FACT-FINDING STUDY ON OPTIONS FOR THE POSSIBLE FURTHER SUPPORT OF THE EUROPEAN HYPERLOOP SECTOR

Final report

Ramboll Management Consulting, TIS, CERTH, SINTEF
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Bright ideas. Sustainable change.

1. EXECUTIVE SUMMARY

Below, we set out the objectives and purpose of the study, followed by the methodology and scope, a summary of the main outcomes of the analysis, more strategic conclusions linked to those and, finally, next steps and recommendations.

Objectives and purpose of the study

This Executive Summary presents the findings of a fact-finding study commissioned by the European Commission's Directorate-General for Mobility and Transport (DG MOVE), aimed at assessing the current state of the hyperloop sector in Europe and evaluating possible avenues for EU-level support. The study was motivated by growing interest in hyperloop as a potentially transformative transport solution capable of delivering ultra-high-speed, low-emission passenger and freight mobility. Though not yet commercially deployed, hyperloop is progressing from conceptual frameworks to testing and prototyping phases, with several European developers at the forefront of global efforts.

The overarching objective of the study was to determine whether, when, and how the EU should engage with the hyperloop sector. More specifically, the study aimed to: map the state of development in Europe; assess hyperloop's alignment with EU climate, transport, industrial and innovation goals; identify key challenges and bottlenecks facing the sector; and recommend if and how the EU should intervene to foster safe, interoperable and equitable hyperloop development. This study was designed to explicitly not be a technology foresight exercise or an endorsement of hyperloop over other modes, but rather a balanced examination of the sector's readiness, potential and policy needs.

Methodology and scope

The study was carried out over nearly two years by a consortium led by Ramboll Management Consulting, in partnership with TIS, CERTH, and SINTEF. A multi-method research design was used to ensure a robust and nuanced evidence base. It consisted of extensive desk research consisting mostly of literature review, stakeholder interviews, technical data collection, demand and environmental modelling as well as a final project workshop to present the results to experts.

Seven major European hyperloop developers were consulted under confidentiality agreements to bring together the current state of knowledge of the sector. Their inputs included technical maturity assessments, cost estimates, infrastructure and operational designs and preliminary business case assumptions. These data were cross validated with the positions of Member State authorities, standardisation bodies, academic institutions and transport operators. The study also reviewed regulatory environments, industrial capacity and public acceptance challenges. Modelling work explored demand forecasts for both passenger and freight transport under varying scenarios, and comparative environmental performance against other modes.

Though inherently limited by the nascent status of the technology and variations in terms of current ideas across developers, this methodology allowed for a credible assessment of where the sector stands, where it might go and what actions the EU might reasonably consider in the short to medium term to support the sector further where needed.

Outcomes: state of the sector, current performance and challenges

The study confirms that hyperloop in Europe has progressed well beyond the ideation stage. Multiple developers are now engaged in full-scale prototype development and partial system integration. The establishment of infrastructure such as the European Hyperloop Centre (EHC) in the

Netherlands, and planned test tracks in Spain and Poland, show that physical assets are emerging to support validation and demonstration activities. Technologies related to propulsion, levitation, pod design, and vacuum environments are typically adapted from aerospace or rail, and several components already exist at TRL levels of 6–7. However, critical functions such as real-time switching, integrated pod control, safety and evacuation systems and full-length vacuum operations remain at lower readiness levels.

Commercial deployment timelines remain conservative. No developer expects operational corridors before 2035–2040, and full network effects would not be feasible before 2060 or later. Earlier deployment could occur in freight-only segments or technology test corridors. These projections reflect both the technical hurdles still to be cleared and the institutional and financial environments into which hyperloop must be integrated. To avoid fragmentation, early projects will need to be carefully coordinated and supported by regulatory learning processes.

In terms of alignment with EU policy objectives, hyperloop holds significant promise. It could serve as a clean, resilient alternative to short-haul aviation and congested interurban road corridors. Environmental modelling suggests that hyperloop, if powered by renewable energy, can dramatically reduce greenhouse gas emissions per passenger-kilometre and tonne-kilometre compared with air, road or even high-speed rail. Its enclosed infrastructure limits land take, reduces noise and is resilient to extreme weather conditions, thereby contributing to broader sustainability goals. Additionally, hyperloop could play a role in supporting the modal shift objectives of the Sustainable and Smart Mobility Strategy and the revised TEN-T Regulation, especially in corridors underserved by existing infrastructure.

Socially, hyperloop may provide improved accessibility and territorial cohesion. It could connect urban and rural regions with travel times comparable to aviation but with lower emissions and better integration into ground networks. Labour market accessibility, regional development and cross-border cooperation could all benefit from reduced travel times. In the freight sector, hyperloop could enhance the speed and flexibility of logistics chains for high-value, time-sensitive goods, though less suited to bulk cargo.

However, the technology's potential cannot be separated from its challenges. Financially, hyperloop infrastructure is capital intensive, with cost estimates between EUR 20-36 million per kilometre, exclusive of stations, land, or rolling stock. Developers argue that operating costs will be lower than rail or aviation, due to automation, electric propulsion and less wear-and-tear, but these assumptions remain speculative. Most current business cases are not bankable, in part due to the long lead times, uncertainty over ridership and pricing models, and lack of regulatory clarity. Although some business cases are evidence-based, there is still a lack of a common goal on the way forward, with cross-border integration being further challenged by diverging national priorities and varying Member State readiness. More detailed feasibility studies, focused on particular contexts at a regional, national and cross-border scale are still necessary to meet the common standards and access to funding required for other transport modes, and to determine a more harmonised network vision.

On the industrial side, Europe holds strong cards. The continent has a competitive base in materials, power electronics, digital control systems and manufacturing. Hyperloop could stimulate high-tech job creation and reinforce value chains already being cultivated under the Green Deal Industrial Plan and the Net-Zero Industry Act. However, dependencies on imported critical raw materials, such as lithium, cobalt, and rare earth elements, expose the sector to global supply risks. Skill shortages in AI, systems engineering and digital infrastructure also present bottlenecks.

From a regulatory standpoint, the sector is entering a critical phase. There is currently no EU-level legal framework for hyperloop certification, safety or interoperability. While some Member States have initiated exploratory activities, the absence of common standards could result in incompatible systems and undermine future cross-border interoperability. Important progress has been made through the establishment of CEN/CENELEC Joint Technical Committee 20 (JTC 20), which is working on voluntary standards for safety, energy use and communications. In parallel, the EU-Rail Joint Undertaking via its research project is exploring how hyperloop could be integrated into the broader European transport network and harmonisation of a commonly agreed concept design for hyperloop. Nevertheless, coordination remains limited, and no Member State has yet implemented a dedicated regulatory sandbox or framework to support real-world testing.

Conclusions

Hyperloop is not yet ready for commercial deployment, but it is maturing quickly and could soon move from prototyping to demonstration. Its potential to contribute to decarbonisation, digitalisation, regional cohesion and industrial renewal makes it a strategically relevant topic for the European Union. The EU is well-placed to support hyperloop development, not by regulating too early, but by enabling innovation, experimentation, and long-term coherence across national and regional systems.

The study concludes that immediate regulatory intervention would be premature and could stifle experimentation. However, the absence of EU engagement risks fragmentation, duplication and lost opportunities. This is why a balanced path is needed: one that supports standardisation, funds real-world pilots, promotes cross-border alignment and guides the sector toward public interest outcomes.

Importantly, the study emphasises that hyperloop is not a substitute for existing rail or aviation systems, but a potential complement. Its optimal role lies in filling high-speed, high-demand corridors underserved by current modes, particularly over medium-long distances (200–1,500 km). Any policy approach should therefore position hyperloop within a multimodal framework and avoid crowding out mature, sustainable options already contributing to EU goals.

Next steps and recommendations

The study proposes a phased EU strategy focused on enabling conditions. In the short term (i.e. 2025–2030), the EU could focus on non-regulatory instruments. This includes promoting national and cross-border regulatory sandboxes, funding pilot projects through Horizon Europe and CEF, and expanding support for technical standardisation via JTC 20. These steps will allow safe real-world testing and knowledge generation without locking in design choices prematurely. The EU could also explore integration of hyperloop into its long-term transport and decarbonisation scenarios, including future revisions of TEN-T.

In the medium term (i.e. 2030–2040), the EU could begin developing a certification framework for hyperloop systems, in cooperation with ERA, EASA and international standardisation bodies. Additional work should support the emergence of a European hyperloop industrial ecosystem, through training programmes, investment support and integration into Net-Zero Industry and STEP initiatives. Public engagement, participatory planning, and education campaigns will be critical to ensure public acceptance and inclusive development.

In the long term (i.e. beyond 2040), if the technology proves viable and competitive, the EU may consider more formal regulatory instruments to support interoperability, market access and safety. However, this should be conditional on accumulated experience, robust evidence, and a clear alignment with wider EU transport and climate goals.

In conclusion, hyperloop is a long-term strategic bet. Its success is not guaranteed, but its promise justifies smart, proportionate and coordinated EU action now, while there is still time to shape its direction. By doing so, the EU can foster innovation, reduce risk, and ensure that the future of hyperloop, if it materialises, reflects the values and priorities of Europe.

2. INTRODUCTION

This document forms the Final report for the Fact-finding study on options for the possible further advancement conditions of the European hyperloop sector,[1] awarded by the European Commission, Directorate-General for Mobility and Transport (DG MOVE) to a Partnership led by Ramboll Management Consulting, and further consisting of TIS, CERTH and Sintef. The contract was signed on 20/04/2023 and ran until 28/02/2025.

This Section aims to clarify the objectives, scope and structure of this fact-finding study, focusing on two key aspects. Firstly, it highlights the intended objectives and scope of the fact-finding study itself, also briefly touching upon the methodology employed to solve these questions. Secondly, it sets out the structure of the report.

2.1 Objective and scope of the report

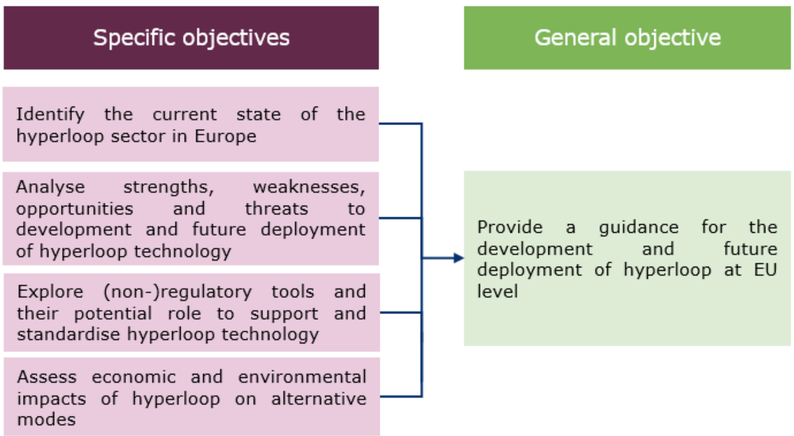
The general aim of this fact-finding study is to establish whether any guidance should be put in place by the European Commission for the advancement, experimentation and eventual implementation of hyperloop and similar technologies at EU level. It does so by considering the present state of technological advancement and foreseen essential requirements, such as those related to safety, reliability, energy efficiency and infrastructure compatibility.

Thus, the fact-finding study aims to set out the current state-of-play of the sector, its likely development over the next years to be able to fully develop leading to eventual deployment and commercialisation. In line with this study aim, the study pursues the following general objective:

> *Provide a guidance for the development and future deployment of hyperloop at EU level.*

Following this general objective, the figure below presents four specific objectives which link to the overarching objective of this fact-finding study:

Figure 1: Specific and general objectives of this fact-finding study



Source: elaboration of the Partnership (2025)

To achieve these objectives, the study employs a comprehensive methodology, consisting mostly of desk research (literature review and data review), expert inputs from the study Partnership, interviews with key stakeholders, mostly the hyperloop developers, who have also provided significant amounts of data, as well as Member State authorities and other industry stakeholders

[1] Specific contract No MOVE/C4/2022-474 implementing Framework contract MOVE/2022/OP/0001.

(e.g. other sectors and suppliers) and a validation during Workshops and High-Level Groups consisting of these stakeholders including one final project Workshop in February. Moreover, we have conducted a modelling exercise with the quantitative inputs received to provide some data on the (likely) trends of the sector; more details on the analytical methods followed for this can be found in Appendix 1. To ensure confidentiality, in the report, the names of the companies providing inputs have been anonymised and provided in the form of numbers (i.e. developer 1-7).

The tender specifications for this fact-finding study outline that the scope of this study comprises the whole EU27, as well as Switzerland. A specific focus lies on those EU Member States hosting hyperloop-related projects (e.g. Spain, the Netherlands and Italy). Furthermore, where useful and feasible within the budgetary constraints, this study has considered the progress made in countries beyond the EU, including Norway, the United States, Canada, China and South Korea. This inclusion of international perspectives enriches the study by incorporating insights from nations that have been at the forefront of hyperloop technology innovation.

2.2 Structure of the report

This fact-finding study provides a structured and evidence-based assessment of the European hyperloop ecosystem. The report is organised into the following sections:

- **Section 1** provides context and outlines the scope of the study. Its overarching objective is to inform future policy guidance and strategic decisions for the development and potential deployment of hyperloop systems at the EU level
- **Section 2** outlines the early development phases of hyperloop technology. It traces the evolution from Elon Musk's 2013 white paper to the current landscape of developers, funding sources, and the state of technology readiness. It also presents indicative timelines for the deployment of passenger and freight operations, as projected by project promoters. The rationale for timely EU-level intervention is then discussed, followed by the identification of areas where EU action can add value. This section also reviews existing initiatives. A preliminary overview of potential regulatory and non-regulatory tools to support the sector is provided
- **Section 3** presents a high-level assessment of the European hyperloop sector, with particular attention to manufacturing capacity and social impact. A SWOT analysis then identifies the key strengths, weaknesses, opportunities, and threats of the sector within the EU context. This analysis lays the foundation for a more detailed examination of financial, socioeconomic, environmental, and technical dimensions in the subsequent sections
- **Sections 4 and 5** focus respectively on passenger and freight transport. They explore current modal share trends and assess the potential integration of hyperloop within these subsectors. Scenario-based modelling is used to estimate passenger demand and assess the implications of different development pathways
- **Section 6** provides an economic and operational analysis, evaluating cost structures, capital expenditure, and potential revenue streams of hyperloop systems
- **Section 7** examines the environmental impacts of hyperloop technology, with a focus on its sustainability performance relative to existing modes of transport
- **Section 8** evaluates performance and safety aspects, including comparative travel times, operational reliability, and accident rate analysis
- **Section 9** concludes the study by synthesising the findings, outlining the key limitations, and offering recommendations for future action at EU level.

3. CURRENT STATE OF THE HYPERLOOP SECTOR

This section provides a comprehensive background to the study topic. Firstly, an overview of the status of hyperloop development in Europe is provided, followed by the road to standardisation of the sector, including an overview of possible regulatory and non-regulatory options to support the sector further.

3.1 Overview of the status of hyperloop development in Europe

This section provides an overview of the study's contextual framework, beginning with an introduction to the initial stages and the state-of-the-art advancements in hyperloop technology development. It then proceeds to discuss the anticipated deployment timelines for both passenger and freight operations.

3.1.1 Early phases and state-of-the-art of hyperloop technology

The concept of hyperloop can be traced back to the 17th century when early ideas involving compressed air tubes for mail delivery emerged. This lineage continues into the 19th century with figures like Isambard Kingdom Brunel, who experimented with vacuum-powered transport systems such as the South Devon Atmospheric Railway, an early attempt to use air pressure instead of onboard propulsion to move trains through sealed tubes. Later, the pursuit of frictionless high-speed transport continued with magnetic levitation railways[2]. The development of hyperloop technology proper began in 2013 following Elon Musk's white paper[3], which reintroduced and modernised the concept. Companies like Hyperloop One and Hyperloop Transportation Technologies (HTT) emerged as pioneers in developing commercial hyperloop concepts. In 2020, Hyperloop One[4] conducted its first passenger test. It has to be noted though that these companies were for a large part active outside the EU and in the case of Hyperloop One ceased their operations in the meantime. Following these earliest developments, several European developers have taken over and taken things forward which is discussed in more detail below[5].

As regards specific initiatives taking place in the EU, seven European and international developers have taken the lead: Hardt Hyperloop (the Netherlands), Nevomo (Poland), Zeleros (Spain), the Institute of Hyperloop Technology (IHT, Germany), the Swiss-American company Swisspod Technologies, the Canadian TransPod, and the American Hyperloop Transportation Technologies (HyperloopTT). These companies started cooperating more closely in December 2020 when they formed the Brussels-based **Hyperloop Association** to promote hyperloop implementation policy, formally signing the association’s founding act on 14 December 2022[6].

In 2020, the **Hyperloop Development Programme**[7] **(HDP)** was initiated as a collaborative effort involving public sector partners, industry parties and research institutions in Europe. It aims to advance hyperloop technology as a secure, environmentally friendly and economically feasible mode of high-speed transport. It comprises four distinct working groups dedicated to cargo, passengers,

[2] Kang, S.-E., Erul, E., Chung, N., Kim, M. J., & Koo, C. (2024). Hyperloop’s role in tourism and hospitality: Challenges and opportunities. Tourism and Hospitality Research. https://doi.org/10.1177/14673584241270848

[3] Musk, E. (2013). Hyperloop Alpha. https://www.tesla.com/sites/default/files/blog_images/hyperloop-alpha.pdf

[4] Formerly known as Virgin hyperloop.

[5] Magnuson et al., 2018, hyperloop in Sweden: Evaluating hyperloops Viability in the Swedish Context, http://www.divaportal.org/smash/get/diva2:1252224/FULLTEXT01.pdf

[6] Niland, J. (2023, February 24) hyperloop companies from international consortium https://archinect.com/news/article/150339163/hyperloop-companies-form-international-consortium

[7] https://hyperloopdevelopmentprogram.com/

the **European Hyperloop Centre (EHC)**, a public-private initiative established in 2020 involving the Province of Groningen, the City of Groningen and Hardt Hyperloop, and exploration of future prospects, including market opportunities for industry and stakeholders.

In September 2023, **Hardt Hyperloop** and its partners in the Hyperloop Development Programme celebrated the installation of one of the first hyperloop pipes at the EHC Kick-off Event. The following month, the Dutch and the Spanish company **Zeleros** publicly announced cooperation through a Memorandum of Understanding, striving for convergence[8]. At the same time, **Swisspod**, together with six leading European research institutes, initiated the Muspell project to develop an innovative thermal energy storage system. This breakthrough aims to advance the efficiency of hyperloop technology by addressing the challenges of waste heat management and low-pressure environments[9]. These advancements were accompanied by further progress in March 2024, when the EHC, finalised its 420-meter test track featuring a lane-switching system. The facility has since opened its doors to organisations seeking to test and refine their technologies, positioning itself as a collaborative hub able to drive innovation within the hyperloop ecosystem. With infrastructure costs that may be potentially lower than high-speed rail, easier spatial integration, and energy consumption up to ten times lower than cars or planes, the hyperloop represents a sustainable and efficient solution to the growing challenges of modern transportation[10]. The following month, Hardt moved into the next phase with the completion of the EHC test track. May 2024 saw the successful completion of the Cargo Doc prototype, a system designed for the seamless loading and unloading of various cargo types such as pallets and ULD aircraft containers.

At the same time, the Polish **Nevomo** is advancing a hybrid transportation solution called **MagRail**, which integrates hyperloop-inspired innovations into existing railway networks. This technology aims to modernise conventional rail systems by enabling a gradual transition to high-speed travel without the need for completely new infrastructure. Unlike other magnetic levitation technologies, MagRail is fully compatible with traditional rail, allowing it to connect to urban centres and ensuring a seamless transport network. Using a combination of magnetic levitation, a linear motor, and autonomous control, the system is capable of doubling the standard speed of conventional rail, reaching up to 550 kph (340 mph). Its cost-effectiveness makes it a viable solution for enhancing current railway networks. Additionally, MagRail has the potential to evolve into a full hyperloop system by introducing vacuum technology, offering a step-by-step approach towards ultra-high-speed mobility[11].

In terms of direct **funding**, in 2023, Hardt Hyperloop secured EUR 12 million for the European Hyperloop Centre. This investment was backed by the EUR 1.1 billion European Innovation Council (EIC) Fund, alongside contributions from the Dutch regional funds InnovationQuarter & Investment Fund Groningen, as well as a mix of existing and new investors[12]. Earlier, in 2021, Hardt Hyperloop

[8] European Institute of Innovation & Technology (October 2023). Hardt and Zeleros form strategic partnership to accelerate the deployment of hyperloop. https://www.innoenergy.com/news-events/hardt-and-zeleros-form-strategic-partnership-to-accelerate-the-deployment-of-hyperloop/

[9] https://www.swisspod.com/our-journey

[10] Hyperloop Development Program, European Hyperloop Center Opens Up For The First Test (2024, March 27), https://www.hyperloopcenter.eu/news-items/european-hyperloop-center-opens-up-for-the-first-test

[11] Nevomo (September 2023). Sustainable future for European transport with MagRail https://www.nevomo.tech/en/sustainable-future-european-transport-magrail/

[12] Inno Energy (2023, July 11) Hardt hyperloop secures EUR 12m investment for the groundbreaking European hyperloop Center https://www.innoenergy.com/news-events/hardt-hyperloop-secures-eur-12m-investment-for-the-groundbreaking-european-hyperloop-center/

received EUR 15 million from the EIC accelerator[13]. According to an article published in December 2024, the Dutch Ministry of Infrastructure and Water Management, together with the State Secretary for Economic Affairs and Climate Policy, will provide EUR 4.5 million in grants to bolster the Hyperloop Development Programme. This initiative, with a three-year total budget of EUR 30 million as part of the Hyperloop Development Programme, is primarily funded by EUR 22.5 million from industry partners. The Dutch province of Groningen has committed an additional EUR 3 million towards the establishment of a test facility[14]. In addition to these developments, in 2022, the Polish company Nevomo secured up to EUR 17.5 million from the EIC accelerator[15]. Zeleros, the hyperloop developer based in Valencia (Spain), has secured EUR 18 million so far in public and private investment from several industrial investors (Acciona, InnoEnergy, Capgemini, Redeia)[16] and European grants like Eureka Eurostars, Spanish Ministry of Science, Horizon 2020, European Innovation Council and Horizon Europe as well as Generalitat Valenciana. In 2023, the Spanish region of Castilla La-Mancha announced a EUR 50 million investment into a real scale hyperloop test track that should be built in the coming years[17].

