Berenschot

OUTLOOK II

Crossroads: perspectives for hyperloop development in the Netherlands

Hyperloop Development Program

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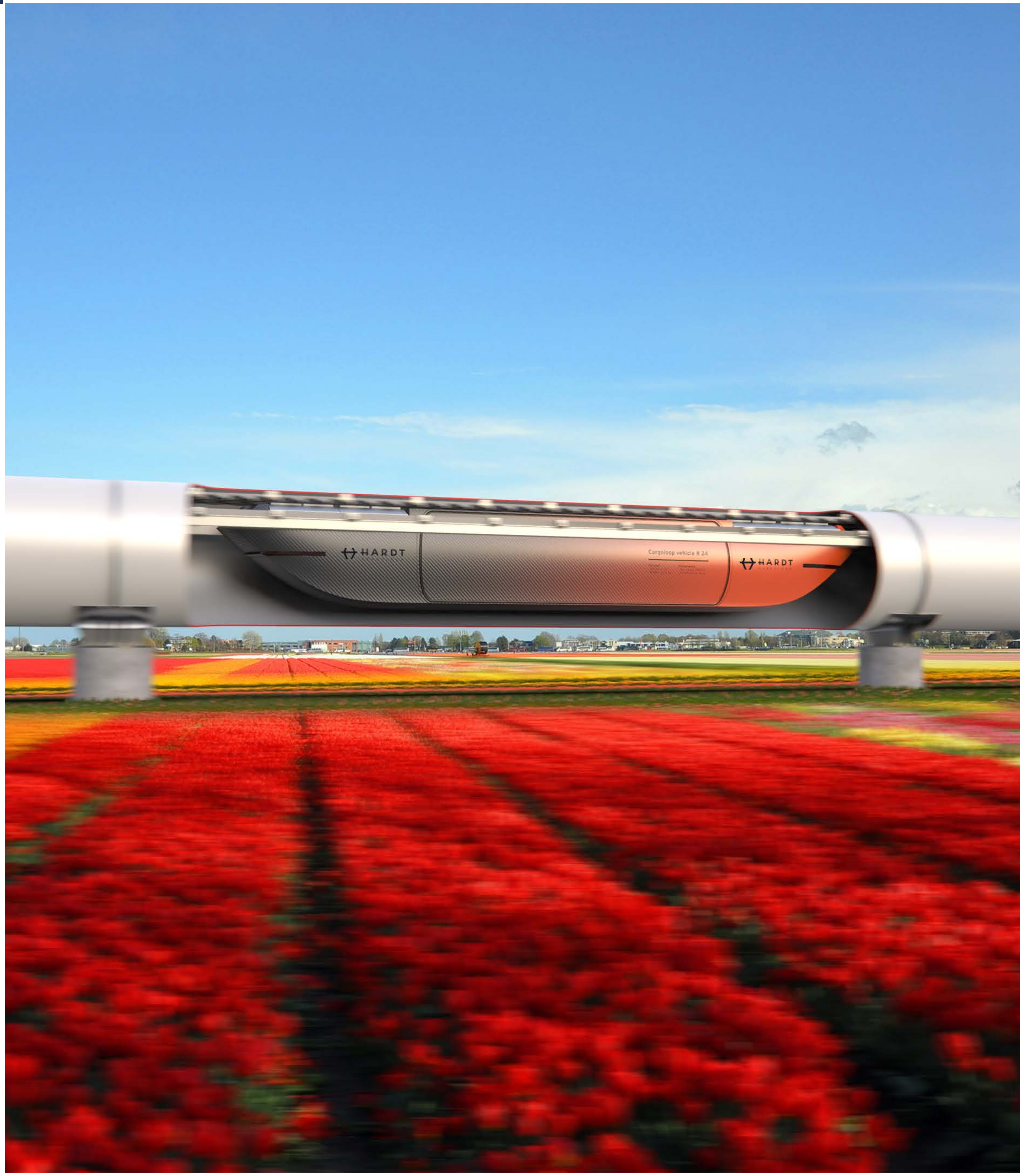


CHAPTER 1.

Introduction

What is a hyperloop?

A hyperloop is a mode of transport using magnetically levitating vehicles ('pods') inside a low pressure tube. In the mobility industry, its target market is situated between that of rail and aviation, where it is able to connect destinations at speeds of up to 1000 km/h. It is a combination of existing technologies from different industries, resulting in a mobility concept with energy consumption comparable to that of high speed rail (HSR), while its catchment area is comparable to that of continental commercial flights. The infrastructure consists of a network of tubes – either on land or underground – facilitating transport of passengers and cargo. The system is completely electrified, working with electromagnetic fields for levitation and propulsion, and with electric vacuum pumps.

1.1 Hyperloop Development Program

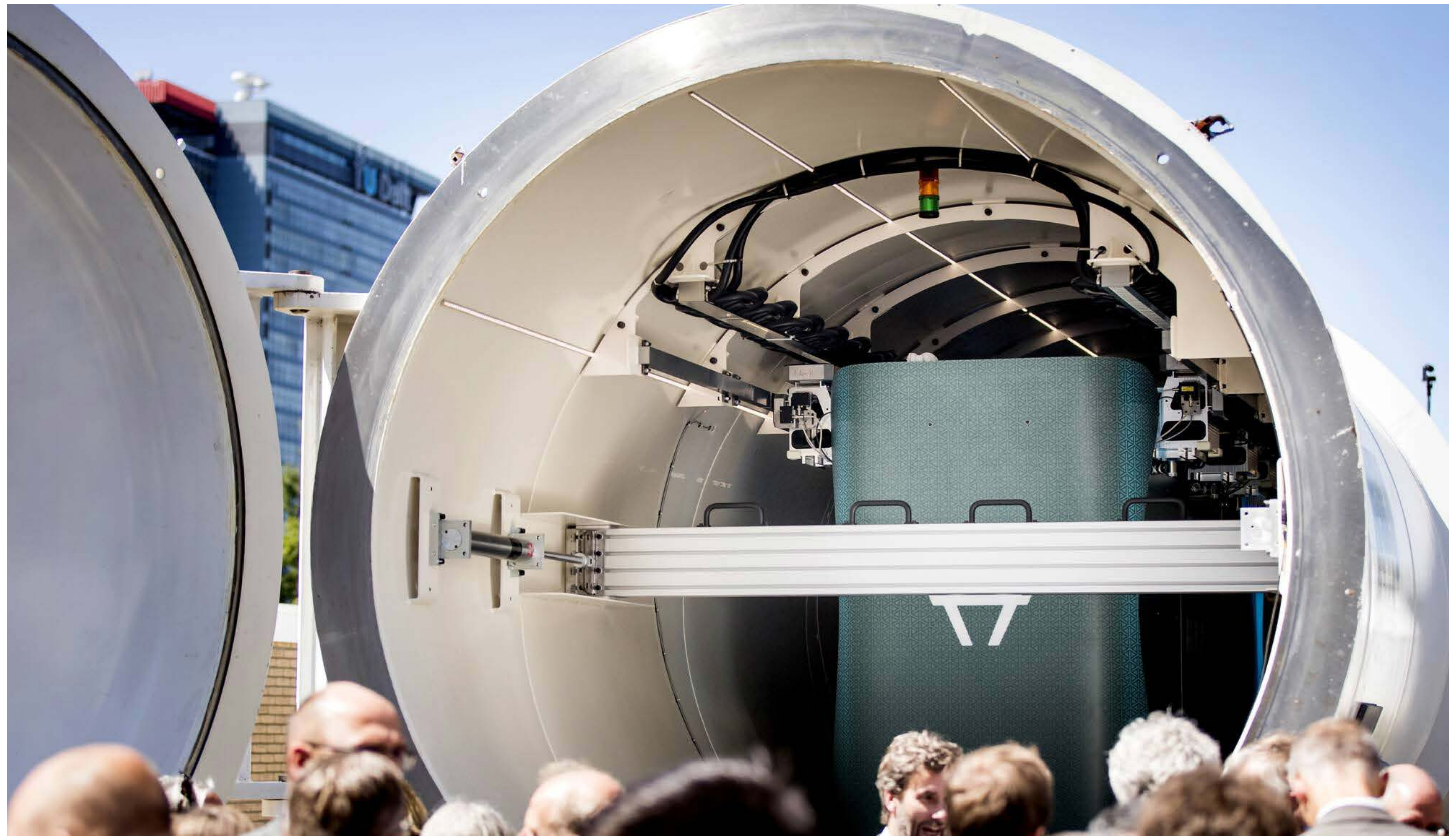
About two years ago, various organizations in the Netherlands joined forces in the Hyperloop Development Program (HDP) to develop hyperloop as a safe, sustainable and commercially viable mode of high-speed transportation and to bring it to commercialization. The HDP is a public-private partnership between the Dutch Ministry of Economic Affairs and Climate Policy and the Ministry of Infrastructure and Water Management, the Province of Groningen and a group of industrial parties, knowledge and research institutes and other private entities. It aims to achieve the following goals:

