**Impact residents**		total: 15 p	**Impact on nature**		total: 30 p	**Land use and urban development**			total: 10 pt		**Transport efficiency**	total: 25 pt		
	Total length	Total length	Curved track	Slope	Crossing key infrastructures		Residents within 300 m			Disturbance to natural areas	Efficiency possible wildlife corridor		Impact urban development	Impact industrial areas	Compatibility with agricultural land			Travel time			
	km	*m*	*% of total track*	*consistent, irregular, challenging*	*low complexity, medium complexity, high complexity*	*score*	*low, medium, high*		*score*	*low, medium, high*	*highly effective, effective, insignificant*	*score*	*low, medium, high*	*low, medium, high*	*compatible, partially compatible, incompatible*		*score*	*minutes*	*score*		**TOTAL SCORE (out of 100)**
Veluwe.A	1,0	0,0	5,9	0	0,0	7	0,0		0	0,0	0,0	0	3	2	0		5	14	14		26
Veluwe.B	1,7	2,1	5,2	0	0,0	9	0,0		0	0,0	0,0	0	0	2	0		2	11	11		22
Corridors.A	1,4	4,0	3,3	2	5,0	16	15,0		15	12,5	0,0	13	0	0	1		1	14	14		58
Corridors.B	0,4	4,0	0,0	2	2,5	9	0,0		0	12,5	0,0	13	6	0	2		8	4	4		33
Corridors.C	0,0	4,0	1,4	2	2,5	10	0,0		0	0,0	0,0	0	6	0	2		8	0	0		18
Straight lines.A	1,4	3,4	7,0	1	0,0	13	0,0		0	0,0	2,5	3	3	2	0		5	21	21		42
Straight lines.B	2,0	4,0	6,1	2	5,0	19	7,5		8	12,5	5,0	18	6	2	0		8	25	25		77
weight	2	4	7	2	5		15			25	5		6	2	2			25			

The results of the multicriteria analysis conducted to assess alignments between Almere Central station and Zwolle station are presented in this section. Table 1 displays the parameters and assigned values for each alignment. Table 2 shows the standardized values for each alignment. Table 3 presents the standardized values multiplied by the weighting factors. Therefore, Table 3 provides the final results of the multicriteria analysis.

APPENDIX II

The plant list provided below showcases plants that are all suitable for the ecological shadow zone along the viaduct. These plants thrive in a shaded climate, clay soil, and maintain a relatively low height, ensuring the preservation of the open character of the polder (Flora van Nederland, 2023).

euphorbia aygdaloides
arum
allium paradoxum
arctostaphylos uva-ursi
poa chaixii
cystoperis fragilis
muscari latifolium
stachys sylvatica
anemone nemorosa
mercurialis perennis
veronica montana
milium effusum
stellaria nemorum
myosotis sylvatica
galium sylvaticum

lysimachia nemorum
carex sylvatica
dryopteris dilatata
epipactis helleborine sussp. Helleborine
campanula latifolia
actaea spicatia
maianthmum bifolium
allium ursinum
moehringia trinervia
blechnum spicant
melica uniflora
geum urbanum
digitalis lutea
lamiastrum galeobdolon subsp. Galeobdolon
pulmonaria officinalis
lamium maculatum
polypodium vulgaren
polygonatum multiflorum
ficaria verna
parietaria officinalis
circaea lutetiana
scilla forbesii
luzula sylvatica
corydalis cava

humulus lupulus
lunaria annua
thlictrum minus
orobanche hederae
geum rivale
osmunda regalis
galium odoratum
alliara petiolata
mespilus germanica
stellaria nemorum subsp. Montana
pulmonaria obscura
myrrhis odorata
luzula pilosa
senecio ovatus
carex strigosa
helleborus foetidus
chrysosplenium alternifolium
corydalis solida
doronicum plantagineum
oxalis acetosella
luzula luzuloides
helleborus viridis

APPENDIX III

The ecological profile of the pine marten illustrates the most favorable conditions for establishing a natural corridor aimed at supporting the habitat requirements of the pine marten as the target species (Broekmeyer & Steingröver, 2001).

European pine marten corridor

Corridor description

Type: dry

Minimum width: 100 m

Maximum interruption: 100 m

Layout of corridor: forest, thicket, wooded bank. Mosaic landscape of bushes and thickets. 50 % higher vegetation, the rest may consist of moist grassland.

APPENDIX IV

The cycling network of Flevoland is presented in this figure, showcasing the newly introduced diagonal bicycle path in the heart of Flevoland. This path offers a novel route for traversing the central area of Flevoland. Map from OpenstreetMap, edited by author.