As a conclusion on the current **technological readiness of hyperloop technology**, according to developers most components already exist at high Technology Readiness Levels (TRLs) in other industries. For instance, infrastructure, traction and control systems, are derived from rail transport, and the fuselage, cabin, and life support systems are adapted from aviation. Nevertheless, there is no full agreement with other stakeholders on whether all of these technologies can be reused directly or should be adapted (significantly) for the specific purpose of hyperloop. Moreover, in any case these would still require significant adaptation or novel development to meet the specific demands of hyperloop-speed and high-frequency operations with small pods. As of 2020, while some technical solutions were closer to being 'technology-ready', others, such as high-speed tube switching, were still in the early stages of development. Despite the considerable progress being made, hyperloop has yet to be tested over long distances, which is a crucial step toward commercialisation[18]. Nevertheless, as highlighted in the 2021 study on a regulatory framework for hyperloop[19], there remains variation in the proposed TRLs for individual hyperloop components, ranging from TRL 2 to TRL 7. For the hyperloop concept to evolve into a commercially viable transport system, all components will ultimately need to reach TRL 8.

[13] Hardt Hyperloop. Hardt Hyperloop has been awarded 15 million euros. https://hardt.global/press/hardt-hyperloop-has-been-awarded-15-million-euros-brusselss-first-hyperloop-investment-package#:~:text=Hardt%20hyperloop%2C%20the%20Dutch%20company,such%20financial%20support%20from%20Brussels.

[14] European Hyperloop Center (December 2024). European Hyperloop Center part of consortium to receive 4.5m EUR funding from Dutch Government. https://www.hyperloopcenter.eu/news-items/european-hyperloop-center-part-of-consortium-to-receive-4-5-meur-funding-from-dutch-government

[15] Nevomo (June 2022). Nevomo has been awarded EUR 175 million in total from the EIC Accelerator issued by the European Commission. https://www.nevomo.tech/en/nevomo-has-been-awarded-eur-175-million-total-eic-accelerator-issued-european-commission/

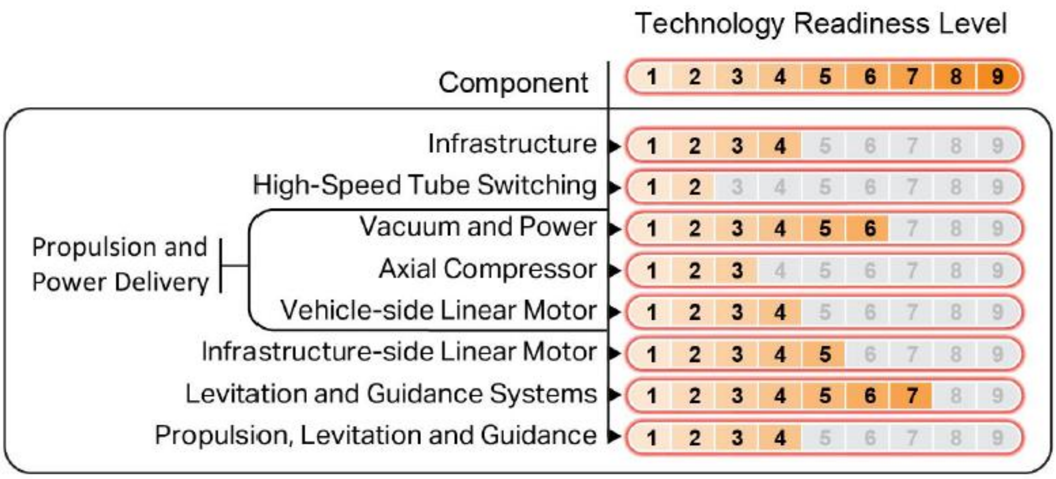
[16] European Institute of Innovation & Technology (August 2021). EIT InnoEnergy, ACCIONA and CAF bet on Zeleros to accelerate hyperloop in Europe. https://eit.europa.eu/news-events/news/eit-innoenergy-acciona-and-caf-bet-zeleros-accelerate-hyperloop-europe#:~:text=ACCIONA%2C%20CAF%20and%20EIT%20InnoEnergy,Zeleros'%20hyperloop%20system%20a%20reality.

[17] CMMNoticias (May 2023). Castilla-La Mancha se postula como centro de ensayo para la nueva alta velocidad que superará los 1000 km/h. https://www.cmmedia.es/noticias/castilla-la-mancha/castilla-mancha-postula-centro-ensayo-alta-velocidad.html

[18] AECOM (2020). "Preliminary feasibility of hyperloop technology"

[19] European Commission (2021). Study on a regulatory framework for hyperloop, an innovative transport technology.

Figure 2: Overview of the Technology Readiness of hyperloop components



Source: AECOM (2020), preliminary feasibility of hyperloop technology

Despite this progress, challenges remain, particularly in integrating these technologies into a fully functional and commercially viable system, especially at the high speeds required for hyperloop. A coordinated effort has been made by the **Hyperloop Development Programme**[20] to map the pathway from Europe's current maturity level towards deployment readiness. This coordinated roadmap or vision paper sees a pathway of coordinated R&D, validation and verification until at least 2030 before commercial deployment of hyperloop becomes feasible.

Considering the developmental stage of the technology, hyperloop developers employ diverse approaches to technical components, leading to variations in capacity, costs, energy efficiency, and safety[21]. Over time, market dynamics or (regulatory) standardisation may lead to a convergence of these approaches. The first steps towards standardisation in Europe are presented in Section 3.2.

3.1.2 Anticipated deployment timelines for passenger and freight operations

The anticipated deployment timelines for hyperloop systems, encompassing both passenger and freight operations, reflect varying projections across promoters, with most aligning on a phased approach that integrates both services simultaneously. The following table outlines the expected timeline envisioned by each hyperloop promoter.

[20] Hyperloop Development Program (2024). Hyperloop. Accelerating progress toward Europe's goal of sustainable transport. https://www.hyperloopdevelopmentprogram.com/download-file/hdp-vision-paper-2024

[21] *Ibidem*

Table 1: Expected timeline for hyperloop deployment according to the different promoters

Hyperloop promoter 1	Anticipates initial operations by 2035, with slow growth initially due to planning complexities, followed by an acceleration of projects as trust and experience with early deployments build momentum in 2040
Hyperloop promoter 3	Outlines a comprehensive timeline, with technology testing on a 10–30 km test track by 2030–2035, full homologation in Europe five years later, and the first 500 km greenfield hyperloop line operational by 2035–2040. According to Hyperloop promoter 3, network effects, including additional lines and the first interconnected node, are projected within the subsequent decade, with an EU core hyperloop network of approximately 5,000 km connecting 20 major cities anticipated by 2060-2090
Hyperloop promoter 4	Envisions construction beginning by 2030, progressing at an estimated pace of 40 km per year across three routes, contingent upon regulatory and standardisation milestones
Hyperloop promoter 6	Forecasts deployment as early as 2036
Hyperloop promoter 7	Plans to establish a full-scale test track within five years, followed by the construction of a pilot line (20–50 km) within ten years, and multiple tenders for hyperloop projects emerging within 15 years in Europe

Source: Elaboration of the Partnership (2025)

It is important to note that these timelines reflect different phases (e.g. construction, testing or entry into services), which vary across promoters. A more detailed analysis of the expected network evolution is available in Section 5.1.

3.2 The road to standardisation

This section describes the efforts that have already been made in the EU to standardise the development (and future deployment) of the hyperloop technology in a consistent and effective way across the continent. Firstly, the rationale behind EU action is highlighted, after which the steps taken so far are described. Following this, an overview of both regulatory and non-regulatory options to support the sector further going forward is finally presented.

3.2.1 Rationale for timely EU action

A key assignment for this study was to effectively understand when potential EU action should take place to stimulate the European hyperloop sector to develop further and which instrument would fit best in this respect as a safeguard for secure investment, rather than hindering the research and development process and causing potential delays. The first element of this would thus be to discuss the timeline and in particular what the rationale for timely EU action is. Indeed, the primary concern expressed by hyperloop companies transitioning from invention to implementation is to recognise the risk of, on the one hand, avoiding excessive regulatory constraints stifling innovation, while also addressing the ambiguity and lack of direction in the absence of any intervention[22].

Specifically, EU action could benefit the development and deployment of hyperloop technology in Europe for several reasons, such as:

- **Investor-friendly environment**: a degree of commercial **certainty** is required to facilitate development of hyperloop technology[23]. This can be achieved through EU action, namely mechanisms such as regulatory sandboxes, testbeds, or living labs, which can instil investor confidence in the viability of the technology. The above-

[22] Arup (2020). Shaping the future of hyperloop. https://www.arup.com/globalassets/downloads/insights/s/hyperloop-report-arup.pdf

[23] *Ibid.*

mentioned EU-Rail **Hypernex research project**[24] has in fact highlighted the **interdependence** between the various technological solutions and the current stage of development. Therefore, this EU intervention could potentially not only attract private capital investments but also align with sustainable transport systems, contributing to the achievement of the objectives outlined in the 2030 Agenda for Sustainable Development[25]

- **Interoperability**: by fostering the development of hyperloop technology at EU level, interoperability can be stimulated. As hyperloop remains in its initial stages, many aspects of its practical implementation remain to be explored. Providing guidance at EU level would help to address these uncertainties and ensure that the technology is developed and deployed through testing, to avoid replicating the same challenges currently faced by EU railway systems
- **Public acceptance**: securing public support is closely tied to ensuring the reliability, security and integrity of hyperloop systems. EU action can play a pivotal role in establishing consistent standards and regulations, which would build trust among passengers, investors, regulatory bodies and safety authorities. This would foster wider acceptance and facilitate the adoption of hyperloop as a transformative transportation solution across Europe[26]

As such, the rationale for EU action lies in its ability to provide clarity, coordination and a unified framework that mitigates fragmentation and fosters innovation. **By addressing safety, interoperability and investment needs, the EU can create an enabling environment for hyperloop development while safeguarding against excessive regulatory constraints**. Building on these more general points, the table below outlines concrete key areas where EU intervention can add value, ensuring progress aligns with broader goals of sustainability, integration and economic feasibility.

[24] http://hypernex.industriales.upm.es/

[25] United Nations (2015). Transforming our world: the 2030 Agenda for Sustainable Development. https://sdgs.un.org/2030agenda

[26] Planing, P., Hilser, J., & Aljovic, A. (2025). Acceptance of hyperloop: Developing a model for hyperloop acceptance based on an empirical study in the Netherlands. Travel Behaviour and Society, 38, 100887. https://doi.org/10.1016/j.tbs.2024.100887

Table 2: Key areas of EU added value in hyperloop development

Ensure very high level of safety for hyperloop transport	Drawing from the successful example of the EU aviation and rail sectors, providing a framework for safety requirements at a supranational level would prevent fragmentation and establish a cohesive safety framework (for more information, including based on evidence from the European Union Agency for Railways, ERA, see Sections 4.3.3 and 9.2).
Unified European approach	By establishing a coherent technical framework that ensures interoperability, the EU can guide diverse innovations towards a unified European approach, generating value, fostering seamless and interconnected transportation systems and ultimately improving efficiency and effectiveness.
Securing investments in hyperloop	By adopting a unified approach without overly strict regulations, innovation remains unhindered, and private investors gain confidence in the potential deployment of the hyperloop technology to the EU-wide market. Increasing investor confidence, in turn results in higher investments in hyperloop development.
Supporting business case for hyperloop in the future transport system	By coordinating efforts, pooling resources and funding test tracks or projects, the EU could help in reducing costs and providing valuable data for larger-scale investments, making hyperloop more feasible and attractive for developers.
Uniform management of safety, security and environmental requirements	Effective hyperloop management needs EU-wide standards like those in aviation and in railways. Flexibility can be retained by letting Member States set targets within common baselines, as seen in aviation security, supporting a strong overarching EU concept.

Source: Elaboration of the Partnership (2025)

These key areas will guide the study's activities, with the fact-finding approach of this study, designed to provide guidance on development and future deployment of hyperloop technology in Europe.

3.2.2 Steps taken so far at EU level

To understand the pathway towards standardisation for hyperloop, it is necessary to first explore the broader context of current transport policies. To take the railway sector as a comparative example, at the heart of the approach taken here lies the **Fourth Railway Package**, which consists of a 'technical' and a 'market pillar'. The technical pillar includes three major legislative acts focused on strengthening the **European Union Agency for Railways** (ERA), established in 2004, the interoperability of the rail system and railway safety. It further aims to reduce costs and administrative barriers to boost the railway sector's competitiveness across Europe which is needed because of the diverse legacy systems already existing across Member States. This in turn leads to challenges to some extent within the network in terms of interoperability, as will also be explored in more detail in Section 4.3.4. The market pillar comprises three other legislative measures related to the liberalisation of the market of domestic passenger rail transport services, the award of public service contracts and the normalisation of the accounts of railway undertakings.

To get the conversation started on how to treat the hyperloop sector from a standardisation point of view, in 2018, hyperloop companies signed an industrial agreement to initiate discussions on standards and regulations for hyperloop at the EU level (involving entities such as DG MOVE and DG RTD of the European Commission, Europe's Rail Joint Undertaking, the Joint Research Centre, ERA, EASA and the EU Member States)[27].

[27] Zeleros (n.d.) Getting closer in the road of a regulatory framework for hyperloop operation. https://zeleros.com/regulatory-framework-for-hyperloop-operation/

At political level, hyperloop was first mentioned at the level of EU policymaking in the Sustainable and Smart Mobility Strategy[28], published by the European Commission in December 2020. Hyperloop is explicitly mentioned in Action 47 of the Action Plan accompanying the Strategy:

> *Assess the need for regulatory actions to ensure safety and security of new entrants and new technologies, such as hyperloop*

In this document, the Commission emphasised the EU's commitment to creating an enabling environment for the advancement of this cutting-edge technology and its associated services. To support its development, the European Commission aimed to foster testing and trials while adapting the regulatory framework to encourage innovation and accelerate market deployment.

In the same year, EU Member States established the **Joint Technical Committee (JTC) 20**, as part of the **European Committee for Standardisation (CEN)** and the **European Committee for Electrotechnical Standardisation (CENELEC)**, tasked with developing common standards and specifications[29]. The CEN focuses on standards for products, materials, services and processes in areas such as aerospace, construction, energy and healthcare, whilst the CENELEC specialises in the electrotechnical field. In February 2020, CEN-CENELEC created **CEN/CLC/JTC 20—hyperloop systems**[30], a committee entrusted with the task of developing European Standards to **guarantee interoperability and security across hyperloop systems**. The proposal highlighted the utmost importance of interoperability, which plays a dual role in ensuring **consistent operations across Europe and facilitating the integration of diverse technologies within a single system**. CEN-CLC/JTC 20 published its first Technical Report in January 2023, including a comprehensive mapping of relevant standards and legislative documents, thereby recognising that many existing standards could be repurposed or modified to suit hyperloop technologies[31]. At the same time, the European Commission is exploring a pan-European regulatory framework for hyperloop, as mentioned in the 2023 Commission Work Programme[32], though this will not be finalised until hyperloop development is more advanced.

Shift2Rail[33], an EU body created by the EU Council Regulation in 2015, targeting research in new and advanced technologies into innovative rail products, funded the Hypernex Project[34], aiming to define a roadmap for hyperloop in Europe. In the context of this project, a discussion took place concerning a 'safety case approach' (i.e. a thorough analytical framework aiming to demonstrate that specific safety claims are substantiated), advocated by hyperloop companies since 2017[35]. The need for a hyperloop-focused regulatory approach was highlighted as well, as up until now the

[28] Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions. Sustainable and Smart Mobility Strategy – putting European transport on track for the future SWD(2020) 331 final. https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52020DC0789

[29] European Committee for Standardization 2023CEN-CLC/JTC 20 Business Plan https://standards.cencenelec.eu/dyn/www/f?p=205:7:0::::FSP_ORG_ID:2739090&cs=182927FD714A2A1F4116CCDD5C71BFF46

[30] CEN-CENELEC, "CEN/CLC/JTC 20 - hyperloop systems", https://standards.cencenelec.eu/dyn/www/f?p=205:7:0::::FSP_ORG_ID:2739090&cs=182927FD714A2A1F4116CCDD5C71BFF46.

[31] CEN/CLC/TR 17912:2023 Hyperloop systems - Standards Inventory and Roadmap' https://standards.cencenelec.eu/dyn/www/f?p=CEN:110:0::::FSP_PROJECT,FSP_ORG_ID:73581,2739090&cs=19F46A5DCA7B78A9D3759C21F62ECF071

[32] European Commission (2022, October 18) Commission adopts its Work Programme for 2023: Tackling the most pressing challenges, while staying the course for the long-term https://ec.europa.eu/commission/presscorner/detail/en/IP_22_6224

[33] https://projects.shift2rail.org/

[34] http://hypernex.industriales.upm.es/

[35] Catapult Transport Systems (2018, September) hyperloop – Opportunity for UK supply chain final report https://cp.catapult.org.uk/wp-content/uploads/2021/07/hyperloop_Report.pdf

hyperloop industry had based its approach mainly on railway standards (e.g. Commission Regulation EU 2016/919[36]).

Since 2021, the **Europe's Rail Joint Undertaking**[37] has replaced Shift2Rail as the EU's partnership for rail research and innovation. Its main objective is to accelerate the development and adoption of modern, interoperable, standardised and integrated rail technologies. In addition, EU-Rail is promoting automation and digitalisation to reduce costs, increase the capacity of rail networks and improve service reliability[38]. More recently, under the **2024 Call for Proposals of the Joint Undertaking**, two key grant agreements were signed: FP2-Morane2 and **Hyper4Rail.** The latter is of particular interest to the present study as it explores hyperloop technical feasibility, economic viability and integration into the EU multimodal mobility network, reflecting EU Rail's forward-looking approach to disruptive innovations and aiming to develop a harmonised concept for hyperloop[39]. The Hyper4Rail Consortium[40], consisting of 27 partners from 13 countries, received EUR 2.3 million grant from Europe's Rail Joint Undertaking initiative in December 2024[41].

In September 2024, the **Hyperloop Conference** took place as the leading international event on high-speed transport. It gathered key players from the hyperloop ecosystem, including start-ups, corporations, suppliers, and investors. After two editions in Europe and one in South Korea, this edition was hosted at BLUE CITY in Rotterdam, Netherlands[42].

Furthermore, the **Mario Draghi Report on the Future of European Competitiveness**[43], published on 9 September 2024, acknowledges the potential for hyperloop development. Indeed, the report mentions hyperloop as part of the advancements expected to contribute to future transport systems, particularly in terms of speed, efficiency and cost-effectiveness. The report emphasises hyperloop's role in addressing the projected 79% increase in passenger transport demand and the expected doubling of freight demand by 2050[44]. The report highlights that the transport sector is undergoing green and digital transformations, with increasing reliance on technologies such as artificial intelligence (AI), big data and autonomous transport systems. Within this context, the reference to hyperloop situates the technology alongside other emerging innovations that would contribute to improving the European transport system in the coming years. Further details on the benefits of AI in transport will be provided in Section 4.3.3.

[36] Commission Regulation (EU) 2016/919 of 27 May 2016 on the technical specification for interoperability relating to the 'control-command and signalling' subsystems of the rail system in the European Union. https://eur-lex.europa.eu/eli/reg/2016/919/oj/eng

[37] Council Regulation (EU) 2021/2085 of 19 November 2021 establishing the Joint Undertakings under Horizon Europe and repealing Regulations (EC) No 219/2007, (EU) No 557/2014, (EU) No 558/2014, (EU) No 559/2014, (EU) No 560/2014, (EU) No 561/2014 and (EU) No 642/2014 https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32021R2085

[38] Europe's Rail Joint Undertaking. https://european-union.europa.eu/institutions-law-budget/institutions-and-bodies/search-all-eu-institutions-and-bodies/europes-rail-joint-undertaking_en

[39] https://rail-research.europa.eu/latest-news/europes-rail-2024-highlights/

[40] https://www.hyper4rail.eu/

[41] De Boer, O. (January 2025). Hyper4Rail consortium has kicked off with EUR 2.8 million EU grant. Hyperloop Connected https://hyperloopconnected.org/2025/01/hyper4rail-consortium-has-kicked-off-with-e2-8-million-eu-grant/

[42] Hyperloop Conference 2024, Rotterdam, The Netherlands. https://rail-research.europa.eu/calendar/hyperloop-conference-2024/

[43] Draghi, M. (2024). The future of European competitiveness—A competitiveness strategy for Europe. European Commission. https://commission.europa.eu/topics/strengthening-european-competitiveness/eu-competitiveness-looking-ahead_en#paragraph_47059

[44] *Ibid*. p 207.

Ahead of the beginning of her second mandate in December 2024, the European Commission President Ursula von der Leyen sent a **Mission Letter to Apostolos Tzitzikostas[45], the Commissioner for Sustainable Transport and Tourism.** In this letter, she stressed the responsibility of each Commissioner in achieving the EU's 2030 targets under the European Green Deal[46] and contributing to the United Nations Sustainable Development Goals. The letter outlined the need for Europe to lead in transport innovation and proposed the development of a strategy for emerging technologies, with a specific reference to hyperloop systems.

Hyperloop is also mentioned in the **EU General budget plan of the Council of the European Union**[47], which addresses their perspective on financing and delivering a harmonised European approach towards hyperloop safety and security to take away the final hurdles to deployment. The technical feasibility of hyperloop has been demonstrated, but the next step is proving its safety and comfort to gain public acceptance. While the EU has heavily invested in research, establishing safety standards remains a key challenge due to the lack of a specific mandate or experience.

3.2.3 Overview of regulatory and non-regulatory options to further support the sector

Based on the logic set out in Section 3.2.1, advancing hyperloop technology as a transport solution in Europe could benefit from both regulatory and non-regulatory support. This section examines the approaches available that could support the development and future deployment of this innovative technology.

Regulatory tools

In terms of **regulatory** options, performance-based regulations and cross-border regulatory harmonisation could be considered to support hyperloop technology in Europe:

- **Performance-based regulations**, which focus on outcomes rather than prescriptive technical specifications would provide the flexibility necessary for hyperloop innovation while ensuring compliance with safety, environmental and operational standards[48]. These regulations could foster technological development without imposing rigid constraints
- **Cross-border regulatory harmonisation[49]** would align national regulations with common European standards, facilitating seamless integration of hyperloop systems across different countries. This would mitigate potential barriers to cross-border operations and enhance network connectivity

Finally, **public-private partnerships** could offer a strategic framework for collaboration between governments and private enterprises, enabling shared investment in infrastructure

[45] Mission Letter to Commission-designate for Sustainable Transport and Tourism (September 17, 2024) https://commission.europa.eu/document/download/de676935-f28c-41c1-bbd2-e54646c82941_en?filename=Mission%20letter%20-%20TZITZIKOSTAS.pdf

[46] Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions, COM/2019/640 final. https://eur-lex.europa.eu/legal-content/EN/LSU/?uri=COM:2019:640:FIN

[47] Council of the European Union (2024). Joint text on the general budget of the European Union for the financial year 2025: Amendments by budget line. https://data.consilium.europa.eu/doc/document/ST-15788-2024-ADD-5-REV-1/en/pdf

[48] Non-Traditional and Emerging Transportation Technology (NETT) Council (2021). Hyperloop Standards Desk Review. https://www.transportation.gov/sites/dot.gov/files/2021-01/NETT%20Council%20hyperloop%20Standards%20Desk%20Review_14Jan2021_final.pdf?