1. To prove the feasibility of hyperloop as a safe and sustainable low-emission method of transport for people and goods.
2. To test and demonstrate in the European Hyperloop Center Groningen that the technology works as intended (designed) and can be operated safely.
3. To identify the future prospects and opportunities for industry and stakeholders clustered around the hyperloop ecosystem.

As part of the third goal, to identify future prospects and opportunities, a hyperloop roadmap for the Netherlands will be developed. This roadmap is a country-specific development agenda for hyperloop in the Dutch context. It will be preceded and substantiated by two outlooks, of which this is the second.

1.2 Recap of the first outlook

The first outlook was published in late 2021 and aimed to inform and inspire. It focused on the role of national and regional authorities and other key stakeholders, on the potential for a hyperloop network in the Netherlands and Europe, and on the opportunities for HDP to contribute to realizing such a network. By combining various sources into one distinct story about hyperloop technology and the high-potential Dutch routes and key stakeholders for achieving the hyperloop ambitions, the first outlook provided an overview of the context in which Dutch hyperloop initiatives have to come to fruition.



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1.3 Method and objectives of this second outlook

In this second outlook, we explore concrete opportunities for strengthening collaboration within the HDP and preparing for the potential next steps. To this end, we conducted interviews with various partners in the HDP network to gain valuable insights into what it will take for a hyperloop to be realized in the Dutch and European context. In the interviews we explored the partners' perspective on the development of hyperloop and on collaboration, both in general and within the HDP. We also explored their vision on the long-term goals for hyperloop and their own positions within that future.

The various partners interviewed reflect the diversity of the stakeholders whose involvement could be required for realizing a hyperloop in the Dutch and European landscape. They included interviewees from public partners such as the Ministry of Economic Affairs and Climate Policy and the Ministry of Infrastructure and Water Management, representing national government, and the City of Rotterdam and Province of Noord-Holland, representing local and regional government, as well as interviewees representing private partners such as NS (Dutch Railways), Royal BAM Group, Tata Steel and Vattenfall. A complete list of interviewees is included in Appendix I.

The second part of this outlook (section 3) comprises a series of case studies of projects that faced barriers similar to those faced by hyperloop, specifically the Transrapid technology & Shanghai Maglev Train, the SCMaglev technology & Chuo Shinkansen, Concorde, the Vegas Loop and the Sydney Metro. These are all examples of disruptive technologies in similarly large infrastructure or technology projects related to transport. Details of how each project developed are provided, along with a brief overview of the main barriers faced, how these barriers were dealt with, the successes and failures of the projects and the lessons that can be learned for a possible hyperloop project (or pilot project).

CHAPTER 2.

Partners' perspectives on hyperloop development

2.1 Introduction

If hyperloop is to have a viable future in the Netherlands and elsewhere in Europe, the HDP needs to develop a vision about the technology's role as a mobility solution while also recognizing the value of key hyperloop components as technological innovations. That is the main message derived from our conversations with the interviewees. This also requires a strong HDP partner network and specific goal-setting. In this section, we discuss these insights and their implications in more detail.

2.2 Two routes for hyperloop development

Through our conversations with the interviewees, we identified two ways to approach hyperloop in the Netherlands:

- as a mobility solution;
- as a technological innovation (or series of such innovations).

As well as gaining momentum as a sustainable solution for our desire to travel long distances quickly, hyperloop has created a technological platform where different components of the technology can be developed. These different components, both in their own right and combined, could also be valuable for other applications and markets. But although the above two approaches are closely connected and can exist alongside each other, they assume different starting points and result in different development routes.

2.2.1 Developing the mobility solution

Hyperloop technology can potentially resolve various mobility problems we encounter in the Netherlands and elsewhere in the EU. But if we are to develop a hyperloop network, decisions guiding the HDP in a specific direction will have to be taken. These decisions concern the hyperloop's geographical focus and the steps needing to be taken to move towards a mobility solution.

With regard to the geographical focus of hyperloop development, we have identified three aspects that act as a framework:

First, any hyperloop line created in the Netherlands has to be, or become, part of a European system. This requires cross-border cooperation and a certain level of standardization. A significant step towards more cross-border cooperation between the Netherlands and Germany was taken in September 2022, when the Ministry of Science and Culture of Lower Saxony, the Province of Groningen and HDP signed a Letter of Intent expressing their intention to promote research and development in various ways. While initial collaboration will focus on the cross-border region of north-west Germany and the northern Netherlands, the institutions support the creation of an open innovation environment for hyperloop research and development. This may also contribute to the standardization that is needed if hyperloop is to provide a solution for cross-border mobility.

Second, a hyperloop connection eastwards and/or north-eastwards would seem most logical, also with a view to future demand for mobility, given that the Netherlands is already well connected to the UK and the south via a high-speed rail link (albeit with low capacity), whereas no such connection currently exists to the east or north. This further emphasizes the importance of the above Letter of Intent: when working on establishing connections to the east and north, the Netherlands can build on the existing cooperation with German partners.

Third, a hyperloop involving the Netherlands would need to be linked to Schiphol airport as this is one of the main European airports and an important hub for connecting Europe to the rest of the world. Hyperloop could be a substitute modality for passengers flying into Schiphol and travelling to and from other European destinations. It could replace short- and medium-distance flights and so free up capacity at the airport. This would make it possible to maintain Schiphol's role as a global hub, while at the same time reducing the number of flights and the environmental impact.