[49] Schroten, A., Van Grinsven, A., Tol, E., Leestemaker, et al. (2020), Research for TRAN Committee – The impact of emerging technologies on the transport system, European Parliament, Policy Department for Structural and Cohesion Policies, Brussels

and risk mitigation. The **Hyperloop Development Programme**[50] is an example of such a partnership, aiming to develop and deploy hyperloop technology in Europe.

Regulatory tools are considered to be premature at this point and not yet effective for hyperloop due to its early stage of development and due to some current weaknesses, which will be further described below (e.g. lack of a clear unbiased business case, see Section 4.3.2). The absence of established standards would complicate the implementation of comprehensive regulations, while cross-border integration faces challenges stemming from differing national priorities and levels of readiness. Consequently, initial technological progress and system integration may need to be advanced through alternative methods, particularly non-regulatory tools as highlighted in more detail below.

Non-regulatory tools

A set of primary **semi-** and **non-regulatory** tools (i.e. living labs, test beds and regulatory sandboxes) is outlined in the table below. While each of these approaches can be employed to provide further support to the sector, each is characterised by distinct features and can foster specific modes of regulatory learning.

[50] Hyperloop Development Program (2023). Hyperloop as part of sustainable transport in Europe https://www.europarl.europa.eu/cmsdata/277661/HDP%20position%20paper%20European%20Parliament%20elections%202024.pdf

Table 3: Non-regulatory options to support the development and future deployment of hyperloop technology in the EU[51,52]

Tool	Regulatory sandboxes	Test beds	Living labs
Description	Schemes that enable the **testing** of innovations in a controlled real-world environment, under a specific plan developed and monitored by a **competent authority**	Experiments to **develop**, **test** and **upscale** a product or service in a dedicated**, near real-world** environment	Experimentation tool to **co-create**, **prototype**, **test** and **upscale** innovative solutions to (local) needs in real-life settings
Technology Readiness Level (TRL) covered by tool[53]	7-9	4 and above	1-9
Applications of the tool	Test technological requirements and performance (e.g. technical standards and regulations) and examine user needs and consumer protection measures	Study the requirements and societal impacts of innovation, evaluate its adoption and public acceptance and identify potential future regulatory demands	Examine regulatory modifications, analyse and apply regulations and evaluate risks to the market and consumers
Relevance	Provide access to technological infrastructure, provision of services and support (including technical and legal expertise) and access to funding opportunities, enabling real-world trials while ensuring safety, legal clarity, and potential market deployment	Provide a technical experimentation environment for hyperloop, sharing knowledge within the innovation ecosystem, engaging with users and the public and facilitating a multi-method approach in R&I process, often with funding support, but without regulatory involvement or oversight from a competent authority	Facilitate direct engagement with real customers, strengthening legal certainty and access to regulatory and compliance support. Provides reassurance regarding enforcement, potential exemptions and boosting investor and consumer confidence

Source: Elaboration of the Partnership (2025)

All three tools have been used in the EU before, both to advance the development and deployment of transport modes, as well as in other sectors. These non-regulatory tools enable the testing, co-creation and refinement of innovative solutions while addressing technical, regulatory and societal dimensions of hyperloop systems. The following examples illustrate instances where these non-regulatory tools have been applied to hyperloop or other innovative mobility modes within the EU:

- **Regulatory sandboxes** have the potential to facilitate the development of hyperloop technology by providing temporary exemptions from standard regulations to enable controlled pilot projects. Although no regulatory sandboxes specifically for hyperloop technologies currently exist, Member States could be encouraged to establish these. A recent initiative involves the introduction of the **interoperability regulatory sandboxes** under the **Interoperable Europe Act** (Regulation EU 2024/903)[54], which are designed to promote innovative trans-European digital public services in a non-sector-specific way.

[51] Commission Staff Working Document (2023) 'Regulatory learning in the EU – Guidance on regulatory sandboxes, testbeds, and living labs in the EU, with a focus section on energy', SWD(2023) 277 final.

[52] Kert, K., Vebrova, M. and Schade, S., (2022) Regulatory learning in experimentation spaces, European Commission, JRC130458.

[53] These indicated levels stem from Kert, K., Vebrova, M. and Schade, S., (2022), Regulatory learning in experimentation spaces, European Commission, JRC130458.

[54] Regulation (EU) 2024/903 of the European Parliament and of the Council of 13 March 2024 laying down measures for a high level of public sector interoperability across the Union

- **The European Hyperloop Center (EHC)[55]** in Groningen, the Netherlands, functions as both a **test bed** and a hub for hyperloop technology research. It includes a 420-meter test track used to trial and showcase hyperloop technologies and related systems. Additionally, the EHC supports collaboration between tech companies, industries and research institutions to further the development of hyperloop systems. Its primary role is to serve as a test centre where organisations can develop, demonstrate and validate their hyperloop technologies
- As demonstration zones in real-world settings, **living labs** allow for the testing of technologies to meet the needs of users. While no living lab dedicated to hyperloop technology is currently being set up in Europe, these demonstration zones are commonly applied to other mobility subsectors. A practical example of this is the **Thessaloniki Smart Mobility Living Lab**[56]**,** through which the entire city of Thessaloniki, Greece serves as a comprehensive testing ground for technological and innovative mobility solutions, including cooperative and autonomous vehicles

In addition to the transport sector, these tools have been leveraged in other domains to foster innovation and technological advancement within the EU, as demonstrated by the following examples. Examining their application in different contexts can provide valuable insights into their versatility and potential for driving progress across various industries.

- In the industry domain, under the framework of the **Net Zero Industry Act**, Member States are encouraged to introduce exceptional and temporary regulatory regimes that establish controlled environments for developing, testing and validating innovative net-zero technologies prior to their commercial deployment. Secondary legislation under the Act provides guidance on the establishment and operation of these **regulatory sandboxes**. Moreover, to enhance collaboration and efficiency, national authorities are required to share best practices, lessons learnt and recommendations annually with the European Commission. Digital provides another example worth mentioning. For instance, through the EU's **Artificial Intelligence Act[57]**, Member States are required to set up at least one artificial intelligence regulatory sandbox by August 2026, setting a precedent for such initiatives.
- In the energy field, **Open Innovation Test Beds (OITBs)** offer facilities for technology prototyping, testing and compliance assessment in industrial environments. Another example can be drawn from the project **Convert2Green** under Horizon Europe, which has established a framework to incorporate circular and carbon-neutral materials into strategic value chains, including autonomous vehicles and renewable energy, as well as to evaluate environmental impacts and create licensing models for shared intellectual property rights
- In the digital domain, the **Limerick's Citizen Innovation Lab** stands out as an example of fostering community engagement through innovation. The lab has introduced initiatives like the creation of a citizen-sourced open-data portal, providing a platform where citizens, researchers and policymakers collaborate. This portal facilitates local policy adjustments and encourages public participation in the development of

[55] European Hyperloop Center (n.d.). https://www.hyperloopcenter.eu/about-us

[56] Hellenic Institute of Transport (2025). https://www.smartmlab.imet.gr/

[57] European Parliament and Council of the European Union (2024) Regulation (EU) 2024/1689 of the European Parliament and of the Council of 13 June 2024 laying down harmonised rules on artificial intelligence and amending Regulations (EC) No 300/2008, (EU) No 167/2013, (EU) No 168/2013, (EU) 2018/858, (EU) 2018/1139 and (EU) 2019/2144 and Directives 2014/90/EU, (EU) 2016/797 and (EU) 2020/1828 (Artificial Intelligence Act) (Text with EEA relevance). http://data.europa.eu/eli/reg/2024/1689/oj/eng

smart city solutions[58]. Additionally, the **Joint Research Centre (JRC) Living Labs**, located across three research sites in Geel (Belgium), Ispra (Italy, and Petten (the Netherlands), offer experimental setups, advanced communication networks, and extensive infrastructure. This approach enables researchers to explore critical dimensions of technology development, such as interoperability, robustness, trust, and user acceptance. The labs examine behavioural changes brought about by new technologies and social trends, providing evidence-based insights[59]

All the above-mentioned examples can act as sources of inspiration to design a specific policy mix that the European Commission could use to further support the European hyperloop sector. Over the course of this report, we will develop these ideas further which will be revisited in the conclusions and recommendations chapter (see Section 10).

3.3 Concluding remarks

Considering its current state, advancing hyperloop technology in Europe could benefit from a combination of regulatory and non-regulatory measures. At this stage, however, the introduction of performance-based regulations and cross-border regulatory harmonisation appears premature, primarily due to the limited technological maturity of hyperloop, a lack of a clear unbiased business case, and the lack of established standards. Additionally, cross-border integration faces challenges linked to diverging national priorities and varying levels of readiness among Member States.

In this context, non-regulatory and semi-regulatory tools represent more suitable instruments to foster the early development of hyperloop systems. These instruments have been successfully applied in other sectors and could contribute to advancing hyperloop technology by facilitating experimentation, supporting regulatory learning and enabling gradual integration into the transport system. Moreover, public-private partnerships could complement these efforts by providing a framework for shared investment and risk mitigation, as illustrated by the ongoing Hyperloop Development Programme.

Box 1. Key takeaways

Regulatory tools

The introduction of performance-based regulations and cross-border harmonisation remains **premature** in the current phase of hyperloop development. **Technological maturity is still limited to some hyperloop players and lacks a harmonised phase of development and harmonised standards. Although some business cases are evidence-based, there is still a lack of a common goal on the way forward, with cross-border integration being further challenged by diverging national priorities and varying Member State readiness. More detailed feasibility studies, focused on particular contexts at a regional, national and cross-border scale are still necessary to meet the common standards and access to funding required for other transport modes, and to determine a more harmonised network vision.**

Non-Regulatory tools

Non-regulatory and semi-regulatory instruments are more appropriate in the current environment **for supporting hyperloop development**. These instruments e**nable experimentation, regulatory learning and** eventually **gradual integration** within **the transport system**. **Public-private partnerships can complement these tools by facilitating investment and risk-sharing, as shown by the Hyperloop Development Programme**.

[58] Commission Staff Working Document (2023) 'Regulatory learning in the EU – Guidance on regulatory sandboxes, testbeds, and living labs in the EU, with a focus section on energy', SWD(2023) 277 final.

[59] European Commission, EU Science Hub (2024), Pilot living labs at the JRC. https://joint-research-centre.ec.europa.eu/living-labs-jrc_en

4. ASSESSMENT OF THE EUROPEAN HYPERLOOP SECTOR

This section presents an overall, high-level assessment of the European hyperloop sector as a whole. Firstly, two specific topics of focus are addressed: EU manufacturing capacity and social impact. Finally, a SWOT analysis of the European hyperloop sector, assessing the sector's main strengths, weaknesses, opportunities, and threats, is provided.

4.1 EU manufacturing capacity

As evidenced in the sections above, the European Commission has shown strong support at the policy level already towards the development of hyperloop in Europe, having identified the major impact it may have towards the achievement of the relevant environmental and sustainability goals included in the European Green Deal. The development of the hyperloop system fits into the EU's broader strategy to **modernise transport**[60], alongside **electrification** in sectors such as road and maritime mobility, where European companies face competition from global leaders, including China, Japan and Turkey.

As an important step in rationalising and minimising capital expenditure (see Section 7.1.2 for a detailed discussion of what this entails), **manufacturing locally** is selected as a key priority for a European hyperloop industry with real perspectives to develop. Therefore, it is of imperative importance to investigate the major industry and manufacturing capacity already available, related to the needs of the European hyperloop sector, as well as any currently existing gaps. It should be a priority to identify the EU's current manufacturing capacity in those sectors to be able to make a concrete plan for how they can be further boosted.

Hyperloop construction will require significant quantities of **steel, concrete, aluminium, copper and advanced composite materials**, industries where Europe already holds substantial capacity. In 2024, the EU produced approximately 152 million metric tons of crude steel, making it the second-largest producer globally. Aluminium production exceeds 4 million metric tons annually, supported by strong recycling programs that enhance sustainability and reduce costs. Europe's electric steel and copper production capacity is also well-established, particularly in Germany, France and Italy.

The European hyperloop sector will also need to secure a reliable supply of **critical raw materials** such as lithium and rare earth elements (e.g. neodymium and dysprosium) for magnetic levitation systems and battery technology. However, Europe currently imports 98% of its rare earth elements and over 70% of lithium from China, which controls approximately 80-90% of global lithium refining and rare earth processing capacity. This supply chain vulnerability underscores the need for securing alternative sources and expanding domestic production through mining, recycling including urban mining programmes.

Moreover, to meet hyperloop's high energy demand, Europe's **electrical grid** will need to scale up. The EU is currently expanding its renewable energy infrastructure, with 22% of total energy consumption coming from renewable sources. The rollout of high-voltage direct current (HVDC) transmission lines and smart grids is improving grid resilience and cross-border power distribution. However, localised grid capacity remains a challenge, particularly in less developed regions, and could hinder hyperloop's large-scale rollout unless resolved.

Like many forms of emission-free transport solutions, one of the main requirements for the hyperloop sector is to have access to **consistent and reliable production of batteries** at a

[60] Besliu, R. (July 2023). More than a pipe dream: Europe's hyperloop ambitions, https://www.theparliamentmagazine.eu/news/article/hyperloop-mobility-climate-change-europe-zeleros-hardt

sufficiently high production level. Therefore, Europe should position itself as a leading player in the battery manufacturing sector. As stated by the leading hyperloop (and batteries) manufacturers in Europe and worldwide, there is a clear need for Europe to have its own battery systems. In fact, large-scale (i.e. able to produce several gigawatt hours, GWh) European battery-producing facilities are on the rise. EU's battery industry is expanding, propelled by the increasing demand for electric vehicles and renewable energy storage solutions. This is supported by investments from both the public and private sectors. The European Commission has promoted collaboration and innovation initiatives like the **European Battery Alliance (EBA)**[61], established in 2017, aiming to create a competitive and sustainable battery value chain within Europe. One outcome of these efforts is the establishment of **gigafactories** across Europe. For instance, the French Verkor, founded in 2020, is marking a step ahead in European battery manufacturing, completing its first gigafactory in Dunkirk, expected to become operational in 2025 with an initial annual capacity of 16GWh[62]. Additionally, companies such as Basquevolt are advancing solid-state lithium battery technology, contributing to the diversification and strengthening of Europe's battery ecosystem[63]. Zeleros stands out as an example of hyperloop promoter specialised in batteries and powertrain systems that applies its skills in support of other EU sectors. Current projections are that by 2030, these initiatives could help Europe achieve a 20% share of global battery production, while China's share would decrease to 60-65%[64].

Nevertheless, hyperloop construction would benefit from synergies with other strategic European industries, particularly offshore wind and electric grid infrastructure. Guideway structures for hyperloop share significant overlap with offshore wind supply chains, including the use of steel, composite materials, and foundation technologies. This creates an opportunity for integrated supply chain development under the EU's **Net-Zero Industry Act (NZIA)**[65], which aims to boost green industrial capacity and strategic autonomy. By extension, hyperloop could help supply offtake to Europe's NZI's and deliver green jobs in the process.

Additionally, hyperloop can drive demand for European-manufactured **electrical components**, including superconducting magnets and high-performance motors. The sector's demand for advanced automation, AI-driven communication systems, and predictive maintenance technology also presents opportunities for European technology firms to capture new market share.

Based on TransPod's final report[66] on the development of a hyperloop system in Thailand, the choice to manufacture a component in a certain location depends on many factors[67], such as:

[61] European Battery Alliance (n.d.). https://single-market-economy.ec.europa.eu/industry/industrial-alliances/european-battery-alliance_en

[62] Verkor (2023). Verkor marks new milestone in future of sustainable mobility, laying the foundation stone of its Gigafactory. https://verkor.com/en/verkor-marks-new-milestone-in-future-of-sustainable-mobility-laying-the-foundation-stone-of-its-gigafactory/

[63] EIT InnoEnergy (2022). BASQUEVOLT, the Basque initiative for the production of solid-state batteries, is launched with the aim of producing 10GWh by 2027. https://www.innoenergy.com/news-events/basquevolt-the-basque-initiative-for-the-production-of-solid-state-batteries-is-launched-with-the-aim-of-producing-10gwh-by-2027/

[64] Besliu, R. (July 2023). More than a pipe dream: Europe's hyperloop ambitions, https://www.theparliamentmagazine.eu/news/article/hyperloop-mobility-climate-change-europe-zeleros-hardt

[65] European Union (2023) EU Net-zero industry act – Making the EU home the home of clean tech industries. https://ec.europa.eu/commission/presscorner/api/files/attachment/874739/Factsheet_Make%20Europe%20home%20of%20clean%20tech%20industries.pdf

[66] TransPod (March 2019). Hyperloop in Thailand – Preliminary study on the implementation of a TransPod hyperloop line in Thailand.

[67] While the cited report refers to the development of a hyperloop system in Thailand, the factors influencing manufacturing location choices are widely recognised as applicable across different geographical and institutional contexts, including the EU. These elements align with standard industrial policy considerations and location theory (e.g. Krugman, 1991; Porter, 1990).

- Availability of raw materials
- Skills of the local workforce, and opportunities to leverage local expertise (for more details, see Section 4.2 below)
- Isolated or central location, logistics, and local transportation network
- Strength of the local economy, and stability of the country
- Ease of operating a business, and efficiency of the banking system
- Tax credits, incentives, and willingness to support and promote transportation, aerospace, and hyperloop industries

From the above factors, the EU as a whole and its Member States can be considered as frontrunners globally speaking in terms of **workforce, logistics, ease of doing business, tax credits and incentives**.

While many of the required competencies are already present in existing sectors, they will need to be adapted and expanded to meet the specific needs of hyperloop systems. Developing hyperloop-specific skills will require targeted training programmes, particularly in structural, mechanical, electrical and civil engineering. Skilled engineers are needed, able to design and construct the pods, the low-pressure tubes, ensure infrastructure sustainability, integrate advanced communication, IoT and AI systems, explore magnetic levitation and plan the routes and overall system operation. Moreover, the workforce should be trained in the use of lightweight material, such as carbon fibre, as well as in the acquisition of the necessary permits and protocols from the various authorities. The skills on which all of the above professions rely basically include green skills, sustainable construction, both environmental and cost wise (given the high cost per km for the construction of the system), formulation of regulatory frameworks for this new, high-speed system and maintenance. Developing scalable models that are easy to maintain over time is critical. This will require innovation in materials and design.

Global competition presents another strategic threat. The United States, China, and Japan are all investing heavily in high-speed transport technologies, and early technological lock-in could limit Europe's ability to adopt new innovations. Additionally, lengthy regulatory approval processes and varying national standards within the EU could delay Hyperloop deployment unless a streamlined regulatory framework is established. Achieving strategic autonomy in critical raw materials, scaling up energy infrastructure, and strengthening workforce skills will therefore be essential for Europe to compete globally in the Hyperloop sector. Public-private partnerships and targeted investments in domestic material sourcing would ensure the successful deployment of Hyperloop technology and secure Europe's leadership in next-generation transport.

Box 2: Key takeaways

Local production is a priority to reduce costs and exploit existing capacities, though certain **gaps remain to be filled.** Hyperloop will require upgrades to the power grid, especially to handle localised peaks in demand.

Nevertheless, significant synergies with strategic European industries (offshore wind, electricity grid, advanced manufacturing) can strengthen the supply chain and create green jobs.

Simultaneously**, the European battery industry is expanding thanks to public and private investment,** supporting energy needs with **gigafactories and innovations**. However, reliance on Chinese critical raw materials **represents a potential vulnerability**, and c**ompetition for critical resources and skilled labour will be intense, given the growing demand from other strategic sectors.**

4.2 Social impact

The social impact of hyperloop is influenced by various factors, including geographical structure, demographic characteristics, economic conditions and technology transfer.

Firstly, hyperloop technology is expected to deliver social benefits in terms of accessibility and connectivity as it enables people to travel greater distances in less time, facilitating work, study and exploration of different cities[68]. As increasing urbanisation remains one of the global megatrends, a growing proportion of the population is expected to reside in cities over the coming decades. **Improvement of accessibility** could enable individuals to consider job opportunities in other cities without being restricted by long commutes, thus limiting the migration of the workforce to more developed areas. High-speed capabilities, which reduced travel times of up to 75% compared to traditional road transport, can appeal to individuals seeking efficiency and convenience in their daily lives, making it easier for people to work in different locations while maintaining their residence elsewhere[69]. In addition, improved accessibility and increased mobility can also enhance opportunities for collaboration, cultural exchange and personal development, while contributing to a fairer distribution of resources, reducing regional inequalities. This, in turn, may lead to a reshaping of demographic patterns[70].

Additionally, **shorter commutes** can positively affect well-being by allowing people to spend more time with family, hobbies and leisure, improving overall quality of life[71]. In fact, research has shown that long commutes are associated with increased stress, reduced sleep, and lower life satisfaction, while shorter travel times contribute to better mental health and work-life balance. Moreover, having more discretionary time allows individuals to engage in more physical activities, pursue personal goals and foster stronger social connections, all of which are linked to greater happiness and productivity[72].

Beyond passenger transport, hyperloop's ability to carry freight has the potential to revolutionise logistics by increasing efficiency and sustainability. Hyperloop could ensure faster access to critical supplies and inventory. Compared to rail, Hyperloop also has the potential benefit of avoiding dedicated last-mile networks, given the flexibility provided by individual pods. With the potential of being switched separately – even if virtually coupled – they would have a considerable and positive impact on capacity, namely for last-mile transport.

Additionally, its sealed environment and advanced design would minimise package damage during transit. By shifting freight transport from road vehicles to hyperloop, the number of delivery trucks on highways would be significantly reduced, resulting in lower emissions and less traffic congestion. With an estimated reduction of up to 90% in delivery-related emissions compared to road transport,

[68] Tomorrow.bio. (2023). The Hyperloop effect: Economic and social impact on local communities. https://www.tomorrow.bio/post/the-hyperloop-effect-economic-and-social-impact-on-local-communities-2023-11-5506319989-futurism

[69] Tomorrow.bio. (2023). The Hyperloop effect: Economic and social impact on local communities. https://www.tomorrow.bio/post/the-hyperloop-effect-economic-and-social-impact-on-local-communities-2023-11-5506319989-futurism

[70] Algın, Y. T., & Çelikkanat Hyperloop Team. (2024). The impact of hyperloop technology on societal and individual well-being. ResearchGate.

[71] Tomorrow.bio. (2023). The Hyperloop effect: Economic and social impact on local communities. Retrieved from https://www.tomorrow.bio/post/the-hyperloop-effect-economic-and-social-impact-on-local-communities-2023-11-5506319989-futurism

[72] World Economic Forum. (2020, July 30). As people return to work, here’s how we can make commuting more inclusive and sustainable. https://www.weforum.org/stories/2020/07/how-we-can-make-commuting-more-inclusive-and-sustainable-post-covid

hyperloop represents a significant leap toward achieving net-zero logistics targets[73]. This rapid supply chain responsiveness enhances public health outcomes, ensures food security, and supports disaster relief efforts by providing critical resources when and where they are needed most.

In the area of **education,** hyperloop has the potential to revolutionise access to education by bridging geographical barriers and empowering students to choose institutions based on quality rather than proximity. By breaking down these barriers, hyperloop opens the door to broader educational opportunities, fostering a more equitable and accessible academic landscape[74].

Moreover, fast and efficient transport is expected to boost **tourism** by encouraging visitors to explore more areas. It may also influence shopping and entertainment habits. Yet, the extent to which people can access hyperloop services would shape demographic distributions and regional balance[75].

In geographical areas affected by external crises such as war and flooding, during emergencies, hyperloop could play a role in **disaster response and recovery efforts**. In war-affected regions, hyperloop could provide a lifeline for displaced populations by enabling safe and rapid relocation to secure areas, while simultaneously sustaining the flow of humanitarian aid. Its ability to evacuate people quickly from dangerous areas could save countless lives during natural disasters or conflict situations. Moreover, the sealed tube system of hyperloop is less vulnerable to weather disruptions, making it a reliable option in disaster-prone regions. In such regions, the vulnerability of an on-ground fixed infrastructure to targeted attacks presents challenges, whereas underground or underwater hyperloop structures may minimise this risk.

Moreover, the **environmental benefits** of hyperloop, such as reduced emissions (for more details on this, see Section 8), could help mitigate the long-term impacts of climate-related crises, especially in flood-prone regions where traditional transport contributes to environmental degradation.

Transport remains a major contributor to global CO_2 emissions, with road vehicles and airplanes being among the primary culprits. The potential reliance of hyperloop on renewable energy sources and its zero-emission operations would also offer substantial environmental benefits that directly translate into social improvements, particularly in urban and densely populated regions. The energy-efficient design of hyperloop, powered in part by solar infrastructure, would minimise its environmental footprint and offers a cleaner, greener alternative to fossil-fuel-based transport systems[76]. As presented in section 8.2, hyperloop systems provide a highly energy-efficient alternative to traditional transport modes. This section outlines the key energy requirements, including pod propulsion, cooling systems, brake energy recuperation, vacuum maintenance for infrastructure, and infrastructure cooling.

The reduction in air pollution has profound implications for public health. Globally, ambient air pollution is responsible for approximately 4.2 million premature deaths each year, with respiratory diseases such as asthma, chronic obstructive pulmonary disease (COPD), and lung cancer accounting for a significant portion of this burden[77]. In Europe alone, long-term exposure to air

[73] World Economic Forum. (2022). Hyperloop's role in sustainable freight and logistics. https://www.weforum.org/press/2024/12/emissions-fall-in-hard-to-abate-sectors-but-still-off-track-to-reach-2050-net-zero-targets/

[74] RS Components. (2018). Engineering the future: Inside London's Hyperlink Hyperloop project. RS Online. https://www.rs-online.com/designspark/engineering-the-future-inside-londons-hyperlink-hyperloop-project

[75] Algın, Y. T., & Çelikkanat Hyperloop Team. (2024). The impact of hyperloop technology on societal and individual well-being. ResearchGate.

[76] TransPod. (2019). Final report: TransPod Hyperloop – Thailand.

[77] World Health Organization (WHO). (2018). Ambient air pollution: A global assessment of exposure and burden of disease. Retrieved from https://www.who.int

pollution causes over 400,000 premature deaths annually[78]. Vulnerable populations, including children, the elderly, and individuals in urban areas with high pollution levels, would benefit immensely from cleaner air facilitated by hyperloop's zero-emission operations.

The development of hyperloop systems creates significant **employment opportunities** during construction, maintenance and operation, positively affecting local economies and reducing unemployment. Additionally, the specialised roles associated with these projects enhance the development of local talent and expertise[79]. These projects generate thousands of jobs across various sectors, including engineering, construction, logistics and operations, helping to reduce unemployment in surrounding areas. In addition, hyperloop's reliance on advanced materials and technologies could increase demand for research and innovation, creating opportunities for local universities and training institutions to partner with hyperloop developers. This could lead to the establishment of educational programs focused on the skills required for this next-generation transport system, further embedding its benefits in the community. Despite the initial challenges, with careful planning and equitable expansion strategies, hyperloop can serve as a catalyst for economic development, social mobility and regional integration.

The development and implementation of hyperloop systems, while offering transformative benefits, come with additional challenges that require careful planning and mitigation.

A challenge arises regarding a **lack of integration with other modes of public transport** (see also section 4.3.3) which would maintain reliance on private vehicles, elevating demand for parking spaces and contributing to congestion in the future. In 2024, London was identified as Europe's most congested city, with drivers spending an average of 101 hours in traffic, marking a 2% increase from the previous year. This congestion resulted in an estimated economic cost of EUR 4.57 billion, averaging EUR 1,120 per driver. Other European cities also experience considerable congestion. Paris reported 97 hours of delays per driver, while Dublin followed with 81 hours. In Germany, drivers spent an average of 40 hours in traffic jams in 2023, with Berlin leading at 55 hours per driver. Beyond health benefits, reduced congestion and quieter urban environments foster improved mental well-being and create safer, more liveable cities. Additionally, noise pollution—linked to 12,000 premature deaths annually in Europe and significant mental health issues such as anxiety and sleep disturbances—could be reduced if hyperloop technologies help diverting traffic from roadways.

Such issues underline the need for strategic station placement and robust connections to public transport networks to promote sustainable, multimodal accessibility. To address these concerns, it is essential to carefully plan hyperloop terminals to ensure they are seamlessly integrated with existing public transport infrastructure and non-motorised travel options. Doing so would minimise negative social and environmental impacts while maximising accessibility and sustainability[80].

Additionally, **public acceptance** of hyperloop can be hampered by perceived risks, such as fears of technological failure or system safety, highlighting the importance of transparent communication and education to alleviate these concerns. The first empirical insights into the acceptance of hyperloop technology highlight positive attitudes, with 68% of respondents showing initial support and over half willing to use it in the future. Acceptance increased after participants received more information, especially among those with little prior knowledge, with reduced travel time and enjoyment being key motivators. Younger participants and frequent users of high-speed trains and airplanes were more inclined to adopt hyperloop, though concerns such as missing windows and high travel speeds should be addressed to boost acceptance further. Nevertheless, since there is

[78] European Environment Agency. (2021). Health impacts of air pollution in Europe 2021. https://www.eea.europa.eu

[79] Algın, Y. T., & Çelikkanat Hyperloop Team. (2024). The impact of hyperloop technology on societal and individual well-being.

[80] Premsagar, S., & Kenworthy, J. (2022). A critical review of Hyperloop (ultra-high-speed rail) technology: Urban and transport planning, technical, environmental, economic, and human considerations.

limited public knowledge about hyperloop technology, increasing awareness and understanding could help in shaping future acceptance and adoption decisions among individuals. Educating the population through public outreach campaigns, interactive demonstrations, and partnerships with local governments can significantly increase trust and acceptance of this innovative transport solution. Research has shown that new technologies often face resistance when their benefits and safety are not clearly communicated. Nevertheless, environmental advantages, including zero direct emissions and reduced energy consumption compared to air and road travel, align with growing societal demand for sustainable solutions. These aspects could collectively improve the perceived usefulness and attractiveness of hyperloop, encouraging wider acceptance[81].

Moreover, studies on the topic of innovation diffusion suggest that early adoption in highly visible regions, coupled with successful pilot projects, can further influence public perception and drive acceptance. Engaging local communities in the planning and implementation phases, as well as addressing concerns about safety, costs, and accessibility, can foster a sense of inclusion and confidence in the technology. Ensuring transparency about construction impacts, pricing models, and long-term benefits will further empower individuals to support and choose hyperloop[82]. Finally, incorporating educational programs into schools and universities about hyperloop technology can influence future generations, embedding knowledge and excitement about its potential from an early age. As performance expectancy aligns with individual values for speed, comfort, and sustainability, targeted education and outreach will be critical to ensure public readiness and enthusiasm for hyperloop's integration into the transport landscape.

Box 3: Key takeaways

Hyperloop's social impact spans improved accessibility, reduced travel times, and enhanced connectivity, supporting job mobility without relocation and reducing regional inequalities. Shorter commutes can boost well-being by lowering stress and enhancing work-life balance. Freight transport via hyperloop could reduce emissions, support disaster response and strengthen supply chains. Access to education and tourism would expand **by overcoming geographical barriers. Environmentally, its zero-emission design improves air quality and public health, especially in urban areas. Economic benefits include job creation and skills development through innovation and infrastructure.**
However, integration with existing transport and public scepticism requires **strategic planning and communication to promote sustainable, multimodal accessibility, reduce socio-spatial inequalities, and ensure that the benefits of hyperloop systems are shared across different communities.**

4.3 SWOT analysis

Below, the main strengths, weaknesses, opportunities and threats not related to the elements already mentioned above under manufacturing capacity or social impact are discussed.

4.3.1 Strengths

Hyperloop is a novel transport technology which has shown the potential to provide benefits compared to traditional modes of transport. For instance, as a high-speed transport technology using magnetic levitation and low-pressure tubes, if it delivers on all its promises, it has the possibility to offer **fast travel times,** as well as **lower levels of pollution,** and can be made emission-free if sustainable energy is used. This is largely thanks to features such as being mostly underground (or

[81] Planing, P., Hilser, J., & Aljovic, A. (2025). Acceptance of Hyperloop: Developing a model for Hyperloop acceptance based on an empirical study in the Netherlands. Retrieved from https://www.sciencedirect.com/science/article/pii/S2214367X24001509

[82] Rogers, E. M. (2003). Diffusion of innovations (5th ed.); Hyperloop Connected (2018). How Hyperloop can transform regional connectivity and accessibility.

elevated) and running through a closed tube which provides important advantages compared to traditional surface-level transport modes like cars, as further highlighted in Section 7.2. Additionally, any sound produced by the capsule could potentially remain confined within the system, preventing it from being heard externally[83]. Its design thus addresses one of the most pervasive sources of environmental noise: road traffic noise, which significantly impacts public health. Urban areas with more than 100,000 inhabitants are particularly affected, with many individuals experiencing high levels of annoyance and sleep disturbance due to transport noise[84]. Moreover, hyperloop is intended to be an automatically operated mode of transport (at grade of automation 4) which would neither require on-board crews nor would it be subject to wear and tear by mechanical contact and friction. In such a way, it would **complement high-speed rail**, especially considering the distances it can cover and the speeds it can reach. This could lead in particular to **countering the shortcomings of aviation** (see Section 8.4) which, between GHG emissions and a projected increase in demand, will face massive challenges during the next decades. Therefore, hyperloop holds significant **environmental potential** compared to other modes. Accordingly, its environmental potential is aligned with the European Green Deal's objectives, according to which the EU aims to achieve a 90% reduction in these emissions by 2050[85].

Positive societal impacts such as emission reduction, improved air quality, and enhanced resource efficiency, can boost economic efficiency and support an environmentally sustainable industry. Hyperloop stands out for its strong **weather resilience**[86], addressing one of the primary factors behind flight delays and cancellations, as reported by EUROCONTROL[87]. These disruptions, which have been worsening due to climate change, could be significantly mitigated by hyperloop's enclosed infrastructure. Furthermore, as a closed transport system, hyperloop eliminates interference from other modes of transportation and pedestrians, enhancing safety design. Additionally, while hyperloop infrastructure does not integrate into existing rail systems, it can still generate complementary economic advantages. Certain components of the hyperloop network can also be developed by modernising current rail infrastructure, such as through the MagRail technology, a magnetic rail system that operates within existing conventional rail transport routes, mentioned in Section 3.1.1[88].

Another notable benefit is the **reduced need for extensive land acquisition**. Hyperloop infrastructure can be designed to follow existing transport corridors and/or be elevated on pylons. This minimises disruption to communities and ecosystems while reducing the financial and bureaucratic hurdles associated with securing land rights. Additionally, by requiring a narrower footprint compared to conventional transport modes, Hyperloop can integrate more seamlessly into dense urban environments or challenging terrains, making it a more viable solution for future infrastructure development. Moreover, hyperloop developers expect that hyperloop requires less tunnelling compared to, for instance, high-speed rail as it will be able to follow existing railway tracks to a larger extent and where it is the case that tunnelling will need to take place, this can be

[83] Favari, E., Maja R., Mariani C. (2020). Forecasting the success of hyperloop technology on Italian Routes: a feasibility study. https://www.researchgate.net/publication/344283426_Forecasting_the_success_of_hyperloop_technology_on_Italian_Routes_a_broad_feasibility_study

[84] European Environment Agency (February 2025). Health impacts of exposure to noise from transport in Europe. https://www.eea.europa.eu/en/analysis/indicators/health-impacts-of-exposure-to-1?activeAccordion=ecdb3bcf-bbe9-4978-b5cf-0b136399d9f8

[85] European Commission, DG MOVE (n.d.). Sustainable Transport, https://transport.ec.europa.eu/transport-themes/sustainable-transport_en.

[86] Hyperloop Development Program (October 2024). Accelerating towards a sustainably connected Europe. https://static1.squarespace.com/static/64e74196d472e811c33e6a78/t/67616e496a09b434b7cc5d06/1734438474582/2024-10-31+Hyperloop+Narrative+-+short+version.pdf

[87] Eurocontrol (2023). European Aviation Trends. Summer 2023: High weather impact on the network. https://www.eurocontrol.int/publication/summer-2023-high-weather-impacts-network

[88] Nevomo (n.d.). MagRail - The next generation of high-speed railways. https://www.nevomo.tech/en/magrail/

done for smaller surfaces considering the smaller surface of hyperloop infrastructure. Finally, research[89] has also shown potential benefits for tourism, such as the **spread of multi-destination travel** and **new job opportunities**, as well as **transport benefits** such as travel time savings, punctuality, reliability, and convenience, and **safety benefits**, such as reduced road accidents due to mode shifts to hyperloop[90], further elaborated in Section 9.

Moreover, hyperloop development aligns with the objectives outlined in the revised Trans-European Transport Network (TEN-T) Regulation[91] (preamble 74), which encourages the development and deployment of sustainable and innovative technologies to enhance the mobility of passengers and freight. Indeed, due to its multi-country and cross border infrastructure, hyperloop can become a project with **high EU added value**, as it could allow to **bring the urban and transport nodes of the TEN-T closer and reshape commercial and labour markets**[92]. The ongoing expansion of urban nodes within TEN-T, which aims to integrate multimodal hubs in all key locations, presents an opportunity for hyperloop to **function as a complementary transport mode** rather than a competitor to existing networks. To this end, promoters participating in the workshop held in February 2025 suggested hyperloop developers should focus on Western Europe, like Amsterdam-Dusseldorf and Hamburg-Berlin. Others advocated instead for focusing on filling gaps in connectivity, particularly in regions where high-speed rail is limited, such as Eastern Europe. While some suggested operating in inner cities, others believe Hyperloop can link major intermodal hubs like airports, rather than operating in highly urbanised areas where infrastructure approval is more complex. This could potentially lead to an increase in car traffic to these hubs/airports. Nevertheless, a recent study from the Hyperloop Development Programme suggests hyperloop's **potential to reduce congestion on roads and at airports** by providing a new, high-capacity transport mode. With a dedicated, sealed-off infrastructure, hyperloop also enhances safety by eliminating risks associated with level crossings, weather disruptions, and human errors[93]. During the workshop, the multimodal hubs of Paris, consisting of a transport node through which at least two modes of transport are connected, was provided as an example. From the discussion emerged the need for interoperability within the hyperloop sector to avoid the same fragmentation issues faced by rail networks.

With its potential to be **faster, more efficient and more sustainable** than other forms of transport such as trains, airplanes and cars, hyperloop has the ability to be an important player in achieving the benefits of the EU twin green and digital transition[94]. To ensure more rapid attainment of long-term European transport goals (e.g. with the 2050 horizon) laid down in the TEN-T Regulation and in targets committed under the Paris Climate Agreement, or the decarbonisation goals embedded in the Green Deal strategy, hyperloop has the potential to transform the industry for both passengers and freight transport. Nevertheless, data provided by various hyperloop promoters reveal varying projections for development timelines and network expansion. To support these projections, Section 5.1 of the present study includes a consolidated analysis based on insights from various of these developers to design the European Hyperloop Network passenger map for 2050.

[89] Kang, S.-E., Erul, E., Chung, N., Kim, M. J., & Koo, C. (2024). Hyperloop's role in tourism and hospitality: Challenges and opportunities. Tourism and Hospitality Research, 0(0). https://doi.org/10.1177/14673584241270848

[90] Hyperconnected Europe (2022). A vision for the European hyperloop network.

[91] Regulation (EU) 2024/1679 of the European Parliament and of the Council of 13 June 2024 on Union guidelines for the development of the trans-European transport network, amending Regulations (EU) 2021/1153 and (EU) No 913/2010 and repealing Regulation (EU) No 1315/2013

[92] Hyperloop Development Program (2024). EU recognizes hyperloop in its transport network policy. https://www.hyperloopdevelopmentprogram.com/news-about-the-hdp/ten-t-regulation-revision

[93] Hyperloop Development Program (2024). Hyperloop Accelerating progress toward Europe's goal of sustainable transport.

[94] Joint Research Centre (2022). The twin green & digital transition: How sustainable digital technologies could enable a carbon-neutral EU by 2050. https://joint-research-centre.ec.europa.eu/jrc-news/twin-green-digital-transition-how-sustainable-digital-technologies-could-enable-carbon-neutral-eu-2022-06-29_en

Nevertheless, building a commercial hyperloop system is expensive and cost estimates run into amounts of billions of Euros, depending on the source and network scale. In terms of capital costs, estimates differ depending on the elements considered. Cost considerations will be discussed in more detail in Section 7.1. While initial capital requirements are high, hyperloop systems promise lower operational costs due to innovations such as magnetic levitation, autonomous operations, and weather-protected enclosed tubes[95].

4.3.2 Weaknesses

Notwithstanding the potential benefits of the hyperloop technology as described above, some challenges remain which would require significant additional efforts to be overcome.

As a starting point, the table below summarises some key technological challenges ahead.

Table 3: Challenges ahead for hyperloop technology development

Challenge	Explanation
Tubes' configuration	The challenge is mainly related to the diameter and pressure of the tubes. This is especially critical if the priority is to achieve interoperability between different hyperloop technologies
Construction of carbon-neutral and fully circular materials	The challenge lies in developing materials that maintain a net-zero carbon footprint across their entire lifecycle, encompassing production, disposal, and the ability to be reused, recycled, or composted within a closed-loop system
Positioning, communication and control systems	The challenge is to create efficient real-time hyperloop control systems by developing a new theory to derive and analyse algorithms for operation control

Source: Elaboration of the Partnership (2025)

More in general, one of the main issues the European hyperloop sector faces is that there is still a lack of a common goal on the way forward, with some promoters still lacking the development of a more detailed business case on hyperloop development (notwithstanding the fact that others are working towards the development of an evidence-based business case). A **high potential business case** can be an "unprecedented gamechanger" for mobility[96], which directly influences the feasibility, acceptance, and overall success of this technology. A well-defined and objective business case for hyperloop technology creates assurance surrounding its potential economic viability and societal benefits. This assurance can lead to consistent support and investment, potentially leading to a harmonised European hyperloop system. Such business cases serve as a foundation for well-informed regulations and investment decisions, ultimately ensuring a more cohesive and beneficial hyperloop system for society and the EU industry. Nonetheless, as previously pointed out, at this stage, business cases developed from the different promoters still show diverging views for a hyperloop network. Yet, ongoing developments may quickly be made.

A start to creating a business case has been made by developers and independent entities. The basis of the positive business case is a combination of potentially lower CAPEX, lower OPEX, superior passenger value proposition, superior socioeconomic value proposition and high capacity. This could lead to the development of a new industry. For instance, Hardt Hyperloop, foresees hyperloop technology revolutionising the transport sector by effectively addressing existing infrastructure challenges and giving rise to an entirely new industry. The company projects that the **total market size for hyperloop transport could reach EUR 6 trillion** by 2050[97]. This indicates a high potential business case for EU industry to supply to this market if Europe decides to embrace the opportunity to take the lead in developing this technology.

[95] Hyperconnected Europe (2022). A vision for the European hyperloop network.

[96] Siderius, P. (ProRail), Verschuren, M. (PTV Group), Guis, N. (ProRail) (2024). Hyperloop zweverig? We reizen verder door de LMS-pijplijn

[97] Hardt Hyperloop. Invest in Hardt.

While hyperloop's potential business case is still evolving, its long-term viability could be strengthened by **prioritising passenger transport over freight** in the initial stages, with cargo transport being integrated later. Some believe hyperloop could **substitute short-haul aviation**, provided that security and boarding procedures remain more efficient than those of air travel. Hardt Hyperloop foresees hyperloop technology revolutionising the transport sector by effectively **addressing existing infrastructure challenges** and giving rise to an entirely new industry. While air travel conventionally serves long-distance trips, recent national initiatives to counter CO_2 emissions, such as the **French government's decision to restrict short-haul flights within the country**[98], may provide additional incentives for strengthening the business case for hyperloop, which will be further addressed in Section 4.3.2. Nevertheless, despite the country's extensive high-speed rail network, the impact of France's flight ban has been limited by the European Commission to only three routes. The ban is temporary and will last a maximum of three years, in line with Article 20 of the revised Air Services Regulation[99], with a mandatory evaluation after 24 months to assess its environmental and market impact. If France wishes to implement a new ban in the future, it will need to follow the same approval process. Moreover, such measures are permitted only as exceptions under EU law and must meet strict conditions. These include proportionality, non-discrimination and a focus on achieving their objectives without distorting competition. Additionally, flight bans are contingent upon the availability of sustainable travel alternatives with adequate service levels, which will be evaluated on a regular basis[100].