As well as the need for geographical focus, it is important to define the steps to be taken to develop a mobility solution. Some interviewees saw freight transport as an interesting starting point: this would mean relatively lower start-up costs and enable hyperloop to gain the support and trust of the general public and various stakeholders. However, most interviewees stated that hyperloop as a mobility solution should focus on passenger transport. Those in favour of focusing on passenger transport pointed out that use cases for short routes were more viable for passengers than for freight. Either way, however, a hyperloop requires infrastructure. And that means a test track first has to be developed. This would also help to gain support and trust, while testing the technology in a controlled environment.

With regard to hyperloop infrastructure, starting with the above geographical focus might be too ambitious. Instead, various interviewees pointed out that a more local infrastructure could be an attractive proposition, especially where there is demand for mobility. They see hyperloop as a potential solution for urban mobility, not least because, over the coming decade, population growth and urbanization are expected to increase stress on Dutch cities and metropolitan regions elsewhere. As a result, existing public transport systems may become overburdened and, therefore, less attractive to commuters. A hyperloop is a way to provide transport at relatively high speeds, with capacity-enhancing turnaround times. By interlinking existing urban transport systems, a hyperloop can provide extra capacity where needed, with a connection between Eindhoven city and Eindhoven airport being given as an example of a potentially attractive hyperloop route in an urban Dutch context.

2.2.2 *Developing the technology*

As well as its value as a possible infrastructure solution, hyperloop is in itself also a unique technological innovation. Both the EU in general and the Netherlands in particular have a longstanding history of investing in knowledge, innovation, research and development. By providing subsidies and removing regulatory burdens, the Dutch government and EU institutions have sought to promote innovation and further development of our knowledge-based economies. The Dutch government, for example, recently allocated €20 billion to the National Growth Fund for 2021-2025 aimed at investments contributing to knowledge development, physical infrastructure, research, development and innovation. This makes the Dutch and European context very suitable for investing in the development of hyperloop technology.

An advantage of the technological innovation route is that it underlines the intrinsic value of hyperloop technology. Even if the hyperloop concept does not produce a concrete solution for mobility, its further development may lead to innovative spin-off technologies, such as low-carbon building materials, new installation techniques, communications and control systems, electric propulsion systems, lightweight fire-proof materials, manufacturing and assembly robotics, logistics automation and optimized production processes. All these innovations will be valuable for the construction, mobility and logistics industries, while also boosting the development of hyperloop technology. This should reduce the risks and barriers associated with investments by mitigating the all-or-nothing scenario that results from seeing hyperloop technology solely as a mobility solution.

2.3 HDP partner network

A strong HDP partner network is vital, regardless of whether hyperloop is developed as a mobility solution or as a technological innovation. Currently, the HDP comprises a stable network of twenty partners. We asked them whether they thought this network needed to be expanded and, if so, in what way. Our interviews identified two ways to expand the partner network:

- Approaching partnership within the HDP network with a start-up mindset. This means expanding the network by adding several small partners so as to ensure that the HDP does not become dependent on one bigger partner;
- Focusing on including larger partners with more knowledge, expertise and funds to contribute to realizing a hyperloop. This is especially important when transitioning from a hyperloop test location to a fully-fledged mobility solution.

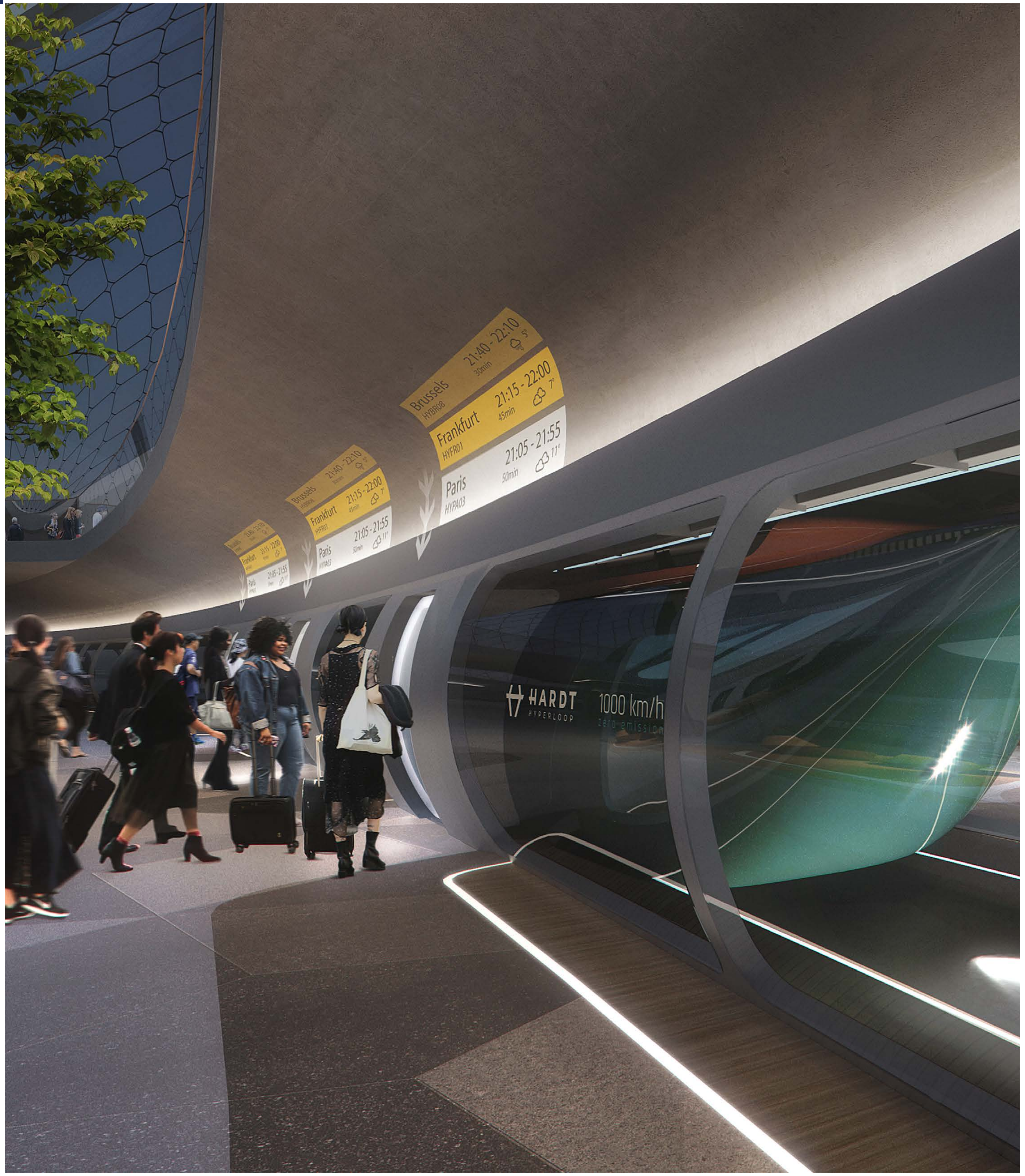
In both situations it is important to keep all partners closely involved so as to be able to use each other’s network and knowledge. One of the suggestions was to put more emphasis on public relations to ensure the HDP sends a unified message to the world. This, in turn, could also result in a more committed and stronger partner network.

2.4 Future of hyperloop

Looking towards the future of hyperloop, the technology provider Hardt has developed a timeline with goals for the short, medium, and long term. In the short term, they would like to establish commercial test routes – Minimal Viable Routes – that are as short as possible. In the medium term, inter-city connections or intra-country corridors should become possible. Within the next 20 to 30 years, continental networks should then be established so that hyperloop becomes a serious competitor for air travel.

Other partners reported setting goals differently. In the case of national governments or authorities operating at a European level, goals are set for up to decades into the future, whereas a local government partner stated that municipalities' goals are mostly set in two- to five-year mobility plans. Similarly, most of the commercial partners in the HDP have shorter timelines for the goals they would like to achieve. As they see it, the HDP should break the development needs down into smaller, more concrete demands so as to make it clearer to the partners how they can contribute, even if full (political) commitment is more difficult to achieve. The HDP is not intended to be just a funding vehicle: most of the partners want to work together to achieve a functioning hyperloop system.

The chances of a strong role for the Dutch exporting industry generally increase if the Dutch government plays a pioneering role at the implementation stage, as clearly shown in the case of the Dutch dredging and water management sector. And even if a hyperloop route in the Netherlands turns out not to be feasible, some of the HDP partners still foresee a role for the Netherlands as a technology developer, given the high level of expertise the country has in transportation and high-tech machinery. Hyperloop technology could then be implemented at transportation greenfield sites in, for example, parts of India, Australia or the US, where there are fewer spatial challenges and where long, continental lines would potentially be easier to establish. The technology developments associated with a hyperloop could then be helpful for other modalities developed in the Netherlands, such as systems and materials for trains, cars or aviation.



CHAPTER 3.

Past and current pilot projects: lessons learned

3.1 Introduction

Any large mobility project has to overcome a multitude of barriers just to gain initial approval, let alone reach completion and successful commercial operation. Infrastructure and mobility projects utilizing new technologies additionally experience barriers such as large upfront investments for societal benefit without a proven business model, competition from existing alternatives, a wide playing field of diverse stakeholders and high uncertainty about possible development setbacks. As any European hyperloop project will face similar barriers, much can be learned from similar projects delivered over the past few decades.

This section presents examples of various disruptive technologies in similar large transport-related infrastructure or technology projects. A short overview of each project is given, together with details of the barriers encountered, the approaches used to resolve them, the successes and failures of the projects and the lessons that can be learned from them for a possible hyperloop project (or pilot project). The cases were selected based on their similarities with hyperloop – such as being high-speed transport modalities or because of the advanced technology used – or the similarity in the barriers faced – such as the high investments or high degree of socio-political decision-making required. We will first examine two case studies of maglev technology, followed by several other large projects involving different transport modalities, such as Concorde, the Vegas Loop and the Sydney Metro.

3.2 Pilots using maglev technology

3.2.1 Transrapid – Shanghai Maglev Train

After more than 20 years of development, the German firm Transrapid, a joint venture of Siemens and ThyssenKrupp, achieved system readiness for commercial applications with their magnetically levitated train in 1991. Between 1994 and 2007, three lines using maglev technology were planned. The long-distance line from Berlin to Hamburg was proposed in 1994, the shorter-distance line from Shanghai's Pudong International Airport to Shanghai in 2001 and the line from Munich's city centre to its airport in 2007. But although all three projects had significant amounts of government funding earmarked, so far only the Shanghai line has been realized.

The most significant barrier that prevented the two projects in Germany from going ahead was cost. A significant underestimation of the building costs, together with an overestimation of expected passenger numbers, led to protracted and costly planning phases. With maglev being a new and almost unimplemented technology, high uncertainty about the project timeline and the possibility of runaway costs influenced decision-making and ultimately brought the German projects to a halt. The Shanghai maglev train (SMT) line was finally built at a cost of just under $40 million per kilometre. This was significantly higher than China's average cost of conventional high-speed rail, which lies between $17 million and $21 million per kilometre. However, China's lower average cost for high-speed rail reflects both its 10,000 km rollout of high-speed rail over a period of seven years and its lower cost of manpower.

European and US building costs for high-speed rail in the same time period ranged, by contrast, from $25 million to $52 million per kilometre.[1]

The Chinese prime minister Zhu Rongji was also a strong supporter of the project, which was intended to be completed within his final term. To speed up construction, Shanghai SMT's end station was placed 9 kilometres from Shanghai's city centre. This meant passengers had to transfer to the subway or a taxi from the SMT to get to downtown Shanghai. Although the SMT line was not necessarily meant to be profitable, it was intended to function as a starting point for rolling out the technology elsewhere in China, and this lack of practicality has impacted the line's ability to inspire new maglev projects.

Barriers: Too optimistic initial estimations of costs and passenger numbers. Societal concerns about energy usage, noise pollution and environmental problems. Availability of more cost-effective alternatives, e.g. traditional high-speed rail. A fatal accident on the German test track in 2006, resulting in 23 casualties, further reduced the maglev concept's popularity.

Approach: The Chinese government 'strongarmed' the high levels of investment needed and facilitated construction of the prestigious trial project.

Success/failure: The SMT was an engineering success, but a business case failure due to the impractical location of the end station. Factors such as the high costs versus alternative transport modes prevented widescale adoption of maglev after the trial project.

Lessons learned:

- Although the maglev technology was matured into a fully functioning commercial product, the Transrapid technology has not been widely adopted.
- With only two tested systems (Siemens and JR Central), hardly any competition for maglev projects exists. The fact that the two systems are also not compatible creates a risk of vendor and technology lock-in. Adoption of new infrastructure technology will proceed more successfully if the technology can be standardized.
- Trial projects should not compromise on practicality. Disregarding this can lead to lower public acceptance of the showcased technology as a viable alternative to traditional modes of transport.

1 High-Speed Railways in China: A Look at Construction Costs, Gerald Paul Ollivier, World Bank, 2014.

3.2.2 SCMaglev – Chūō Shinkansen

Japan has made significant efforts in high-speed rail since the 1960s. The introduction of the Shinkansen, or ‘bullet train’, by the Japanese National Railways (JNR) put the country ahead of the pack in train transport and public transport in general as these trains significantly cut travel times between the major cities. The privatized company JR Central is now trying to repeat this with the introduction of a train using SCMaglev (Super Conducting Maglev) technology. The SCMaglev train, travelling 350 kilometres in 40 minutes, is expected to cut travel times between Tokyo and Nagoya by half on the Chuo Shinkansen line, which is planned to open in 2027. After completion of this first stretch, development will commence on the second phase of the line, which will connect Nagoya and Osaka.

The SCMaglev system is the sum of decades of maglev research in Japan, partly initiated by JNR and the Japanese government. After privatization, JR Central decided to make maglev a reality by funding it themselves, with a partial loan from the Japanese government. The project has been inspired by years of government-funded research and the previous success of the ‘bullet train’. Here, therefore, the barriers to starting a project of such magnitude are lower, given the company’s experience in handling such an operation and making it profitable. Government support for research, mainly in the early stages (1970s), can also be seen as a key factor in making the Chuo Shinkansen a reality. Nevertheless, there are still obstacles to overcome.