Another business case elaborated by the industry is formed by a 2019 feasibility study focused on deploying hyperloop technology across the U.S. Great Lakes region[101], (encompassing the area between Chicago, Cleveland and Pittsburgh) which revealed that the entire corridor is expected to experience **robust passenger and freight market activity, resulting in substantial revenue generation**. This revenue is projected to cover all development, manufacturing and construction costs, (or capital costs), and all operation and maintenance costs, (or operational costs)[102], ultimately yielding a net financial return of 6.5% (nominal) and an economic return of 11.8% (nominal)[103]. Furthermore, the potential regional economic impact on the U.S. Great Lakes Region affected by the deployment of hyperloop transport would lead to **significant employment growth**, (creating more than 900,000 new jobs across various sectors), along with a **substantial increase in income**, (approximately twice the initial capital costs of the hyperloop project[104]).

When considering a comparative analysis of the **benefits of hyperloop for passenger transport in relation to other transport modes, the business case appears to be strong**. To provide a concrete example, a comparison study by Deutsche Bahn Engineering & Consulting estimates a **maximum capacity of over 19,636 passengers per hour**[105] at 700 km/h, which could potentially be higher at lower speeds or with longer convoys. In comparison, **high-speed rail**

[98] Lesdom, A. (June 2023). France Legally Bans Short-Haul Flights, Forbes.

[99] Regulation (EC) No 1008/2008 of the European Parliament and of the Council of 24 September 2008 on common rules for the operation of air services in the Community (Recast)

[100] CER (2023). High-speed rail as a strategic tool for achieving European transport policy goals: smart, integrated and sustainable mobility. https://www.cer.be/images/publications/essay-series/05_CER_ESSAY_FS.pdf

[101] Hyperloop TT, "Great Lakes Feasibility Study", https://mma.prnewswire.com/media/1055193/hyperloopTT_Great_Lakes_Feasibility_Study.pdf?p=pdf.

[102] *Ibid.*

[103] Financial returns represent the specific cash flow available for immediate use by the asset owner. Economic returns encompass both the financial returns and additional rights or benefits that may not yet have materialised as cash flows, such as those arising from pending invoices yet to be disbursed.

[104] Hyperloop TT (2019), "Great Lakes Feasibility Study", https://mma.prnewswire.com/media/1055193/hyperloopTT_Great_Lakes_Feasibility_Study.pdf?p=pdf.

[105] DB Engineering & Consulting (2022). Hyperloop Comparison Study, p.14

transport theoretically accommodates 16,600 passengers per hour[106]. Its **throughput could be considerably higher than other high-speed transport modes**. This has significant positive implications for the financial viability of hyperloop technology, as the transport industry typically relies on substantial economies of scale to ensure profitability.

Concerning the distances to be covered, a study commissioned by Amsterdam Schiphol Airport notes that **hyperloop is suitable for markets with distances of 100 - 3000 km**, with a sweet-spot between 500-1750 km, which aligns with the **traditional scopes of intercity rail and air transport**[107]. **The study presents hyperloop as a sustainable means of transport** that could contribute to "sustainable ways to accommodate aviation demand, reduce airport congestion and maintain the competitive position of AAS as an international multi-modal hub." Hence, hyperloop may also play a role in maintaining accessibility of existing vital infrastructure. Hyperloop could also provide **significant value for shorter distance intercity transport**, as evidenced by the study commission by the Province of North-Holland in the Netherlands[108]. The study concludes that connections with nearby cities between 50-250 km from Amsterdam could lead to agglomeration benefits and increased GDP.

Moreover, **road transport**, which particularly focuses on 'last mile' services, stands to **benefit from the potential alleviation of road congestion resulting from the integration of hyperloop transport in Europe**[109], further enhancing the opportunities to promote the adoption of hyperloop transport.

Regarding **freight transport**, the business case for developing hyperloop technology could be seen in a **broader perspective with other modes**. The portion of the freight market currently interested in the high speeds that hyperloop could offer is presumed to be the existing market for air freight, accounting for only 2% of ton-miles but representing 40% of freight value[110]. Although this means hyperloop could play a significant role in high value-added logistics services, the overall impact on traffic is low. The **business case** for such services could be viewed in combination with passenger transport to achieve additional benefits of the investment into the network, **increasing the attractiveness of such investments**. This could free up capacity on existing infrastructure to accommodate more freight on rail, contributing to the goal of doubling rail freight traffic by 2050[111].

Unbiased business cases stimulate public bodies at the national and supranational level in allocating funds and making investment decisions for transport projects. **With a compelling business case for hyperloop, they may be willing to allocate significant resources to a technology that could bring high economic viability**. With a strong case in place, hyperloop could potentially complement and enhance transport projects with more established track records. As previously pointed out, ongoing developments are leading to rapid changes in the sector's state of development, namely in the preparation of unbiased business cases.

Although further efforts are needed, a shift in institutional mindset is becoming apparent, with President Ursula von der Leyen, Commissioner Tzitzikostas, and former BCE President Mario Draghi expressing their support for the initiative in recent months, as described above. Nevertheless, most

[106] *Ibid.*

[107] Schiphol (2020). Hyperloop naar de toekomst. https://www.schiphol.nl/nl/innovatie/blog/hardt/

[108] Hardt Hyperloop (2020). Hyperloop concept study with Province Noord-Holland. https://issuu.com/hardthyperloop/docs/report_hyperloop_noord-holland_-_hardt

[109] Alves, F. (2020) "The effects of hyperloop on the long-range personal and freight transportation industry in Europe" Universidade Católica Portuguesa. https://repositorio.ucp.pt/bitstream/10400.14/29666/1/152118028_Filipe_Coelho_Alves_DPDFA.pdf

[110] *Ibid.*, p 21.

[111] Green Deal: Greening freight for more economic gain with less environmental impact - European Commission

of the concerns relate to the financial and economic viability of deploying and commercialising the technology as discussed in more detail in Section 7. Moreover, there are certain technical barriers as discussed in more detail under threats in Section 4.3.4.

4.3.3 Opportunities

For a technology like hyperloop to be effectively implemented, it must be integrated into an ecosystem that actively accelerates its development. This requires a setting where innovation is not only encouraged but structurally supported. In this context, fostering collaboration among partners while maintaining the integrity of competitive business models, creates a dynamic balance between shared progress and market-driven incentives, ultimately driving efficient advancements. This could be accomplished through the co-financing of a shared European testing facility or a network of facilities, enabling companies to trial and demonstrate their technologies while contributing to the development of a unified Hyperloop standard with strong commercial potential. The Hyperloop Development Programme vision paper of December 2024[112] suggests that a network of research and development centres could be aligned with the ongoing efforts on the European Strategy Forum on Research Infrastructures (ESRFI) 2026 roadmap to create a robust and sustainable European Research Infrastructure ecosystem. Public investments can support research, experimentation, and risk reduction in early stages. Both guarantee schemes and launch aid similar to those used in the aviation industry (e.g. Airbus) can finance hyperloop. As a complementary approach, public-private partnerships (PPPs) would enable the mobilisation of private capital for large-scale implementation and operational management of the infrastructure.

While regulation usually follows innovation, the prevailing view is that a certain degree of regulatory support may be required to capitalise on all opportunities and develop the sector further and for investors to gain confidence that the technology will be permitted to operate[113], as mentioned also above in Section 3.2.1. Given that hyperloop is a new technology, there are still many unknowns regarding its practical implementation, and an enhanced policy framework would help to address these uncertainties and ensure that the technology is developed and deployed in a responsible and sustainable manner.

, the 2021 study highlights three main challenges in developing a future regulatory framework for hyperloop. First, the concept and its technologies are still evolving, making it difficult to define an appropriate regulatory structure; a gradual, iterative EU-level approach is therefore considered most viable. Second, the allocation of responsibilities among stakeholders remains unclear and will require a solid understanding of system operations. Third, political dynamics—including divergent national interests and regulatory caution from safety authorities—may complicate progress. Strengthening institutional capacity and technical expertise will also be essential as the system develops[114].

to fully capitalise on these opportunities, a structured framework that offers clarity and direction can further support development and attract investment. As hyperloop technology is still under development, its deployment heavily depends on the ability to attract investments. In this context, **semi-regulatory considerations could support investor confidence and create the necessary conditions for the technology's market introduction**. In this way, the EU does not even have to free up resources for these investments themselves. Merely showing that there is

[112] Hyperloop Development Program (2024). Hyperloop Accelerating progress toward Europe's goal of sustainable transport.

[113] ARUP (2020), "Shaping the future of hyperloop - How regulation can drive development and innovation", https://www.arup.com/perspectives/publications/research/section/shaping-the-future-of-hyperloop

[114] European Commission (2021). Study on a regulatory framework for hyperloop, an innovative transport technology.

political support for the development of hyperloop in the EU at the highest levels and that the next steps are already being prepared could motivate private investors further to come up with these.

Currently, **many hyperloop companies adopt a comprehensive approach that involves developing both the infrastructure and the pods** (passenger/freight capsules) to support the hyperloop system. An example of this is the case of Zeleros, which focuses on the development of both pods and infrastructure[115]. However, if hyperloop technology were to be regulated under the same framework as traditional railway transport (considered the most similar mode of transport to hyperloop and which is the approach more or less taken so far), this approach might require adjustments. For instance, the **existing EU legislation mandates the separation of infrastructure management from passenger and freight operations to address competition concerns**[116]. This conflicts with the integrated approach favoured by hyperloop companies, potentially impacting their investments. In response, hyperloop developers might need to adapt their investment strategies to align with the legal requirements, leading to potential changes in their business models. So far, research findings indicate that **different hyperloop development companies have expressed a positive attitude towards establishing industry standards** to create a conducive regulatory environment[117]. According to these reports, hyperloop developers believe that **defining standards collectively, while having an independent body to assess and enforce them, would facilitate market entry**[118]. For instance, HyperloopTT and TÜV SÜD, an international engineering services company, voluntarily collaborated to develop comprehensive guidelines. These companies partnered up to establish certification guidelines for hyperloop systems, formulating guidelines that combine HyperloopTT's Hazard Analysis and Risk Assessment with pre-existing regulations from diverse sectors like railways, urban transit systems, aerial cableways, amusement rides, aviation and industrial processes[119]. Rather than introducing entirely novel standards, the document primarily emphasises the adoption of optimal practices for ensuring safe operations, and the guidelines have been successfully integrated into HyperloopTT's business proposition. These guidelines were then presented to both the European Commission and the U.S. Department of Transportation for their consideration, demonstrating the sector's readiness to embrace a technical regulatory framework[120].

Similarly, the 2020 annual work plan of the former **Shift2Rail** included a call for proposals to gather "*all relevant stakeholders around a common encompassing activity on **innovative concepts for guided transport modes**. The outcome of this activity should provide clarity on operational concepts and standardisation possibilities and also enable a structured discussion with policymakers around safety/security and transport system(s) integration at [the] European level*"[121], further indicating the industry's willingness to explore opportunities for standardisation in the field. This positive outlook within the sector has also led to the **adoption of a European standard for hyperloop transport by CEN-CENELEC** mentioned above, which **hyperloop developers adhere to even in the absence of a mandatory EU requirement to do so**[122]. In a previous report from 2021, stakeholders had already highlighted the necessity of establishing international standards for

[115] Zeleros, "Connecting the world in a matter of minutes", https://zeleros.com/network/.

[116] Directive 2001/12/EC of the European Parliament and of the Council of 26 February 2001 amending Council Directive 91/440/EEC on the development of the Community's railways, art 6(2).

[117] ARUP (2020), Shaping the future of hyperloop - How regulation can drive development and innovation, https://www.arup.com/perspectives/publications/research/section/shaping-the-future-of-hyperloop, p 13.

[118] ARUP (2020), "Shaping the future of hyperloop - How regulation can drive development and innovation", https://www.arup.com/perspectives/publications/research/section/shaping-the-future-of-hyperloop, p 13.

[119] HyperloopTT, "HyperloopTT Assets", https://www.dropbox.com/sh/p85hepf1y829aju/AABFrZs_-KhBRz-xc2I35LYga.

[120] U.S. Department of Transport (January 2021) "Hyperloop Standards Desk Review", p 8.

[121] Europe's Rail (2020) "Shift2Rail Annual Work Plan and Budget 2020", p 126.

[122] CEN-CENELEC, "Transport and Packaging", https://www.cencenelec.eu/areas-of-work/cenelec-sectors/transport-and-packaging-cenelec/railways-and-hyperloop-systems/.

hyperloop[123]. Taking a comparative perspective with the railway sector again, the Fourth Railway Package unlocked for railway operators active in different Member States the possibility of offering passenger services throughout the EU[124]. If this framework was extended to include hyperloop transport, it would have the potential to **ignite cross-border investments across multiple Member States, fostering a landscape of increased collaborations and cooperation agreements among hyperloop developers**. The realisation of these opportunities relies on a clear and well-defined framework, as without it, the potential of cross-border investments and partnerships might not be fully harnessed. Furthermore, EU legislation enforces rules for **fair access to railway infrastructure** and stipulates that public service contracts must undergo competitive tenders[125]. Applying a similar framework to hyperloop would ensure that **different hyperloop service providers or operators have equal opportunities to use the same infrastructure to offer their services**. This would prevent any monopolies and promote healthy competition within the hyperloop industry. Such a framework may attract investors as it ensures a **level playing field** and reduces the risk of infrastructure access barriers favouring incumbents over new entrants, which is essential in the development of a new service/product[126]. The existence of public service contracts awarded through competitive tenders means that the **relevant authorities would be involved in overseeing the hyperloop operations and service quality**. This can provide investors with greater **certainty about the market demand and potential revenue streams**, as these contracts would likely come with defined terms and financial arrangements. Ultimately, securing investments in hyperloop requires a supporting environment that remains adaptable to and supportive of ongoing technological advancements in the sector (e.g. being technologically neutral).

While sea freight and short-sea shipping are among the slowest transport modes, their low cost makes them suitable for most cargo.[127]. In response to this need, recent presentations by Hyperloop One have focused on putting the hyperloop tubes underwater to reduce reliance on costly land acquisition. This approach have been explored in the context of enhancing **offshore port facilities**, considering that numerous ports currently face capacity spatial constraints due to limited available land. By unloading containers from ships and transporting them via hyperloop tubes to be sorted and distributed inland using equipment on offshore platforms, this approach offers a **promising solution to expand port facilities and address the pressing capacity challenges**[128]. Hyperloop One projected a cost of nearly USD 65 million (equivalent to EUR 149 million in 2022) per kilometre for an underwater track between Helsinki and Stockholm, which includes the cost of vehicles[129].

Additionally, the 2021 study on a regulatory framework for hyperloop[130] identified the need to **address intermodality requirements** ensuring seamless integration with other transport modes within a single journey and aligning with the Sustainable and Smart Mobility Strategy. For passenger transport, integration should focus on shared hubs connecting hyperloop with bikes, buses, trains,

[123] European Commission (2021). Study on a regulatory framework for hyperloop, an innovative transport technology.

[124] Directive (EU) 2016/2370 of the European Parliament and of the Council of 14 December 2016 amending Directive 2012/34/EU as regards the opening of the market for domestic passenger transport services by rail and the governance of the railway infrastructure.

[125] Directive 2001/14/EC of the European Parliament and of the Council of 26 February 2001 on the allocation of railway infrastructure capacity and the levying of charges for the use of railway infrastructure and safety certification.

[126] OECD (May 2023) "Competition and Innovation, Part I: a theoretical perspective", para 27.

[127] Duan et al. (2019) "Freight service network design with heterogeneous preferences for transport time and reliability" 124 Transportation Research Part E: Logistics and Transportation Review 12. https://doi.org/10.1016/j.tre.2019.02.008

[128] Taylor et al. (2016) "hyperloop Commercial Feasibility Analysis: High Level Overview" NASA, p. 2 https://rosap.ntl.bts.gov/view/dot/12308

[129] HyperloopOne (July 2016) "Pre-feasibility study Stockholm – Helsinki using HyperloopOne technology".

[130] European Commission (2021). Study on a regulatory framework for hyperloop, an innovative transport technology.

and planes rather than standalone terminals. Key factors include efficient pod movement, fast boarding and disembarking, smooth passenger and luggage flow, integrated security screening, and unified ticketing systems to ensure effortless transitions between modes. For freight, intermodality means reducing handling when shifting between transport modes, improving security, and increasing efficiency. This requires aligning hyperloop with standard container and pallet sizes, enabling fast loading and unloading, and streamlining administrative processes such as reservations, payments, and invoicing.

Lastly, **AI can enhance hyperloop in multiple ways**, as outlined in a 2019 briefing by the European Parliament for multiple transport modes[131] following the Communication of the European Commission on the EU strategy for automated mobility[132]. Taking railway as an illustrative case, AI is transforming the industry by improving automation, efficiency and maintenance while enhancing both passenger and freight transport. The development of the **Automatic Train Operation (ATO) system** has been one major contribution, being able to work across various rail segments. The predecessor of Europe Rail started working towards a **standardised ATO framework**, while major rail operators including the French SNCF are actively testing and deploying autonomous train technologies. Trains can rely on AI-powered sensors, cameras, and radars to detect signals and obstacles, replicating the sensory and cognitive functions of human drivers. AI is also being used to analyse passenger behaviour on platforms, ensuring automatic door closures happen safely. Another application is related to rail freight operation enhancement. As intermodal container transport grows, the technology is being used to improve train scheduling and optimise resource utilisation. Real-time data exchange and synchronisation efforts have already shown promising results, with successful ATO tests conducted on freight routes such as the Betuwe corridor between Rotterdam and Germany. AI will also be crucial in predictive maintenance. Beyond operations and maintenance, AI is revolutionising asset management through digital twin technology. By creating a virtual representation of rail infrastructure and train components, AI helps predict failures, track system degradation, and suggest design improvements. Infrastructure managers, including Rete Ferroviaria Italiana (RFI), are leveraging AI-powered digital models to integrate geolocation data and provide a detailed technical overview of railway networks.

Ultimately, AI is reshaping rail transport by increasing automation, improving reliability, and optimising resource management. From driverless trains and real-time freight coordination to predictive maintenance and digital asset monitoring, AI-driven technologies are making rail systems more efficient, safer, and better suited to future mobility demands[133].

4.3.4 Threats

Within a hyperloop network, **various technologies could be implemented**, and the **compatibility** between different propulsion and levitation technologies **is crucial**. The use of diverse technologies can lead to the creation of pods and tracks that are not interoperable with those of competitors, resulting in inefficiencies. While the ongoing development of hyperloop technology has already resulted in various efforts to assess its feasibility, due to differing categorisations and definitions of hyperloop system components, there has been **inconsistency in how existing standards are applied to this emerging transport mode**. There is a general consensus on the applicability of existing standards in the following categories: risk assessment and safety targets, basis of structural and mechanical design assumptions and analysis, materials,

[131] European Parliament (2019). Artificial intelligence in transport. Current and future developments, opportunities, and challenges. https://www.europarl.europa.eu/thinktank/en/document/EPRS_BRI(2019)635609

[132] Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee, the Committee of the Regions. On the road to automated mobility: An EU strategy for mobility of the future.

[133] Europe's Rail (September 2024). Increasing railway line capacity starts with increased automation. https://rail-research.europa.eu/latest-news/increasing-railway-line-capacity-starts-with-increased-automation/

vehicle/capsule, fire protection and evacuation, electromagnetic compatibility and exposure, information security and certification[134].

Non-interoperable regulatory frameworks at national level would pose significant challenges to the seamless deployment of hyperloop transport. Firstly, these **would impede the integration of hyperloop technology with existing infrastructure**, leading to negative implications for the sustainability of the current transport systems (i.e. and going against the fact that partly making use of existing infrastructure is one of the major advantages of hyperloop, see above under strengths). This way, a **lack of harmonisation may result in the duplication of infrastructure**, requiring additional land for the construction of separate hyperloop tracks alongside existing railway lines. This duplication would not only consume valuable land resources, but it would also have **environmental and economic consequences**, as it can lead to increased land use, higher construction costs and potential disruption to local communities. Moreover, non-interoperable regulatory frameworks could risk **limiting service provision** among hyperloop systems within Member States.

Avoiding **non-interoperable regulatory frameworks at national level** and ensuring the adoption of a unified technical framework could on the contrary have significant consequences for stakeholders such as EU institutions, agencies and other bodies, as these entities would be heavily involved in developing, and in many cases also hold the responsibility for adopting, such a framework. Non-interoperable regulatory frameworks would instead create a fragmented market for hyperloop developers as varying technical requirements, safety standards, and certification processes in each Member State make compliance complex. This fragmentation would hinder the scalability and efficiency of hyperloop deployment across multiple countries. **Adapting to non-interoperable frameworks also increases complexity and costs, requiring modifications to technology and operations**. The development of common standards can avoid unnecessary burdens for companies which would have to comply with differing or conflicting standards[135].

In addition, the goal of establishing **interoperable railway systems** includes facilitating **smooth transfers between trains**. To assess the transfer experience, ERA has analysed transfer times at border sections. This analysis found discrepancies between planned and actual transfer times for freight and passenger trains. Freight trains often experience longer and more variable transfer times, with over half of the analysed sections in 2023 recording average delays exceeding one hour. In contrast, passenger trains exhibit more stable and predictable transfer times, with average deviations of ±6 minutes. Factors influencing these variations include infrastructure design, geographic conditions, operational constraints, and necessary technical adjustments. These findings underscore the existing challenges in achieving efficient and seamless transfers, particularly for freight operations, at the analysed border sections. Considerations on ensuring seamless transfer through interoperable hyperloop systems will also be paramount in view of the high speed at which hyperloop pods travel, and for which efficient and safe management of hyperloop operations and transfers needs to be guaranteed.

A useful reference can be found in the aviation sector, where standardisation seems to have been successful. At the international level, the International Civil Aviation Organisation (ICAO), active since 1947, is responsible for establishing the necessary standards and recommended practices for aviation worldwide. The first common standards for aviation safety in Europe were developed by the Joint Aviation Authorities (JAA) based on the voluntary cooperation of Member States between 1970 and the early 2000s[136], while the European Union Aviation Safety Agency (EASA) became active in Europe in 2002. The long duration of standardised practices in aviation has contributed significantly to the level of interoperability seen today. A primary reason that could be named is the

[134] U.S. Department of Transport (January 2021) "Hyperloop Standards Desk Review", p 15.

[135] European Commission (2021). Study on a regulatory framework for hyperloop, an innovative transport technology.

[136] JAATO. (n.d.). https://jaato.com/virtual-home/

potential for **global connectivity** that aviation enjoys. Furthermore, **aviation has experienced rapid growth in recent decades**. This has **spurred technological advancements**, paving the way for opportunities to **streamline standardisation processes**[137].

The adoption of standards and initiatives by the ICAO — such as the Aviation System Global Block Upgrades[138] and a revised Global Air Navigation Plan[139]) — has resulted in regulatory consistency, technological advancement, and operational benefits for aviation worldwide. At the EU level, **interoperability is a fundamental component of the Single European Sky (SES)[140]**, which seeks to standardise and harmonise air traffic management (ATM) within the EU and with cooperating States. Among the SES regulations, one specifically addresses ATM system interoperability[141], allowing the European Commission to adopt Implementing Rules and Community Specifications for introducing new ATM technologies. Finally, the Single European ATM Research Programme (SESAR)[142], established with the purpose of defining, developing, and ultimately implementing the next-generation European ATM system, also adopts interoperability as one of the eleven key performance areas used to evaluate ATM performance.

With digitalisation driving the transition from conventional railways to hyperloop, the railway sector has traditionally relied on an application-centric approach for data exchange among multiple actors[143]. This approach has prioritised individual applications or software programmes rather than broader interoperability and system integration. As a result, isolated digital environments have emerged, hindering interoperability, slowing down innovation, and increasing maintenance costs. From ERA's perspective, this is being addressed through a linked approach to databases and the development of a knowledge graph. Differently, the air transport sector, through the SES initiative, has taken steps towards standardisation. For instance, SES' designation of EASA as the exclusive certifying authority for both airborne and ground equipment, ensured uniform certification practices. This harmonisation is particularly relevant as digitalisation makes data exchange between ground and airborne systems increasingly common.

Overall, without harmonisation, fragmentation could lead to duplicated infrastructure, increased costs and market inefficiencies, as the experience of the railway sector suggests. Digitalisation in the railway sector further underscores the need for a unified approach to facilitate efficient data exchange and system compatibility. Lessons from the aviation sector highlight the benefits of early standardisation, which facilitated smoother integration.

4.4 Concluding remarks

In terms of strengths, hyperloop offers notable advantages in speed, sustainability, and system resilience, with the potential to significantly reduce emissions, noise and land use. Its promises of

[137] International Energy Agency (IEA), Tracking Aviation. https://www.iea.org/energy-system/transport/aviation.

[138] International Civil Aviation Organization (2011). Aviation System Block Upgrades. https://www.icao.int/Meetings/anconf12/ASBUs/ASBU%20Working%20Doc%20full%20version_Edition2_V3.pdf

[139] International Civil Aviation Organization (2016). Global Air Navigation Plan 2016-2030 https://www.icao.int/airnavigation/documents/ganp-2016-interactive.pdf

[140] Regulation (EC) No 549/2004 of the European Parliament and of the Council of 10 March 2004 laying down the framework for the creation of the single European sky

[141] Regulation (EC) No 551/2004 of the European Parliament and of the Council of 10 March 2004 on the organisation and use of the airspace in the single European sky

[142] Commission Implementing Regulation (EU) 2021/116 of 1 February 2021 on the establishment of the Common Project One supporting the implementation of the European Air Traffic Management Master Plan provided for in Regulation (EC) No 550/2004 of the European Parliament and of the Council, amending Commission Implementing Regulation (EU) No 409/2013 and repealing Commission Implementing Regulation (EU) No 716/2014

[143] Rojas et al. (September 2021). Leveraging Semantic Technologies for Digital Interoperability in the European Railway Domain, International Semantic Web Conference 2021.

design features enabling safer, more efficient and weather-resilient transport align well with current EU climate and mobility objectives. Despite cost uncertainties, it stands as a promising complement to existing networks in supporting the green and digital transition. In terms of challenges, hyperloop still faces several technical and operational hurdles, such as ensuring interoperability, developing carbon-neutral materials and establishing reliable control systems. Additionally, while early business cases suggest promising socio-economic returns, the absence of a clear, widely accepted assessment of its viability may limit coordinated investment and policy support. Further work is needed to clarify its role within Europe's future transport system. In terms of opportunities, hyperloop development could benefit significantly from a supportive ecosystem combining innovation, public-private cooperation and semi-regulatory tools. Coordinated efforts such as co-financed testing facilities, shared standards and gradual regulatory alignment could accelerate progress and attract investment. A structured framework would also help developers adapt to existing EU rules while maintaining sectoral momentum. A coordinated approach to intermodality is equally crucial to maximise efficiency and connectivity across transport networks. Advances in AI and interest in freight integration, including offshore applications, further expand the scope for future deployment. In terms of threats, the lack of interoperability may hinder the efficient deployment of hyperloop in the EU. Diverging technologies and fragmented national frameworks may lead to incompatible systems, higher costs and duplicated infrastructure. The aviation sector offers a relevant example, having achieved effective standardisation across borders.

Box 4: Key takeaways

Strengths

Hyperloop holds strong potential in terms of speed, sustainability, and resilience. It promises reduced emissions, noise, and land use, contributing to the **EU climate and mobility goals**. As a complement **to existing transport networks, it could support the twin transition.**

Challenges

However, technical and operational barriers (interoperability, carbon-neutral materials, control systems) remain. **Uncertainties on** EU-wide **costs and socio-economic returns**, as well as a l**ack of common assessment**s, limit **investment and** EU **policy coordination**.

Opportunities

There is a significant scope for progress **through innovation, public-private cooperation, and semi-regulatory tools**. **Co-financed testing, shared standards, and regulatory alignment could accelerate deployment**. At the same time, advances in AI and **freight integration, including offshore, broaden the application scope**.

Threats

Nonetheless, diverging technologies and national frameworks risk fragmenting the landscape. The a**bsence of interoperability may lead to inefficiencies and higher costs**.

5. PASSENGER TRANSPORT ANALYSIS

This chapter describes the expected market position and demand projections for passenger transport during the period 2025-2050. Firstly, hyperloop deployment and European network is described, followed by modal share trends for long-distance passenger transport, expected passenger demand in 2050 and hyperloop impact on induced demand. The results presented in this section stem from the reports published by hyperloop developers, as well as preliminary stakeholder consultation. Whenever limited or less granular, data was extrapolated using a number of assumptions presented in Appendix 1. It is also worth pointing out that the analysis presented herein relied on data provided by a number of hyperloop promoters and other stakeholders in the summer of 2024. Moreover, the assumptions considered by each stakeholder also varied. Whenever possible, we outline these differences in the report. Nonetheless, the analysis below should be considered as a broader view of how a possible hyperloop network could be considered in the medium-term in the EU27. Yet not all assumptions could be necessarily quantified, as inputs were often provided in a qualitative basis.

5.1 Hyperloop deployment and European network

To conduct an analysis of the potential passenger transport, it is essential to first take a step back and understand the anticipated deployment and evolution of the hyperloop network. Data provided by various hyperloop promoters indicate different expectations for development timelines and network growth.

As previously stated in 3.1.2, Hyperloop promoter 6 forecast deployment by 2036, while Hyperloop promoter 4 as early as 2030. In addition, Hyperloop promoter 4, the first long-distance hyperloop lines, carrying commercial passengers at 1,000 km/h, are projected to become operational by 2045[144]. Hyperloop promoter 5, in its Vision 2050, anticipates a south-north link connecting Barcelona to Munich and a southern link connecting Lisbon to Naples, with potential extensions to a Eurasian corridor in 2050[145]. Hyperloop promoter 6 proposes an alternative vision for Europe by implementing the concept of "interconnected loops", aiming to implement independent loops based on the same technology and develop the network across decades by enabling technology upgrades. At this stage, based on the information shared with the contractor's team, promoters primarily envision hyperloop as an intercity transport solution rather than a network within individual cities or a large-scale commuting service.

Hyperloop promoter 1 projects a steady increase in operational network length, expecting up to 160 kilometres growth annually by 2040, and from there 1,200 growth a year. By 2050, it estimates a cumulative operational network length of 10,060 kilometres, which will further expand to 22,060 by 2060, as detailed in the table below[146].

Table 4: Hyperloop network operational per year

	2035	2040	2045	2050	2055	2060
Kilometre network operational annually	120	160	1,200	1,200	1,200	1,200
Cumulative operational kilometre	120	720	4,060	10,060	16,060	22,060

Source: Hyperloop promoter 2

[144] Data sent retrieved during data collection phase.

[145] Zeleros, *Vision for hyperloop in Europe 2050*, available at: https://zeleros.com/vision-for-hyperloop-in-europe-2050/

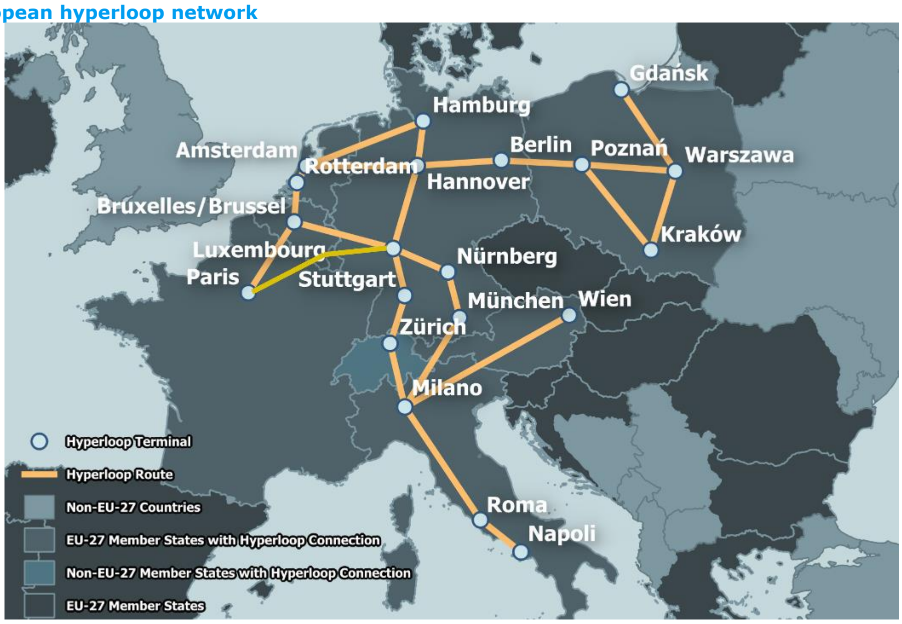
[146] Data sent retrieved during data collection phase.

On the other hand, Hyperloop promoter 6 outlines a rollout beginning in 2036, with an initial network growth rate of 50 kilometres per year for the first five years. This will be followed by an accelerated growth phase with a higher rate of 100 kilometres per year lasting six years[147].

Concerning a hyperloop network covering partially Europe, we have integrated the insights from Hyperloop promoter 1, Hyperloop promoter 2, Hyperloop promoter 3 and Hyperloop promoter 5, in order to create the European hyperloop Network passenger map for 2050. This network map will help feed the analysis of the different scenarios foreseen.

As presented in Figure 3, in 2050 the hyperloop transport network is expected to cover the Netherlands, Belgium, Luxembourg, Germany, France, Italy, Austria and Poland. This would represent a coverage of 6,207 km. Thus, according to these projections, the European hyperloop network is not expected to be operational in 20 EU Member States by 2050, with no impact on demand expected in these countries. This was used as one of our scenarios.

Figure 3: European hyperloop network



Source: elaboration of the Partnership (2025), adapted from hyperloop promoter 1, 2 and 5

Box 5: Workshop inputs on defining a European Hyperloop Network

Hyperloop European Network: workshop discussion

One of the key takeaways from the February workshop was the importance of integrating hyperloop system with the TEN-T network to strengthen its business case.
In this case, hyperloop is considered as a potential addition to the network for cross-border inter-city connections, where no competitive rail links exist (for example, Warsaw-Berlin-Amsterdam), and can provide missing links where conventional transport modes such as high-speed rail cannot offer solutions or are too difficult to implement. Finally, hyperloop **can also connect smaller cities not connected to the HSR network to the large agglomerations. This approach reinforces Hyperloop's complementary role alongside existing transport modes, particularly rail, rather than competing with them.**
In this context, promoters have proposed to start work on identifying routes where hyperloop could complement the existing TEN-T network.

Source: Inputs from the workshop participants

Given these diverse projections, and in alignment with PRIMES-TREMOVE and other EU sources, the analysis presented here in focuses primarily on the year 2050. Prior to this date, significant activity is not anticipated at a larger scale. It is also worth mentioning that PRIMES-TREMOVE was

[147] *Ibid.*

used as the basis to estimate passenger projections for the different modes of transport with a potential deployment of hyperloop systems, in line with the baseline scenario presented in the Support study for an impact assessment on new rules for making the passenger rights framework resilient and future-proof[148]. The analysis presented herein incorporates different scenarios developed to capture potential variations in deployment and growth. These scenarios were considered by considering the relevant desk research findings, as well as early outputs from the preliminary stakeholder consultation. The table below provides a concise overview of the four scenarios, together with the three sub-scenarios.

Table 5: Description of scenarios and sub-scenarios

Scenario	Description
Scenario 1	No-policy change scenario considering substitution market share provided for Hyperloop to replace all rail passengers and air passengers (excluding extra-EU Flights)
Scenario 2	No-policy change scenario considering substitution market share provided for Hyperloop to replace high-speed rail passengers (excluding conventional rail) and air passengers (excluding extra-EU Flights)
Scenario 3	New Substitution Market Share (conservative) for Hyperloop to replace high-speed rail and intra-EU air passengers considering no-policy change scenario
Scenario 4	Substitution market share provided for Hyperloop to replace high-speed rail passengers (excl. conventional rail) and air passengers (excluding extra-EU Flights) and additional 5% of induced demand relative to the baseline scenario
Sub-scenario	**Description**
Sub-scenario 1	Hyperloop network covering the EU27 (22,060 km)
Sub-scenario 2	Hyperloop network only covering 8 Member States (Austria, Belgium, France, Germany, Italy, Luxembourg, the Netherlands, Poland) (6,207 km)
Sub-scenario 3	Hyperloop network only covering Benelux (632 km)

Source: Elaboration of the Partnership (2025)

5.2 Modal share trends for long-distance passenger transport

Another critical aspect in drafting the scenarios was the consideration of hyperloop's modal shift from existing transport modes. hyperloop promoters agree that air transport is the primary competitor for hyperloop transport, whereas there are strong natural synergies with the rail sector. These synergies stem from hyperloop and rail's shared emphasis on sustainable, high-capacity and efficient land-based transport solutions, making them complementary rather than competitive. Moreover, hyperloop could complement rail transport by alleviating network congestion and helping to overcome its current capacity limitations.

Another key point of consensus among hyperloop promoters is that hyperloop will primarily compete with intra-EU flights rather than extra-EU flights. Consequently, the implementation of hyperloop is not expected to impact the extra-EU aviation market.

Regarding intra-EU flights, hyperloop promoters predict a significant modal shift from aviation to hyperloop. Hyperloop promoter 2, which includes Hyperloop promoter 1, Hyperloop promoter 5, Hyperloop promoter 3, and Hyperloop promoter 7, estimates a modal shift from aviation to hyperloop of 66%[149], while a study from Hyperloop promoter 1 indicates 64.9%[150]. Similarly, Hyperloop promoter 6 anticipates a modal shift of 53% from aviation to hyperloop[151].

[148]*Support study for an impact assessment on new rules for making the passenger rights framework resilient and future proof*, 2024, available at: https://op.europa.eu/en/publication-detail/-/publication/1ad56c92-3366-11ef-b441-01aa75ed71a1/language-en

[149] Hyperloop Development Program, Hyperconnected Europe: A vision for the European network, 2022.

[150] Hardt hyperloop, Concept Study on the impact of hyperloop on the Development perspective "Compacte Metropool, 2020.

[151] Data sent retrieved during data collection phase.

In terms of modal shift from rail to hyperloop, Hyperloop promoter 1 projects a shift of 44.7%. According to Hyperloop promoter 7, the modal shift from rail to hyperloop is expected to be lower than that from aviation to hyperloop due to differences in the type of rail services and the distances they cater to. Conventional rail, which often serves shorter-distance and regional trips, is expected to experience a shift to hyperloop for routes where hyperloop offers significant time savings or better connectivity. However, the shift is limited because hyperloop is optimised for long-distance travel. For shorter distances, conventional rail remains competitive[152].

5.3 Expected passenger demand

As previously pointed out, estimates from different hyperloop developers show that passenger demand will shift from traditional modes of transport to hyperloop, considering a mode-substitution factor[153].

We have developed various scenarios to assess the impact of hyperloop operations on passenger demand, given the uncertainties regarding the impact of hyperloop deployment in the entire transport system, as well as due to the lack of unbiased data154. The various scenarios consider different levels of hyperloop implementation in Europe. The four scenarios considered are as follows:

1. Excluding extra-EU flights (i.e. considering that hyperloop transport will only substitute intra-EU air transport, as abovementioned)
2. Excluding conventional rail transport, as it is not foreseen that hyperloop will substitute conventional rail, which covers mostly regional services. In this second scenario, we used the share of high-speed rail services for all Europe, as reported in the Statistical Pocketbook: EU Transport in figures 2024155. Under this scenario, conventional rail is excluded entirely from the baseline passenger total and is therefore not considered in the analysis.
3. "Conservative" scenario. The specific assumptions underlying these scenarios will be detailed in subsequent sections.
4. Induced demand scenario

In addition, and for each of these scenarios, we have outlined three micro-scenarios:

1. The first scenario foresees that hyperloop transport will have an impact on transport demand (for passenger and freight) at an EU-27 level by 2050.
2. The second scenario considers that hyperloop transport will only have an impact in transport demand in eight EU-27 Members States (Netherlands, Luxembourg, Belgium, Germany, France, Italy, Austria and Poland) in the same year.
3. In the third scenario, we consider that hyperloop operations will only be limited to the Netherlands, Belgium and Luxembourg in 2050.

Considering the results from the stakeholder consultation and desk research, we have considered scenario 3 to be the most realistic. This is partly due to the build-up of hyperloop in Europe, as a the hyperloop system is expected to grow from a limited network connecting major hubs to a more extensive system spanning multiple Member States. This network will also integrate with conventional rail services, including suburban and regional connections. The improvement of the

[152] Eurotube Foundation, Potential analysis for vacuum transport technologies in public transport in Switzerland: Life-cycle analysis with focus on energy consumption and environmental impact of a vacuum transport infrastructure, 2023.

[153] Under this context, substitution factor refers to an estimated portion of the market share that a hyperloop transport system could potentially capture from the existing transport modes.

[154] All projections currently available have been estimated by hyperloop developers, which may include a certain level of bias.

[155] European Commission, Statistical Pocketbook: EU Transport in figures 2024.

combination of rail and hyperloop services would improve the overall competitivity and could induce additional passenger demand on the network.

Therefore, this section only presents the results from scenario 3, with the results from the other scenarios being presented in Appendix 1. Hence, we have thus projected the estimated market share in terms of the number of passengers for the year 2050 in the EU-27, considering the previously mentioned European coverage for scenario 3.

Firstly, the substitution factors from Hyperloop promoter 1 were used to estimate the market share in terms of passenger numbers for hyperloop transport156. This refers to the proportion of passengers shifting from existing transport mode (i.e. rail and intra-EU air transport) to hyperloop[157]. The table below presents the substitution factors estimated by Hyperloop promoter 1.

Table 6: Substitution per mode on international passenger trips in Europe

Modes	Substitution factor
Air	-64.9%
Rail	-45.1%

Source: Hyperloop promoter 1

In addition, according to data retrieved following the workshop held on 14th February, the addition of 700 track-km of hyperloop to the 7,000 track-km of rail (around 10% of the network) leads to an additional 20% demand on the combined rail and hyperloop network[158]. This indicates that the addition of hyperloop could improve the modal share and traffic of rail systems.

Scenario 1: No-policy change scenario considering substitution market share provided for hyperloop to replace all rail passengers and air passengers (excluding extra-EU flights)

Based on these substitution factors, we have estimated the market share of hyperloop transport, considering the coverage of only Belgium, the Netherlands and Luxembourg, and assuming that hyperloop will only have an impact on passenger demand in intra-EU air transport (i.e. excluding extra-EU flights)[159]. When envisioning a European hyperloop network that partially covers three EU Member States, hyperloop is estimated to account for approximately 15% of the total passenger transport demand in Europe[160], in terms of the number of passengers, as presented below. As previously mentioned, the baseline scenario (i.e. a scenario of no hyperloop development) was drawn from the Support study for an impact assessment on new rules for making the passenger rights framework resilient and future-proof[161].

[156] Hardt hyperloop, Concept Study on the impact of hyperloop on the Development perspective "Compacte Metropool"

[157] Bus and coach passengers and passenger car are not considered in this analysis as no estimated modal shift from such modes was provided.

[158] ProRail Study.

[159] While the scenario considers the replacement of rail and air passengers, the selected geographical scope (Benelux) already has a limited share of air travel. However, the methodology has been applied consistently across all scenarios.

[160] Excluding bus and coach passenger transport.

[161] *Support study for an impact assessment on new rules for making the passenger rights framework resilient and future proof*, 2024, available at: https://op.europa.eu/en/publication-detail/-/publication/1ad56c92-3366-11ef-b441-01aa75ed71a1/language-en

Table 7: No-policy change scenario considering substitution market share provided for hyperloop to replace all rail passengers and air passengers (excluding extra-EU Flights) in Benelux

Mode	Number of passengers in 2050 (millions)	Passenger Market Share with hyperloop
Intra-EU Air transport	442	3%
Rail (conventional and high-speed rail)	11.380	85%
Hyperloop	1.936	15%

Source: elaboration of the Partnership (2025)

Furthermore, we have projected passenger numbers over a 10-year period from 2050 to 2060. In the absence of more detailed data, the growth in passenger numbers for 2050-2060 is assumed to follow the same growth rate observed during the 2040-2050 period, relative to the baseline. Based on this assumption, hyperloop is projected to account for 2,121 million passengers by 2060, assuming a network covering three Member States, with passengers shifting from both conventional rail and high-speed rail and intra-EU flights to this new mode of transport.

Table 8: Passenger number projections (in a 10-year series) under scenario 1

Mode	2050 Number of passengers per mode (million)	2055 Number of passengers per mode (million)	2060 Number of passengers per mode (million)
Intra-EU air	442	463	484
Rail	11.380	11.910	12.486
Hyperloop	1.936	2.026	2.121
Total number of passengers in the modes considered	13.757	14.398	15.090

Source: elaboration of the Partnership (2025)

Scenario 2: No-policy change scenario considering substitution market share provided for hyperloop to replace high-speed rail passengers (excluding conventional rail) and air passengers (excluding extra-EU Flights)

As previously stated, it is likely that hyperloop will not substitute conventional rail passenger demand. Consequently, we have excluded conventional rail from the analysis of the present scenario, focusing solely on high-speed rail. This implies that conventional rail would remain unaffected by the implementation of hyperloop, with only high-speed rail being considered in the analysis. To achieve this, we have used the share of high-speed rail services of 32.6%[162].