These obstacles include the costs of the project, which are high and more than anticipated. When the construction plans were announced in 2007, the costs of the first phase were budgeted at €36 billion, but these have since escalated to around €76 billion, mainly due to the construction-related challenges of digging tunnels through the Japanese Alps. Environmental concerns are also being raised regarding the construction of the track: the tunnels through the mountains could cause water resources in certain regions to dry out, as has happened during the construction of other railway lines. While risk assessment reports state this to be highly unlikely, local populations and governments remain wary and are pushing back on the construction of the Chuo Shinkansen track, thus illustrating the importance of public perception and local involvement in projects of this magnitude.

When the maglev technology was being tested, test tracks were constructed at the location of the future Chuo Shinkansen corridor, thus cutting costs by not creating infrastructure purely for testing purposes. This approach would also hold value when constructing hyperloop test tracks. After successful initial tests on the test tracks, the SCMaglev system has been proposed for the American Northeast Maglev line, between Washington D.C. and Baltimore, for which an environmental impact statement is currently being prepared.

Barriers: The main barriers the project is facing are high costs and environmental concerns. These concerns stem from past experience and are thus deeply rooted.

Approach: Railway operator JR Central is financing the project in the expectation, based on its earlier experience with the commercial operation of the 'bullet train', of generating profits for years to come. However, the unexpected rise in costs means JR Central is now looking for alternative ways to support the project, such as a loan from the Japanese government.

Success/failure: Pending. However, the involvement of a large-scale transportation stakeholder has ensured that the technology has been tested and researched, which can be considered a success in its own right. Although substantial amounts have been invested in this project and infrastructure is currently being built, this is no guarantee of future success.

Lessons learned:

- Local involvement and collaboration are essential for ensuring the planning of projects stays on track.
- Projects costing more than projected almost seem to be a given among projects of this scale.
- Developing test tracks at the location of prospected corridors can help to reduce building costs and to acquire the necessary land early in the development process.
- Because the Japanese rail transportation industry has been privatized in a specific way, long-term investments – but also gains – are solely for the railway companies. Risks caused by political cycles or market regulations (and changes in market regulations) are consequently mitigated.

3.3 Pilot projects in other domains

3.3.1 Concorde

Concorde was the first and only commercial supersonic transport aircraft. The initial agreement between the French and British governments to develop it was signed in 1962, with an initial development budget of £150 million and a sales price of just under £20 million per aircraft, which was competitive with the price of the Boeing 747 at the time. However, development costs ballooned due to inflation and unforeseen costs and increased sevenfold to £1.13 billion for developing and manufacturing the first four aircraft.

Due to a tripling in the sales price, as well as the aborted development of an American supersonic transport aircraft and the high-profile crash of a Tu-144 (another supersonic airliner), all orders except for those placed by Air France and British Airways were cancelled between 1970 and 1980. As a result, France and Great Britain nationalized the development project, with the two government-owned airlines – Air France and British Airways – commissioned to operate the aircraft.

Because the two governments wrote off the development costs, the airlines could operate the aircraft profitably. But their margins were eroded by increasing fuel costs, not helped by the supersonic aircraft's very high fuel consumption, and the high costs of maintaining the small fleet, which lacked benefits of scale. Then, in July 2000, a Concorde jet

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had a major accident in Paris, with all 109 people aboard being killed. The entire Concorde fleet was subsequently grounded in 2003 as it was no longer financially viable. Nevertheless, Concorde proved that "European governments and manufacturers could cooperate in complex ventures, and it helped ensure that Europe would remain at the technical forefront of aerospace development."[2] The Concorde collaboration resulted in the establishing of Airbus Industries.

Barriers: High development costs, high operating costs.

Approach: Development was backed by national government funds. But the estimated development costs were reduced for political appeasement reasons.

Success/failure: Concorde resulted in the development of new technology that made supersonic transport possible. The resulting product also became a long-lasting symbol of pride. The project's success was limited, however, by the aircraft's high fuel consumption and resultant high operating costs. Insufficient technical assessment also led to a lengthy development process, with corresponding cost overruns, and this reduced public and political support.

Lessons learned:

- Although high upfront expected project costs may lessen the chances of approval, cost transparency will help to improve political and public opinion. Building a pilot project that can be incrementally expanded into a profitable product may be a helpful route for dealing with this aspect.
- Highlighting the low operating costs due to the nature of hyperloop technology and its limited vulnerability to changes in external factors such as fuel costs may help a hyperloop project's business case.
- A point of concern is that the material required to construct hyperloop infrastructure includes rare earth minerals, which are vulnerable to price fluctuations because of the widespread role they will play in the energy transition. While the impact that demand for hyperloop materials will have on global supply chains is expected to be relatively low, such price fluctuations can impact on the costs of infrastructure investments.

2 Case Study Report: From Concorde to Airbus, Alberto Domini and Julien Chicot, Joint Institute for Innovation Policy.

3.3.2 Vegas Loop

In 2019, the Las Vegas Convention and Visitors Authority (LVCVA) selected The Boring Company (TBC) from a range of applicants proposing a transport solution for the Las Vegas Convention Center (LVCC). TBC's idea was to create two tunnels with a combined length of 2.7km under the convention center, with electric cars running through the tunnels between three stations to transport visitors. While the idea of creating a tunnel for personalized transport by electric vehicles was unique, the main criterion for selection was the low cost of TBC's project. The latter was consequently awarded a $48.7 million contract to complete the project.[3] The proposal by the other finalist, Doppelmayr Garaventa Group, was an above-ground transit system, which was estimated to cost $215 million.

Owing to the risk involved in contracting the unproven tunnelling company, LVCVA included certain clauses in the fixed-cost contract for the project. Payment would be made only upon completion of specific milestones, such as tunnels, stations and the internal system infrastructure. Seventy per cent of the contract would be paid once the system was ready for passengers, with the final amount being paid in three instalments upon achieving transportation capacity of 2,200, 3,300 and 4,400 passengers per hour, respectively. In addition, the contract made provision to impose fines of up to $4.5 million for failure to meet agreed targets.

The LVCC Loop opened to the public in April 2021, when the LVCC itself reopened after being closed as a result of the Covid-19 pandemic. After a trial run with passengers in May 2021 to test the maximum capacity of the system, TBC stated that it had achieved transporting capacity of 4,450 people per hour. In April 2022, an LVCVA board member stated that "The system has met (our) expectations and (our) customer's expectations", after TBC's contract to operate the LVCC Loop was renewed for a year. Expansion of the system is currently underway to connect hotels and resorts to the system, with the first resort already connected by its own tunnel. This is the first part of a 50km planned expansion, termed the Vegas Loop, that will span the entire city, with a total of 55 stations. The expansion will be privately funded, with the city planning a franchising fee to fund 'civic stations' in places where stations would be of use, but where property owners would not be able to afford the price tag of over $2 million dollars per station. In April 2022, TBC received an additional $675 million in private funding from investors.

Similar to hyperloop, the Vegas Loop represents a new transport modality. It does so by using electric road vehicles in a new dimension, under the ground. Another major advantage cited by the LVCVA board was that construction of the Loop could take place without disturbing above-ground activities. An upcoming improvement will be the introduction of autonomous (or semi-autonomous) driving, which will allow higher driving speeds and a reduction in driver costs. TBC will contribute to knowledge on hyperloop technology through engineering work and testing

3 Public Hearing on the Budget and Board of Directors meeting, Las Vegas Convention Center, 22-05-2019.

at its hyperloop test track, and through the hyperloop student competition. TBC's website mentions the possibility of hyperloop systems running through its tunnels, and it is envisaged that the company's tunnelling machines will eventually be able to create subterranean hyperloop networks.

Barriers: New transport modality by unproven constructor; infrastructure with relatively high cost per kilometre.

Approach: Competitive tender procedure, with the client limiting its risks by making payment only upon completion of milestones. Limited technical innovation thanks to using existing tunnelling technology and existing electric vehicles

Success/failure: By identifying an opportunity for a small-scale project to demonstrate the benefits of a new mode of transport, TBC has been able to attract new investments and has created scope to develop the machinery necessary for eventually realizing a hyperloop.

Lessons learned:

- TBC was able to demonstrate its concept by using its own capital to take on the risks of an infrastructure project, thus accelerating the decision-making for approval of the project.
- This project's success can be used as the basis for building a larger network, where benefits of scale will come into play.
- Identifying innovative applications for parts of the hyperloop technology means these individual parts can be developed profitably, with a suitable business case, while also furthering the hyperloop ecosystem.

3.3.3 Sydney Metro

Following the rapid growth in Sydney's population, which increased by one million between 2004 and 2019, a solution had to be found for the increased congestion on the city's road and rail systems. The Sydney Metro opened its first line, with 13 stations and 36 kilometres of twin tracks, in 2019, with plans to expand to a total of 4 lines, 46 stations and 113 kilometres of twin track. Although the initial plans were published in 2001, they had to be revised several times before work on the metro tunnels could start over ten years later.

Despite the many supporters of expanding the existing heavy railway system (including the federal government), the state government of New South Wales (NSW) opted for a light rail system. A 2011 cost-benefit study found that the metro rail link would be three times more beneficial for the state than the planned alternative of a heavy rail line. The first part of the Sydney Metro, the Northwest line, was fully funded by the NSW state government at an initial project cost of A$8.3 billion (the project was completed A$1 billion under budget). A large share of this cost related to Australia's first A$3.7 billion public-private partnership contract for the trains and systems, including a 15-year operating contract. The planned expansions are expected to cost at least an additional A$30 billion, although higher inflation and cost rises due to the Covid-19 pandemic are leading to cost overruns.

The new metro system is incompatible with the double-decker carriages that run on the existing heavy rail system, which is an argument often used against the developing of the metro system. To compensate for the light rail cars' lower capacity, their frequency is higher, resulting in 50% more hourly capacity. The automatic train operation (ATO) system is helping to achieve this higher frequency. This situation is not entirely dissimilar to that faced by a hyperloop, where it has to compete and is also incompatible with existing rail infrastructure. In the case of the Sydney Metro, arguments in favour of modernizing, and thereby increasing the scale, safety and sustainability of the infrastructure, were ultimately the deciding factors.

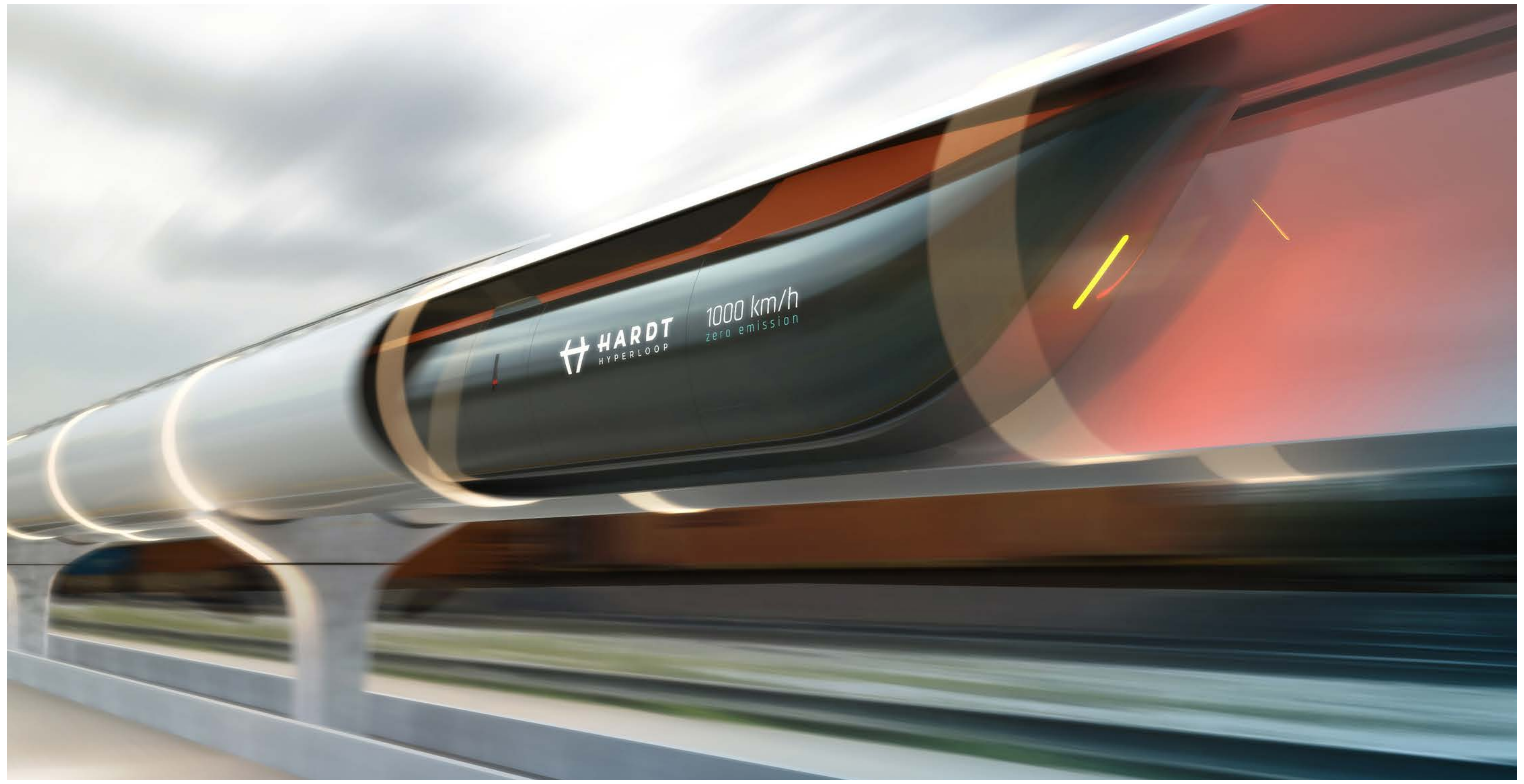
Barriers: Large multi-billion investment, where an alternative – expanding the existing rail system – was available.

Approach: Realistic estimate of project costs; well-researched and dedicated government support for prioritized large infrastructure investment; the investment was made possible by the region's sustained strong economic growth.

Success/failure: The first Sydney Metro line was delivered on time and below budget in a period of financial stability and can be considered a major success. As the remaining parts of the construction work are being carried out against the background of the effects of Covid-19 and increasing inflation, it remains to be seen how these parts of the project will turn out financially. The government's resolve to continue its support will also be tested by the expected 2022-2023 economic downturn.