Furthermore, we needed to estimate transport demand for two distinct groups: Member States with a hyperloop system implemented and those without one. Using Eurostat data[163,164], we calculated the share of total EU transport demand represented by the Member States with hyperloop, enabling an estimation of the proportion of high-speed rail and intra-EU flight passenger demand that would shift to hyperloop. This approach allowed for an estimation of the number of passengers transitioning from these modes to hyperloop, while, relative to the baseline, high-speed rail and intra-EU flight passenger demand is expected to remain unchanged in the Member States that will not be covered by hyperloop systems. Based on this analysis, we estimated the modal shift to hyperloop, as outlined in Table 9. In this scenario, high-speed rail is projected to account for 82% of long-distance travel in Europe, while hyperloop is expected to represent 8%.

[162] Statistical Pocketbook: EU Transport in figures 2024

[163] Eurostat, Air transport of passengers by country (yearly data) (avia_paoc)

[164] Eurostat, Rail transport of passengers (rail_pa_typepas)

Table 9: Market share of passenger transport and number of passengers under no-policy change scenario considering substitution market share provided for hyperloop to replace high-speed rail passengers (excl. conventional rail) and air passengers (excluding extra-EU Flights) considering a hyperloop Network that covers BENELUX

Modes	Number of passengers in 2050 (millions)	Passenger Market Share with hyperloop
Intra-EU Air transport	473	10%
High Speed Rail	3.914	82%
Hyperloop	369	8%

Source: elaboration of the Partnership (2025)

Additionally, Table 10 presents the projected number of passengers over a 10-year period from 2050 to 2060. By 2060, hyperloop is expected to account for 404 million passengers, assuming a network spanning eight Member States and shifting passengers from intra-EU flights and high-speed rail.

Table 10: Passenger number projections (in a 10-year series) under scenario 2

	2050 Number of passengers per mode (million)	2055 Number of passengers per mode (million)	2060 Number of passengers per mode (million)
Intra-EU air	473	495	517
Rail	3.914	4.097	4.295
hyperloop	369	386	404
Total number of passengers in the modes considered	4.756	4.977	5.216

Source: elaboration of the Partnership (2025)

Scenario 3: New substitution Market Share (conservative scenario) for hyperloop to replace high-speed rail and intra-EU air passengers considering no-policy change scenario

Lastly, a scenario with a lower modal shift towards hyperloop was developed to address potential overestimations in the projected market shares[165]. To account for this, a correction factor was applied to the baseline substitution factor of 62%[166].

This adjustment would result in a hyperloop substitution factor (modal shift) of -6% for intra-EU air passenger demand and -4% for high-speed rail passenger demand at a lower bound (90% of the provided factor). At an upper bound, the substitution factor increases to -19% for intra-EU air passenger demand and -13% for high-speed rail passenger demand.

This adjustment establishes a more conservative scenario for hyperloop development, resulting in an estimated hyperloop passengers ranging from 37 million passengers (0.8% of total transport demand) and 111 million passengers (2.3% of total transport demand) in the countries where hyperloop is expected to be implemented.

[165] The estimated market shares are mostly based on projections from hyperloop developers, which may contain an element of bias. Therefore, in order to account for a more unbiased scenario, and in the absence of more granular data, the consortium has drawn a more conservative scenario based on anecdotal evidence, based on findings from the desk research and stakeholder consultation.

[166] A correction factor ranging between 0.7-0.9 was applied to the substitution market share obtained by hyperloop developers.

Table 11: Market share of passenger transport considering a hyperloop Network that covers BENELUX, excluding extra-EU flights and conventional rail, 2050 (conservative scenario)

Modes	Number of passengers in 2050 (millions)	Passenger Market Share with hyperloop
Upper bound		
Intra-EU Air transport	482	10%
High Speed Rail	4.225	88%
hyperloop	111	2,3%
Lower bound		
Intra-EU Air	489	10%
High Speed Rail	4.291	89%
hyperloop	37	0,8%

Source: elaboration of the Partnership (2025)

Additionally, Table 12 presents the projected number of passengers over a ten-year period from 2050 to 2060. By 2060, hyperloop passenger demand is expected to range between 41 million and 122 million passengers, assuming a network spanning three Member States and shifting passengers from intra-EU flights and high-speed rail.

Table 12: Passenger number projections (in a 10-year series) under scenario 3

	2050 Number of passengers per mode (million)	2055 Number of passengers per mode (million)	2060 Number of passengers per mode (million)
Upper bound			
Intra-EU air	482	504	527
Rail	4.225	4.502	4.720
hyperloop	111	117	122
Total number of passengers in the modes considered	**4.817**	**5.123**	**5.369**
Lower bound			
Intra-EU air	489	512	535
Rail	4.291	4.573	4.794
hyperloop	37	39	41
Total number of passengers in the modes considered	**4.817**	**5.124**	**5.370**

Source: elaboration of the Partnership (2025)

5.4 Hyperloop impact on induced demand

In addition to the passengers shifting from existing transport modes to another, hyperloop promoters anticipate an induced increase in total passenger demand relative to the baseline. This arises from the improved transport connection between two cities and reduced travel times, which typically encourage more people to travel. Therefore, according to promoters, hyperloop developers would encourage further passenger growth in transport modes.

A hyperloop promoter has estimated an induced demand of 25%, aligning their projection with figures reported by the OECD for induced demand from the implementation of high-speed rail[167]. However, another hyperloop promoter (Hyperloop promoter 4) foresees a more measured annual increase in demand, estimating a yearly growth of 3–5% in passenger and freight volumes. Reflecting this more gradual perspective, the Team has adopted a conservative scenario, projecting a 5% increase in overall demand. Both scenarios exclude extra-EU flights and conventional rail. Yet, it is worth highlighting that this figure was considered considering anecdotal evidence, as the granular data available on induced demand varies considerably between the different sources.

[167] OECD, *The Economics of Investment in High-Speed Rail*, 2014.

Table 13: Market share of passenger transport considering a hyperloop Network that covers the BENELUX, excluding extra-EU flights and conventional rail, with 5% induced demand 2050

Modes	Number of passengers in 2050 (millions)	Passenger Market Share with hyperloop
Intra-EU Air transport	478	9,5%
High Speed Rail	4.192	82,9%
hyperloop	388	7,7%

Source: elaboration of the Partnership (2025)

The table below presents the projected number of passengers over a 10-year period from 2050 to 2060. By 2060, and assuming additional passenger demand of 5% relative to the baseline, hyperloop is expected to account for 428 million passengers, assuming a network covering three Member States and shifting passengers from intra-EU flights and high-speed rail.

Table 14: Passenger number projections (in a 10-year series) under scenario 4

	2050 Number of passengers per mode (million)	2055 Number of passengers per mode (million)	2060 Number of passengers per mode (million)
Intra-EU air	478	500	523
Rail	4.192	4.467	4.684
hyperloop	388	409	428
Total number of passengers in the modes considered	**5.058**	**5.377**	**5.635**

Source: elaboration of the Partnership (2025)

6. FREIGHT TRANSPORT ANALYSIS

Since the outset, hyperloop promoters have anticipated shifting all continental air freight and mail flows in EU and time-sensitive goods from long-haul trucking. However, it is important to highlight that promoters do not foresee shift from sea freight transport and rail, as the goods transported by these modes of transport are containerised and non-time critical. Moreover, some hyperloop promoters have distanced themselves from freight services, considering them less competitive and not as a viable alternative as in passenger transport.

The share of freight likely to transition to hyperloop depends on the type of goods and their time-sensitivity. High-value, time-critical shipments such as fresh goods, pharmaceuticals and e-commerce orders are expected to see the most significant shift from trucks to hyperloop.

Hyperloop demand is anticipated to primarily derive from long-haul trucking. According to projections from hyperloop promoter 2, by 2050, hyperloop could carry approximately 80% of time-sensitive goods currently transported by long-haul trucks. This would represent 19% of the total long-haul trucking demand[168].

Based on these estimates and the expected freight transport activity (Gtkm) outlined in the EU Reference Scenario, a fully operational EU-level hyperloop network could account for 470 Gtkm, translating to 13% of total freight demand in 2050[169].

Table 15: Market share of freight transport considering a hyperloop Network that covers EU-27

Modes	Freight transport activity in 2050 (Gtkm)	Freight Market Share with hyperloop
Hyperloop	470	13%
Rail	726	20%
Heavy goods and light commercial vehicles	2.003	56%
Inland waterways and domestic maritime	396	11%

Source: elaboration of the Partnership (2025)

Hyperloop network only covering 8 Member States (Austria, Belgium, France, Germany, Italy, Luxembourg, the Netherlands, Poland)

As above, an additional scenario was drafted, which presents a refined perspective, focusing on the deployment of hyperloop in eight member states, which represents a more realistic network coverage compared to the broader EU-wide scenarios. Under this scenario, hyperloop is projected to handle up to 262 Gtkm of freight transport activity in 2050, accounting for 7% of the total EU-level freight demand.

Table 16: Market share of freight transport considering a hyperloop Network that covers eight Member State

Modes	Freight transport activity in 2050 (Gtkm)	Freight Market Share with hyperloop
hyperloop	262	7%
Rail	726	20%
Heavy goods and light commercial vehicles	2.211	62%
Inland waterways and domestic maritime	396	11%

[168] hyperloop Development Program, Hyperconnected Europe: A vision for the European network, 2022.

[169] In the freight analysis, unlike passenger demand, there are no sub-scenarios excluding elements such as extra-EU flights or conventional rail. Additionally, as hyperloop promoters primarily focus on passenger services rather than freight, the information available on freight is more limited, resulting in a broader and less detailed overview compared to the passenger analysis.

Source: elaboration of the Partnership (2025)

Hyperloop impact on induced demand

Hyperloop promoter 4 projects an additional annual demand increase of 3-5% for both passenger and freight transport, attributed to induced demand generated by the introduction of hyperloop services.

Under these assumptions, and in a scenario that there is an EU-27 level coverage, hyperloop is projected to achieve 493 Gtkm of freight transport activity by 2050.

Table 17: Market share of freight transport considering a hyperloop Network that covers EU-27 level with induced demand of 5%

Modes	Freight transport activity in 2050 (Gtkm)	Freight Market Share with hyperloop
hyperloop	493	13%
Rail	762	20%
Heavy goods and light commercial vehicles	2.103	56%
Inland waterways and domestic maritime	415	11%

Source: elaboration of the Partnership (2025)

7. ECONOMIC AND OPERATIONAL ANALYSIS

This section presents an economic and operational analysis of hyperloop in Europe. Firstly, cost considerations are presented, followed by expected socioeconomic benefits. Similar to the previous sections, it is worth noting that the analysis presented in this section relies on the data received from a number of available sources in the summer of 2024. Yet, different scenarios and assumptions were considered by the different sources, so they may not be directly comparable. Thus, the following assessment should be considered as indicative.

7.1 Cost considerations

Below, firstly, capital expenditure (CAPEX) estimates for hyperloop systems are presented, followed by operational (OPEX) expenditure estimates. However, it is relevant to highlight that generalising both CAPEX and OPEX figures is complex and highly sensitive as costs drivers are volatile, set by market mechanisms and can greatly differ throughout Europe.

7.1.1 Capital expenditure estimates for hyperloop systems

In order to conduct a comprehensive market analysis, it is essential not only to assess the projected demand for both passenger and freight transport services but also to understand the key considerations for hyperloop systems and potential revenue streams. This section evaluates both the capital expenditure[170] (CAPEX) and operational expenditure (OPEX) projections for the year 2050, followed by an analysis of potential revenues from passenger and freight services[171].

The projections for infrastructure costs (excluding vehicles) per kilometre (EUR/km) across various promoters are relatively consistent, as shown in the table below. In this regard, estimates presented herein considers an average of these values as a reference for estimating CAPEX regarding infrastructure, i.e. EUR 36,616,000. In this context, two key aspects should be emphasised. Firstly, this figure exceeds the estimated CAPEX per kilometre for high-speed rail in Europe. Cost estimates for high-speed rail vary across sources. According to the European Commission's Assessment of Unit Costs for Rail projects (CAPEX)[172], the capital expenditure per kilometre for high-speed rail in Europe is EUR 18 million in 2024 prices[173,174]. Meanwhile, ECA estimates this costs to be approximately EUR 25 million[175].

However, in accordance with feedback retrieved following the workshop held on 14th February, high-speed rail costs estimations do not include land acquisition costs, while the figures provided by hyperloop promoters do. According to feedback received, hyperloop requires a strip of land of only 8 meters wide for routing, compared to higher values for high-speed trains and even greater values for highways[176]. Nonetheless, safety margins also need to be considered in this assessment, meaning that potently this would require more land than originally foreseen.

[170] Capital expenditure refers to the funds invested in building, upgrading and maintaining physical assets such as infrastructure and equipment.

[171] In the absence of more granular data, CAPEX and OPEX estimates were only provided for 2050 rather than fort a longer time series.

[172] European Commission, *Assessment of Unit Costs for Rail projects (CAPEX)*.

[173] Eurostat, HICP – annual data (average index and rate of change). 2017: 101.96; 2024: 130.21

[174] This figure considers the construction of new lines. Adding upgrades, signalling, telecommunication and electrification this figure raises up to EUR 24.8 million.

[175] ECA, A European high-speed rail network: not a reality but an ineffective patchwork, available at: https://www.eca.europa.eu/Lists/ECADocuments/SR18_19/SR_High_Speed_Rail_EN.pdf

[176] Neu, W., Eschment, L., Lamme, S., and Schüning, T., *Hyperloop as an innovative new mobility mode: Squaring the circle in high-speed transportation systems?,*2024.

According to another hyperloop promoter, considering a land acquisition of 3.2 ha/km and a cost of EUR 2,000,000 / ha for high-speed rail, the cost of high-speed rail is increased to EUR 31.4 million per kilometre.
Another important note is that CAPEX per kilometre can vary significantly between Member States, as is the case with high-speed rail. According to the INECO report[177], costs per kilometre range from EUR 88.9 million in the Netherlands to EUR 17.7 million in Spain. Therefore, it is crucial to consider that similar variations may apply to hyperloop capital expenditure.

Table 18: Capital expenditure estimates from different hyperloop promoters for a hyperloop 700/km greenfield investment

	CAPEX - hyperloop Infrastructure (EUR/km)
Hyperloop promoter 2	33,960,000
Hyperloop promoter 6	38,970,000
Hyperloop promoter 7	36,918,000

Source: elaboration of the Partnership (2025), based on data provided by hyperloop promoters

At this stage, an important caveat must be acknowledged. As hyperloop is an emerging technology, cost estimates remain theoretical and subject to continuous revision. Following the workshop, hyperloop promoter 6 informed the team that their CAPEX estimates had recently been revised downward, from EUR 38.97 million to EUR 31.8[178] million per kilometre. Additionally, an independent industry expert stated that, in a European context, an average capital per route km of less the EUR 20 million per kilometre is a realistic target for hyperloop. Furthermore, another hyperloop promoter stated that for infrastructure supporting an average speed of 400 km/h, the estimated cost is EUR 18 million per kilometre when built along highways, benefiting from lower land acquisition costs. Another important concern raised regards tunnelling to ensure city centre stations, which is often omitted from the costs provided. This underscores the fact that cost analysis is highly sensitive to future technological advancements and not yet based on real data, which will have a significant impact on cost estimations and business viability. For the purposes of this report, the team will retain the previously presented average CAPEX estimates to ensure consistency in the analysis.

Additionally, according to Hyperloop promoter 7, the breakdown of hyperloop infrastructure costs per category is detailed below, outlining the proportion and projected cost of each category per kilometre constructed. This categorisation provides insights into the allocation of resources required for the development of hyperloop systems. However, it is important to note that this categorisation is based on a Swiss network model with four stations over approximately 300 km. This setup can significantly inflate the relative cost of certain categories, such as stations, as a percentage of total costs. Specifically, the 19.6% station cost figure applies only to this network configuration, where an underground station is constructed every 100 km in one of Europe's most expensive countries. Nonetheless, due to the lack of alternative hyperloop infrastructure cost breakdowns, Table 19 is provided as a reference.

[177] Ineco, *Efficiency of the Spanish sector in the development of the high-speed railways*.

[178] This figure considers a contingency cost, without it the CAPEX would be EUR 24.5 million per kilometre.

Table 19: Hyperloop infrastructure costs per category

	Share	EUR/km
Launchers	1.3%	476,008
Stations	19.6%	7,176,736
Other material	1.3%	476,008
Electrical system	4.6%	1,684,336
Vacuum system	9.2%	3,368,672
Guidance system	2.8%	1,025,248
Liner	5%	1,830,800
Safety cave	4.1%	1,501,256
Main tunnel	51.1%	18,710,776

Source: elaboration of the Partnership (2025)

Based on this analysis, and by aligning these costs with the scenarios outlined in the previous section, the total costs are estimated to range between EUR 23 billion and EUR 808 billion as shown in the table below.

Table 20: Total infrastructure capital costs under the three scenarios

	Coverage (km)	Total infrastructure costs (excluding vehicles), EUR
EU-Level	22,060	808 billion
8 Member State	6,207	227 billion
BENELUX	632	23 billion

Source: elaboration of the Partnership (2025)

To estimate capital expenditure related to vehicles, the first step was identifying the number of operational vehicles projected for 2050 and the passenger capacity per vehicle, based on data retrieved from hyperloop promoter 2. Additionally, Hyperloop promoter 6's estimations for vehicle CAPEX were incorporated, calculated at EUR 188,336 per passenger.

Table 21: Number of hyperloop Vehicles, passengers per vehicle, hyperloop vehicle cost in 2050

	Estimations
Number of hyperloop Vehicles in 2050 (hyperloop promoter 2)	15,000
Pax per vehicle (hyperloop promoter 2)	52
Hyperloop Vehicles Cost, EUR/Pax (Hyperloop promoter 6)	188,336

Source: elaboration of the Partnership (2025)

These assumptions allowed to estimate vehicle-related capital expenditure by aligning this data with the passenger demand scenarios outlined in the previous section, with costs varying from EUR 70 million to EUR 425 million. The resulting vehicle capital expenditure projections for each of the four scenarios are presented in the table below.

Table 22: Vehicle capital costs under the three scenarios

Scenario	CAPEX related to vehicles, EUR
EU-Level	425 million
8 Member State	234 million
BENELUX	70 million

Source: elaboration of the Partnership (2025)

An additional capital expenditure that remains unquantified at the European level is the construction of hyperloop stations, given the significant variation in costs due to location-specific factors. Estimates for generic stations are challenging to establish at this stage, as costs depend heavily on local conditions, urban density, and integration with existing transport infrastructure. While costs may align with railway stations, hyperloop stations could entail added complexity due to specialised infrastructure requirements, such as battery charging systems and enhanced safety checks. However, as reported by hyperloop promoter 5, hyperloop may require less boarding space due to smaller vehicle size. Besides, existing rail-based tracks could potentially be repurposed to enhance flexibility in accessing city centres. Furthermore, scaling costs based on passenger flow, could provide a useful framework. Yet, such projections may not account for regional variations in labour, materials, and regulatory national demands across Europe. Therefore, stations will significantly influence financial analysis, representing an additional capital expenditure.

7.1.2 Capital expenditures according to non-hyperloop promoters

In addition to the data provided by the hyperloop promoters, it is essential to include independent and unbiased data from a non-hyperloop promoter from another mode of transport to provide additional context and validation. To estimate costs aligned with DB's assumptions, and to ensure consistency, the same operational networks length projected for 2050 by hyperloop promoters have been used. The same source provides cost projections for various infrastructure components. For standard construction at ground level or elevated sections, estimates costs at 8,000 kEUR/km, which, for the projected hyperloop networks, varies between EUR 5 billion and EUR 176 billion. Concerning bridges, notably for spans exceeding 50 meters, estimates a cost of 22,000 kEUR/km, resulting in a total expenditure of EUR 14 billion to EUR 485 billion. In addition, for power, signalling, and telecommunication systems, projects costs of 2,000 kEUR/km, which would lead to a total between EUR 1 billion to EUR 44 billion for the full network. Regarding tunnels, estimates costs of 30,000 kEUR/km, amounting between EUR 19 billion and EUR 662 billion to cover the projected networks by 2050. Comparing these figures to those provided by hyperloop promoters, a non-hyperloop promoter from another mode of transport estimates for tunnel construction are approximately 60% higher.

A similar disparity is observed in rolling stock costs, where the non-hyperloop promoter projects 105,000 EUR/seat, amounting to EUR 19 billion in total—significantly higher than the figures presented in Table 23 based on data from hyperloop promoters.
Overall, while the projections based on the data provided by the promoters foreseen an overall capital expenditure range between EUR 23 and 808 billion, projections based on these assumptions amount between EUR 39 billion and EUR 1,387 billion.

Table 23: Capital expenditures estimations from a non-Hyperloop promoter from another mode of transport

	EU-level	8 Member States	BENELUX
Track work (standard construction: ground level/elevated)	EUR 176 billion	EUR 50 billion	EUR 5 billion
Bridges (> 50 m span)	EUR 485 billion	EUR 137 billion	EUR 14 billion
Tunnel	EUR 661 billion	EUR 186 billion	EUR 19 billion
Power, signalling/telecommunication systems	EUR 44 billion	EUR 12 billion	EUR 1 billion
Rolling stock	EUR 18 billion	N/A	N/A
Total	EUR 1.386 billion	EUR 386 billion	EUR 39 billion

Source: elaboration of the Partnership (2025)

7.1.3 Operational expenditure estimates for hyperloop systems

In addition to capital expenditure, the economic analysis incorporates operational expenditure (OPEX), which covers the ongoing costs associated with operating hyperloop systems. As in previous sections, the reference year for analysis is 2050. Yet, to provide a more comprehensive perspective, cumulative costs for the period 2036–2050 are also considered where applicable.

Infrastructure maintenance

For infrastructure maintenance, hyperloop promoter 2 projects annual costs of EUR 720 million, with cumulative costs for the 2036–2050 period amounting to EUR 3.30 billion. Hyperloop promoter 6 provides an alternative estimate, projecting annual infrastructure maintenance costs of EUR

77,000 per kilometre[179]. Based on this cost per kilometre estimate, infrastructure maintenance expenses are projected to range between EUR 49 million and EUR 1.70 billion across the three scenarios, as shown in the table below.

Table 24: Infrastructure maintenance costs projections according to hyperloop promoters under the three scenarios

	EU-level	8 Member States	BENELUX
Infrastructure maintenance	EUR 1.70 billion	EUR 478 million	EUR 49 million

Source: elaboration of the Partnership (2025)

From a non-hyperloop promoter perspective, a non-hyperloop promoter from another mode of transport estimates infrastructure maintenance costs to range between a lower bound of 53,750 EUR/line-km per year and an upper bound of EUR 129,000 EUR/line-km annually for 2050. This would represent a cost ranging from EUR 1.19 billion to EUR 2.85 billion at the EU-level. Non-hyperloop promoter from another mode of transport attributes this variability to factors such as operating pressure, wage levels, and maintenance strategies, particularly those involving frictionless technologies.