Lessons learned:

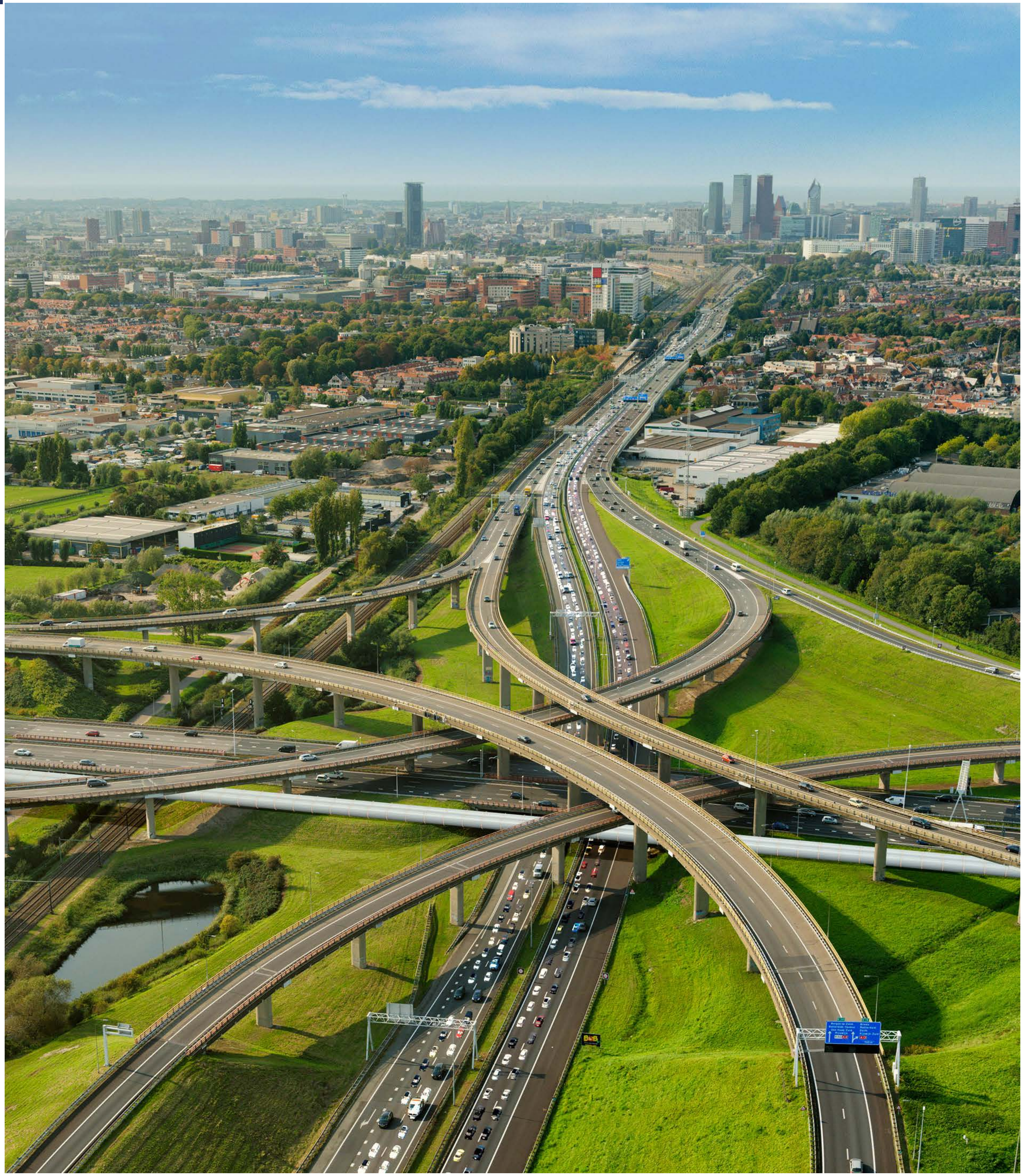
- The Sydney Metro was able to be built as a completely new mode of transport because congestion on existing modes had become so high that the cost-benefit ratio of investments in existing rail and road projects had decreased. Similar situations may offer opportunities for a hyperloop.
- It can take several years, and cancellations, before plans start being executed. However, this time can be helpful in terms of creating gradual acceptance for a hyperloop project. Multiple revisions of project plans will reduce the chances of the overhasty design decisions and overoptimistic budgeting that have led to the failure (or partial failure) of other pilot projects.



3.4 Conclusion

The above case studies provide an overview of several major transport innovations, how they came to be implemented and what lessons can be learned. To conclude the overview, we see several trends that can be extracted for the HDP:

- Futuristic 'next-gen' technology like maglev appear to remain relevant as time passes, as shown by the construction of another high-speed maglev line in Japan, and the fact that maglev is being considered for the Northeast Corridor in the US, 20-50 years after the technology's initial introduction. This perspective may stimulate public spending on developing hyper-innovative projects as it shows that, down the line, the community (national and international) stands to gain from efforts that, at the time, may still seem futuristic.
- Acquiring the required high amounts of capital for investment could be facilitated through transnational cooperation. National strengths such as innovative capacity and the availability of labour and raw materials can be matched with countries that have a transportation demand that can be met using the unique features of hyperloop technology. Public investment risk can partly be mitigated by a tailored tendering approach, although it is important that governments are willing to take on some risk in return for the universal gains to be had.
- It is important to keep in mind the long-term sustainability of the technologies used. Aspects such as the need for certain rare materials (or fuel usage in the case of Concorde) should be analyzed for long-term risks or dependencies that could endanger hyperloop technology's long-term viability.
- Consideration could be given to more small-scale projects, where some of the technology developed for hyperloop can be re-used. This is a way to reap benefits from hyperloop technology, with projects functioning as a steppingstone for technological development. A local mobility solution could be an example of where hyperloop technology could be used. If these solutions can work in parallel with existing modalities, this could reduce resistance to their realization.



CHAPTER 4.

Conclusion and recommendations

This second outlook provides some guidance for the HDP and its activities in 2023. The two outlooks published so far comprise building blocks for the hyperloop roadmap for the Netherlands that will be developed over the coming year. Ideally the building blocks and the roadmap will be linked, with the 2023 HDP activities already contributing to the development strategies to be set out in the roadmap.

Clearly define the direction of travel

Based on the interviews and case studies, the HDP is recommended to actively focus on two strategies:

- developing hyperloop as a mode of transport by exploring and determining functional use cases in existing mobility networks;
- developing the different key technologies that make up hyperloop, while being mindful of the individual value of these components.

Similar to other start-ups and initiatives (e.g. e-aviation and Fairphone), HDP could put more emphasis on this second aspect, including clearly highlighting these key technologies and their importance.

Whether the two options of a cargo loop and a passenger hyperloop should also be kept open can be questioned. After assessment of a separate cargo loop, the general consensus among the partners was that this was not a viable option and that the HDP should focus on developing a single infrastructure for passengers and cargo. For the stakeholders, the concept and long-term perspective of the hyperloop could be strengthened if the HDP were to outline more clearly how the potential development of cargo solutions would align with the passenger ambitions.

Create perspective for the partners and the Dutch context

Most of the HDP partners are keen to stay involved and play their part in both the HDP and the future development of hyperloop. However, it is not always easy for them to envisage their hyperloop future and to identify how to best contribute to current developments. Some partners find it difficult to dedicate significant resources to the partnership. These partners, including local and regional governments, are looking for low-threshold options for contributing to smaller-scale, not-too-time-consuming projects and initiatives. Actively creating these kind of opportunities will enhance partners' overall commitment and also keep them up-to-date about what is going on within the program. The Hyperconnected Europe initiative is a good example in this respect.

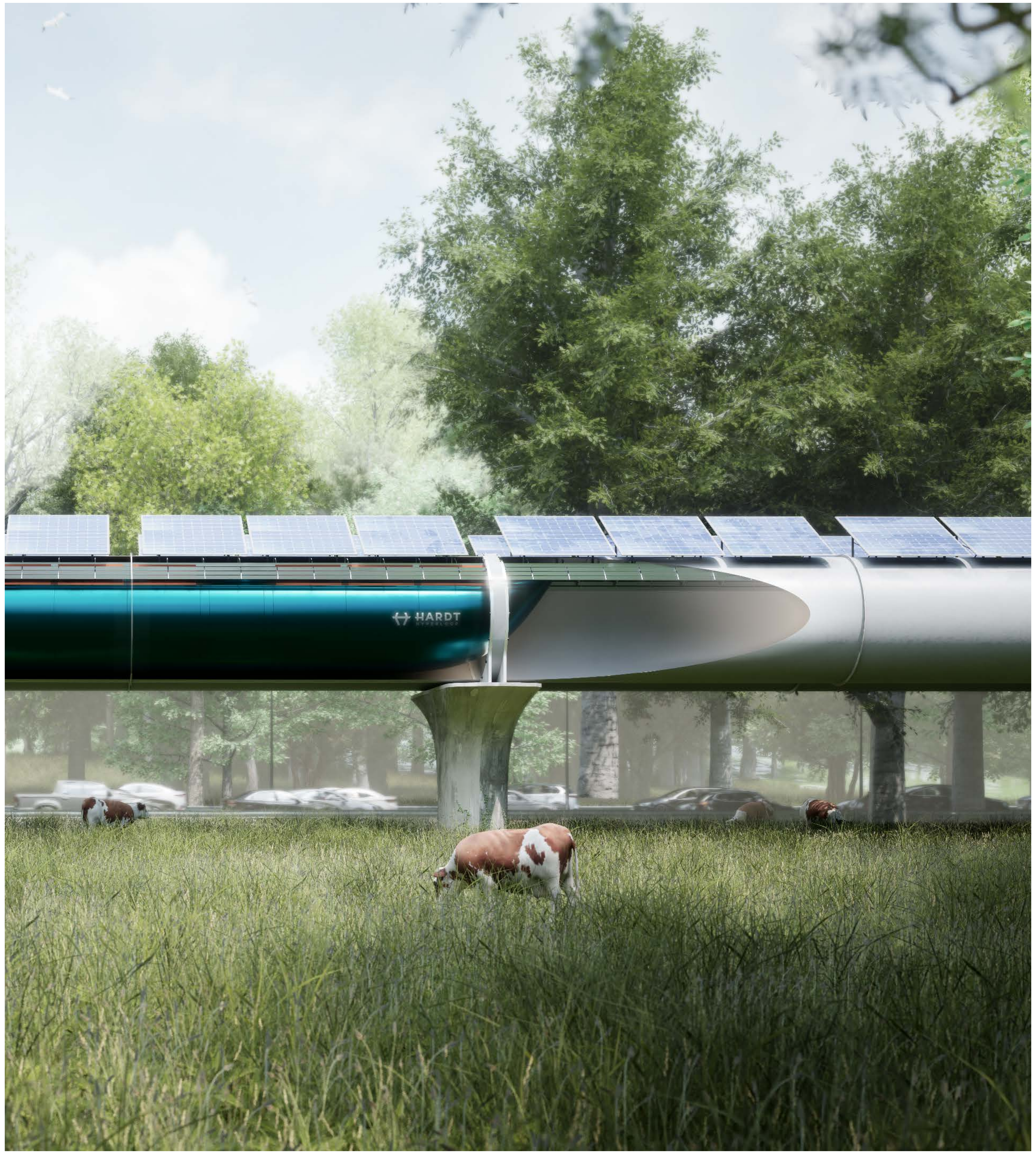
For some partners, their future involvement is very much linked to the development of hyperloop in the Netherlands. There are different views on the likelihood of hyperloop routes coming to fruition in the Dutch context. Partners commonly stated that any Dutch route should be part of a wider European network. Concerns were also expressed regarding land use constraints and spatial planning and financing challenges. The particularities of the Dutch and maybe even Western European situation could lead to the conclusion that a hyperloop is initially more likely to be built in other parts of the world. On the other hand, it could also be decided to demonstrate feasibility in the Netherlands and elsewhere in Europe. If a hyperloop can be delivered in this context, it should definitely be feasible in many other parts of the world. Further thinking and testing are still required, but the best approach to adopt should definitely be addressed in the Dutch hyperloop roadmap.

Raising the funding and sharing the risks requires financial engineering

The next steps in hyperloop development, including the delivery of a first (test) route, require significant investments. Raising and agreeing the funding is always a challenge for major infrastructural investments in the Netherlands. The case studies considered show that development and investment budgets are an even bigger hurdle for new and innovative initiatives.

The Dutch government is currently making large investments in infrastructure and innovation and in knowledge development. At the same time, recent Dutch examples and the planning and decision-making procedures in place make it unlikely that the central (or regional or local) government will pick up the entire bill for an initial hyperloop route, given the inherent uncertainties of realizing infrastructure for new modalities. In the current circumstances, no HDP partner seems to have the financial power or appetite to kick-start and underwrite the development.

While the budgets and risks are substantial, most of the investments in the innovative mobility solutions considered did deliver at a certain point in time. Financial engineering, involving partners with a long-term commitment, seems to be the best way to raise the money and share the risks. However, further consideration still needs to be given to the options and the most likely future financial partners. Significant contributions from venture capitalists and the EU could well be the way to also get smaller private investors and Dutch national and regional governments on board.



Appendix I

Organisatie	Organization
Balance – Consultancy	Balance – Consultancy
Koninklijke BAM Groep	Royal BAM Group
Gemeente Rotterdam	Municipality of Rotterdam
Hardt	Hardt
Ministerie van Economische Zaken en Klimaat	Ministry of Economic Affairs and Climate Policy
Ministerie Infrastructuur en Waterstaat	Ministry of Infrastructure and Water Management
Nederlandse Spoorwegen (NS)	Dutch Railways (NS)
Provincie Noord-Holland	Province of Noord-Holland
Tata Steel	Tata Steel
Vattenfall	Vattenfall

Berenschot

The Netherlands is constantly evolving. Major changes are taking place in society, the economy and the nature of organisations. As a management consulting firm we have closely followed these developments for over 80 years while working towards a progressive society. The drive to make a meaningful and proactive contribution for people and society is part of our DNA and our advice and solutions have helped to make the Netherlands what it is today. Always seeking sustainable progress.

Everything we do is carefully researched, substantiated and examined from many different angles. That is the foundation for solid recommendations and smart solutions, which may not always be what people were expecting. It is this capacity to surprise and look beyond the obvious that makes us unique. We are not in the business of simply tackling symptoms. We don't stop until the issue is solved.

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