Table 25: Infrastructure maintenance costs projections according to a non-hyperloop promoter from another mode of transport under the three scenarios

Infrastructure maintenance	EU-level	8 Member States	BENELUX
Upper bound	EUR 2.85 billion	EUR 801 million	EUR 82 million
Lower bound	EUR 1.19 billion	EUR 334 million	EUR 34 million

Source: elaboration of the Partnership (2025)

Vehicle maintenance

Regarding vehicle maintenance, hyperloop promoters present differing estimates. Hyperloop promoter 6 and Hyperloop promoter 5[180] provide similar figures for passenger vehicle maintenance costs in 2050 at EU-level. Hyperloop Promoter 2, however, forecasts higher vehicle maintenance costs for passenger services, estimated at EUR 4.24 billion annually in 2050.

Table 26: Vehicle maintenance costs projections according to hyperloop promoters under the three scenarios

Vehicle maintenance	EU-level	8 Member States	BENELUX
Hyperloop promoter 6	EUR 1 billion	EUR 284 million	EUR 29 million
Hyperloop promoter 5	EUR 1.6 billion	N/A	N/A
Hyperloop promoter 2	EUR 4.2 billion	N/A	N/A

Source: elaboration of the Partnership (2025)

A non-hyperloop promoter from another mode of transport projections for vehicle maintenance costs range from 0.005 EUR/seat-km per year to EUR 0.018 EUR/seat-km annually in 2050, ranging between EUR 86 million and EUR 309.7 million, at an EU-level network. This variability is attributed to factors such as the number of seats per pod, wage levels, utilisation rates, maintenance strategies, and advancements in inspection and maintenance technologies.

[179] High-speed rail has infrastructure maintenance operational costs of EUR 50,000 per kilometre (Source: Feigenbaum, B., High-Speed Rail in Europe and Asia: Lessons for the United States).

[180] For freight vehicles, Zeleros projects lower costs, estimated at EUR 133 million in 2050.

Table 27: Vehicle maintenance costs projections according to a non-hyperloop promoter from another mode of transport under the three scenarios

Vehicle maintenance	EU-level	8 Member States	BENELUX
Upper bound	EUR 309.7 million	EUR 87.1 million	EUR 8.9 million
Lower bound	EUR 86 million	EUR 24.2 million	EUR 2.5 million

Source: elaboration of the Partnership (2025)

Other costs

Other additional costs include insurance, which hyperloop promoter 2 projects to have a cumulative cost of EUR 2,4 billion from 2036 to 2050. For selling, general, and administrative (SG&A) costs, it is expected to reach EUR 6.7 billion annually by 2050, with a cumulative value of EUR 34.1 billion for the same period. Hyperloop promoter 6 estimates that SG&A costs will represent approximately 13% of sales.

Staff costs show some variability between estimates. Hyperloop promoter 2 projects annual staff costs of EUR 1.87 billion, amounting to a cumulative value of EUR 9.62 billion over the 2036–2050 period. In contrast, Hyperloop promoter 6 estimates staff costs at EUR 200,000 per kilometre, corresponding to a total of EUR 4,4 billion for the entire operational network, and EUR 1,24 billion for a network covering eight Member States.

Table 28: Staff costs projections under the three scenarios

	EU-level	8 Member States	BENELUX
Staff	EUR 4.4 billion	EUR 1.24 billion	EUR 126.4 million

Source: elaboration of the Partnership (2025)

Energy usage also represents a significant operational expense. Hyperloop promoter 2 estimates annual energy costs at EUR 3,1 billion, with a cumulative cost of EUR 13,6 billion for the 2036–2050 timeframe. Hyperloop promoter 6's projections for energy-related expenditures are 0,125 EUR/pax/km per year, which would range from EUR 12,7 million to EUR 82,9 million. The significant variation in energy usage costs can be explained by differences in the scope of what is included in the estimates from the hyperloop promoters. The estimates from hyperloop promoter 2 likely incorporates a broader range of elements, such as energy infrastructure cooling, auxiliary systems, and standby operations, whereas the lower estimate focuses more narrowly on direct operational energy costs, such as pod propulsion.

Finally, other fixed facilities could add up to EUR 6,36 billion per year, according to hyperloop promoter 2.

Comparison with other modes

According to hyperloop promoter 2, the operational expenditure per passenger seat is expected to be significantly lower than that of high-speed rail. This is primarily due to fully automated operations, eliminating the need for drivers and allowing personnel costs to be focused on passenger services. However, it is important to highlight that rail is also expected to undergo automation within the same timeframe, leading to a reduction in operational costs for the sector[181]. Moreover, automation in the high-speed rail would entail lower capital expenditure and installation costs compared to Hyperloop, as it does not require the construction of an entirely new infrastructure network and allows for the reuse of existing rail vehicles. This means that any reduction in operational costs comparatively to high-speed rail would need to result instead from lower overall system costs, such as reduced maintenance needs, increased resilience, and other efficiency gains.

[181] Moreover, since train driver pay accounts for only a marginal share of total operational costs, it has not been a priority in the rail sector.

Additionally, hyperloop promoters claim that the shorter turnaround time of hyperloop systems means fewer vehicles are required, leading to lower maintenance costs. Energy consumption is also projected to be substantially lower, with the potential for hyperloop infrastructure to generate surplus energy for other uses, further reducing energy costs, provided that the costs of creating and maintaining the vacuum are not considered, assuming the vacuum is generated using solar or a self-sufficient energy source. Lastly, maintenance requirements for the guideway are considered to be minimal, as the vehicle does not come into direct contact with the infrastructure. However, guideway have additional maintenance costs that are not considered here.

Hyperloop promoters argue that hyperloop connections can be financially viable, and that they also have the potential to be privately financed and operated under build or availability schemes, similar to models currently used for some rail projects. However, a cost-benefit analysis following European Commission guidelines is necessary to confirm this and to fully determine whether the routes deployed would be financially viable.

7.2 Financial and socioeconomic and benefits

Below, the expected financial benefits of hyperloop are described first, followed by the expected socioeconomic benefits.

7.2.1 Financial benefits

Following the presentation of costs, it is crucial to analyse the socio-economic benefits that hyperloop systems are expected to generate.

A key aspect to consider is ticket fares, which represent a point of consensus among hyperloop promoters. Both Hyperloop promoter 6 and hyperloop promoter 2 anticipate fares of EUR 0.20 per kilometre. Similarly, Hyperloop promoter 7 has estimated that a ticket for the Zurich-Geneva route would cost EUR 52.64[182]. When converted to EUR, this aligns closely with the ticket fares projected by other promoters. The table below provides an overview of estimated ticket fares for various routes. These values are similar to airline average prices per km which are between EUR 0.15 and EUR 0.25 dependent on various factors[183].

Table 29: Estimation of hyperloop ticket fare for different routes

Example of routes	Distance (km)	Estimation of ticket fare, EUR
Milan-Frankfurt	533	106
Vienna-Rome	765	152
Warsaw-Amsterdam	1,126	224
Hamburg-Paris	747	149
Paris-Brussels	264	53

Source: elaboration of the Partnership (2025)

For freight services, hyperloop promoter 2 projects a cost of EUR 0.13 per tonne-kilometre, reflecting the potential economic benefits for cargo transport. As seen above, hyperloop promoters have reached a consensus on a ticket fare of 0.20 EUR/km, which serves as a critical parameter for estimating the potential revenue generated by hyperloop services. Using this benchmark, it is possible to calculate the expected revenue for passenger services under three distinct network scenarios: EU-wide coverage, an 8 Member States network, and a BENELUX-system. The table below presents the potential revenue for passenger services under the three network coverage scenarios. These estimates highlight the significant variation in revenue potential based on the scale of the hyperloop system's deployment.

[182] CHF 50, considering an exchange rate EUR:CHF of 0.95.

[183] The impact of COVID-19 on airlines' price curves - ScienceDirect

Table 30: Passenger services potential revenue under the three scenarios

	EU-level	8 Member States	BENELUX
Potential revenue	EUR 110 billion	EUR 61 billion	EUR 18 billion

Source: elaboration of the Partnership (2025)

Additionally, ticket fares can be used to estimate freight service revenues within the 8 Member States scenario, using projections of tonne-kilometres, of EUR 34 billion.

This analysis also allows for a breakdown of the total revenue generated by the hyperloop system. In the eight Member State scenario, passenger services account for 64% of the total revenue, while freight services contribute the remaining 36%.

In addition to the direct revenue for hyperloop on long-distances, hyperloop may also generate additional traffic for rail transport, as previously presented.

7.2.2 Socioeconomic benefits

Hyperloop systems are expected to generate significant socio-economic benefits beyond direct financial considerations. As pointed out by Hyperloop promoter 7, key advantages include value of travel time savings, which enhances productivity and well-being by reducing travel times compared to current transport modes. Additionally, hyperloop systems could significantly reduce noise pollution, lowering external costs and improving quality of life, particularly in urban areas.

Another key benefit highlighted by hyperloop promoter 1 is land value appreciation. The development of hyperloop infrastructure is expected to increase property values in areas surrounding stations and corridors, as improved connectivity makes these locations more attractive for businesses, residential areas, and commercial activities. This can drive economic growth, boost investment, and encourage urban expansion in previously less accessible regions. Considering edge of town locations for hyperloop stations, a key socioeconomic benefit, similarly to rail station, is the strong connection between the central rail station and a peripheral hyperloop station, which can evolve into a multimodal hub. Ideally situated in a high-density, mixed-use area, this setup promotes transit-oriented development. An example provided by hyperloop promoter 1 is Amsterdam Zuidas, a secondary main railway station developed south of the central station. Yet, this would need to be fully corroborated by in-depth demand studies for the different routes. Nonetheless, it is worth noting that further evidence is still necessary through more detailed studies.

Moreover, hyperloop promoters consider that, by attracting both passenger and freight demand from less efficient modes, hyperloop could also boost regional connectivity and economic development, further amplifying its societal value. Rather than competing with rail, hyperloop is envisioned as a complementary mode, addressing current rail capacity constraints and providing additional routes that align with the TEN-T vision for an integrated and efficient transport network.

Finally, environmental sustainability is another benefit, with hyperloop offering a greener alternative to aviation and road transport, aligning with EU carbon neutrality goals. This is the focus of the next section.

8. ANALYSIS OF ENVIRONMENTAL IMPACTS

In this section, we discuss several expected environmental impacts, beginning with greenhouse gas emissions and energy demand for hyperloop, followed by energy consumption, life cycle assessment and, finally, comparison with other transport modes.

8.1 Greenhouse gas emissions and energy demand for hyperloop

Hyperloop represents an opportunity for the European transport sector to significantly reduce greenhouse gas emissions, aligning with the EU's ambitious environmental and climate objectives. As a highly energy-efficient, low-emission transport mode, hyperloop systems have the potential to replace carbon-intensive alternatives like aviation and road freight for medium and long-distance journeys. This shift could contribute substantially to the EU's goal of achieving climate neutrality by 2050, as outlined in the European Green Deal and Sustainable and Smart Mobility Strategy, by addressing one of the largest sources of emissions, transport, which accounts for approximately 25% of the EU’s total greenhouse gas emissions.

The table below presents the estimated energy consumption per transport mode, expressed in Wh/passenger/km, as provided by hyperloop promoter 2.

Table 31: Energy usage per transport mode

	Energy usage expressed in Watt-hours/passenger/km
Hyperloop	55
High-speed rail	94
Maglev	169
Train diesel	294
Train electric	152

Source: Hyperloop promoter 2

Hyperloop promoter 5 highlighted that hyperloop could help prevent extra-EU flights from further polluting European skies by encouraging long-haul flights, such as those from North and South America, to land at coastal airports in countries such as Portugal, France, or the Netherlands. Passengers could then complete their journey to inland destinations via hyperloop, thereby reducing the emissions associated with flights that would otherwise continue to central or inland airports.

A non-hyperloop promoter from another mode of transport provides a comprehensive assessment of greenhouse gas (GHG) emissions, including CO2, CH4, and N2O, stated in CO2 equivalents, for various transport modes. This data allows for a comparative analysis of the environmental impacts of air, rail and hyperloop systems.

Table 32: Greenhouse gases per transport mode

Transport modes	Greenhouse gases (CO2, CH4, N2O stated in CO2s equivalents grams per kilometre)
Short Distance Rail	54
Long distance rail	29
Maglev	44.6
Hyperloop	24
Air domestic	214
Car	154
Long-distance bus	36
Public urban transport	55

Source: a non-hyperloop promoter from another mode of transport

The emissions for these transport modes are detailed in the table below, covering three network coverage scenarios: EU-level, eight Member States, and BENELUX.

Table 33: Greenhouse gases estimations for air, rail and hyperloop under the three scenarios

Transport mode	EU-level	8 Member States	BENELUX
Air	9,060	16,632	24,755
Rail	16,963	23,104	27,786
Hyperloop	13,243	7,312	3,252

Source: elaboration of the Partnership (2025)

Based on these figures, it becomes evident that expanding the coverage of a hyperloop network across Europe would significantly reduce the total transport emissions. This trend can be attributed to the high energy efficiency and low greenhouse gas emissions of hyperloop systems when compared to traditional modes of transport such as aviation and rail. As the network coverage increases, a larger share of passenger and freight transport can shift to hyperloop, displacing more emission-intensive modes. This not only lowers the overall carbon footprint of the transport sector but also supports Europe's broader climate goals by promoting a more sustainable and environmentally friendly alternative for both passenger and freight mobility.

In addition, as reported by an independent expert on a LCA focused on hyperloop promoter 1's technology, the environmental impact of hyperloop can be further minimised by powering the system with renewable electricity, either generated directly by hyperloop infrastructure or produced specifically for its operation, thereby contributing to the expansion of renewable energy capacity.

Furthermore, high passenger intensity plays a crucial role: the more frequently the system is used, the lower the infrastructure impact per passenger-kilometre. The inclusion of freight transport within the hyperloop network could further optimise infrastructure usage, reducing the overall impact per passenger-kilometre.

Finally, prioritising the efficient use of materials in construction and maintenance would further enhance sustainability and resource optimisation within the hyperloop system.

8.2 Energy consumption

Beyond its potential to reduce greenhouse gas emissions, hyperloop systems offer a highly energy-efficient alternative to traditional transport modes, using advanced technologies like regenerative braking and reduced aerodynamic resistance. By integrating with renewable energy sources, hyperloop can significantly reduce its carbon footprint per passenger or tonne-kilometre.

Hyperloop promoter 7 presents specific data on the energy consumption of hyperloop systems, broken down into multiple operational components. These include pod propulsion, cooling systems, brake energy recuperation, vacuum assurance for infrastructure, and the cooling of infrastructure. These energy metrics are measured in kWh per passenger-kilometre.

Table 34: Hyperloop energy consumption

	kWh/pkm
Pod operation (including propulsion, cooling and brake energy recuperation)	0.06
Vacuum assurance of infrastructure	0.015
Cooling of infrastructure	0.027
Total (excluding infrastructure cooling)	0.075
Total (including infrastructure cooling)	0.102

Source: Hyperloop promoter 7

8.3 Life-cycle assessment

A life-cycle assessment is a comprehensive method used to evaluate the environmental impact of a system throughout its entire life cycle. Specifically, the Global Warming Potential (GWP) focuses on the greenhouse gas emissions generated across all stages of a system's lifespan, measured in grams of CO_2 equivalent per passenger-kilometre (gCO_2-eq./pkm). This metric accounts for both direct and indirect emissions, offering a holistic view of a system's environmental footprint.

For the hyperloop system, the LCA considers emissions from several components. Infrastructure emissions stem from the construction and maintenance of the network, including tubes, stations, and supporting structures. The launcher and substation, which are responsible for propelling pods and maintaining operations, require significant energy and material inputs. The pods themselves contribute to the footprint through their manufacturing, maintenance, and eventual disposal, particularly due to emissions from critical components like batteries. Finally, energy supply emissions are linked to the production and delivery of the electricity used for system operations, which varies depending on the energy mix.

Table 35: Life-cycle assessment for hyperloop components

	gCO2-eq./pkm
Infrastructure	5.87
Launcher and substation	0.34
Pods	1.52
Energy supply	0.8
Total	8.53

Source: Hyperloop promoter 7

By aggregating these values, the life cycle GWP for hyperloop systems has been estimated for the three network scenarios, offering insights into the broader environmental implications of hyperloop deployment. The Life-cycle Assessment results highlight the variation in Global Warming Potential across the three scenarios (EU-level, 8 Member State, and Benelux), with differences driven by the scale of the network and associated infrastructure and energy demands. These findings underline the importance of optimising components like energy supply and infrastructure to minimise environmental impacts while scaling hyperloop systems.

Table 36: Life-cycle Assessment for hyperloop components under the three scenarios (gCO2-eq./pkm)

	EU-level	8 Member States	BENELUX
Infrastructure	3,239	1,788	530
Launcher and substation	188	104	31
Pods	839	463	137
Energy supply	441	244	72
Total	4,707	2,599	771

Source: elaboration of the Partnership (2025)

8.4 Comparison with other transport modes

Hyperloop promoter 7's findings[184] provide a comparative analysis of the environmental impacts of various transport modes in Europe, including long-distance trains, and two types of aircraft (short-haul and very short-haul). The analysis incorporates both conventional fossil kerosene and synthetic kerosene for aviation.

According to Hyperloop promoter 7, conventional aircraft have the highest climate impacts, primarily due to significant fuel consumption and the combustion of fossil kerosene. Although

[184] Beckert, P., Pareschi, G., Ehwald, J., Sacchi, R., Bauer, C., (2024), *Fast as a plane, clean as a train? Prospective life cycle assessment of a hyperloop system*

synthetic kerosene reduces climate impacts compared to conventional fuels, aviation will remain substantially more impactful than hyperloop and train systems, as the production process of synthetic kerosene is energy intensive. Additionally, the infrastructure required for airports, coupled with energy-intensive ground operations and maintenance, further contributes to aviation's carbon footprint. In contrast, both hyperloop and trains demonstrate considerably lower climate impacts, with comparable performance in this category. As indicated by hyperloop promoter 7, the hyperloop system benefits from an efficient design that optimises infrastructure use, supported by high load factors (80%). This allows the hyperloop to distribute environmental costs effectively over a large passenger base, reducing per-passenger-kilometre impacts. However, it is worth noting that aviation also achieves similar load factors, and rail could reach comparable levels if services were limited to peak times or operated with heavy yield management. The difference lies in the fact that rail has a low marginal cost for additional capacity, making it viable to run trains even when they are not fully occupied. Nevertheless, this assumption for hyperloop's load factors and the maximisation of infrastructure capacity still requires confirmation with real data.

Furthermore, hyperloop infrastructure is more material-intensive, requiring substantial amounts of steel and copper, and the pods have a notable environmental footprint due to their reliance on batteries. Trains, lacking emission-intensive batteries, have a slightly lower material footprint than hyperloop but operate at lower utilisation rates (28%), which diminishes their efficiency.

On the other hand, regarding land use, hyperloop promoters added that aircraft relying on synthetic kerosene have the highest impacts, driven by the space requirements for wind power generation, which is essential for producing synthetic kerosene. However, it is important to note that land use concerns related to synthetic kerosene production can be mitigated if it is produced using offshore wind power or even nuclear energy. Trains and fossil-fuel aircraft show similar land use impacts, largely influenced by infrastructure needs. In contrast, the hyperloop system exhibits the lowest land use-related impacts, primarily because of its elevated tube design supported by pillars. Concerning water consumption results are less favourable for hyperloop and train systems compared to aviation. This is due to the reliance on electricity generated from hydropower, which carries a higher water footprint. Aircraft consume less water in comparison. Material resource consumption is also a consideration, with hyperloop systems requiring more materials, particularly copper, than aircraft and trains. For particulate matter formation, hyperloop systems show the lowest impact, whereas aircraft using synthetic kerosene demonstrate the highest. Train systems have higher particulate matter formation impacts than hyperloop, mainly due to track abrasion. In terms of summer smog, both hyperloop and train systems achieve the lowest impacts, while aircraft contribute significantly more, largely due to emissions from kerosene combustion. When considering energy efficiency, measured by cumulative energy demand, hyperloop and train systems perform far better than aviation, showcasing superior energy performance.

However, it is important to consider that the urgent need for rapid decarbonisation of the transport sector may be more immediately addressed through mature technologies that are already commercially available and capable of delivering emissions reductions. While hyperloop has the potential to be a transformative low-carbon transport mode, it is still in the early stages of development and would require a longer time horizon to reach large-scale deployment. Given the constraints on government budgets and the need to meet climate targets in the short to medium term, prioritising existing low-carbon transport solutions may be the most effective approach for immediate impact, while continuing to support hyperloop’s development as a future complementary option.

9. PERFORMANCE AND SAFETY

Below, we firstly discuss the comparative travel time across modes, followed by an analysis of safety features across transport modes.

9.1 Comparative travel time across modes

Travel time is a critical factor in the attractiveness of hyperloop systems, offering transformative reductions compared to existing transport modes. By combining high speeds, efficient boarding processes and optimised hub locations, hyperloop has the potential to dramatically reshape the landscape of long-distance travel in Europe.

hyperloop systems are designed to achieve top speeds of up to 600 km/h, according to Hyperloop promoter 8 and Hyperloop promoter 7, balancing energy efficiency with operating pressure and infrastructure constraints. Even at cruising speeds, hyperloop outpaces rail and aviation for shorter routes (due to reduced boarding and security check times), offering a significant competitive advantage.

Table 37: Key travel time parameters provided by promoters

	Value
Average speed (hyperloop)	600 km/h
Average speed (aviation)	800 km/h
Access/egress time for hyperloop	15 minutes
Access/egress time for aviation:	90 minutes
Nominal cruising speed	530 km/h
Throughput on main lanes during peak times	25,000 passengers per hour per direction

Source: elaboration of the Partnership (2025), based on contributions from promoters

It is important to consider that while the cruising speed of aviation typically ranges between 800–850 km/h, overall average speeds are significantly lower due to ascent, descent, and ground movements. In contrast, hyperloop is expected to accelerate rapidly to full speed and maintain it for a larger portion of the journey, particularly over shorter distances. This operational advantage could result in competitive travel times compared to aviation, especially for regional and intercity routes. Passenger boarding processes are another area where hyperloop distinguishes itself from competing modes. With smaller vehicles, wide boarding doors, and efficient station layouts, hyperloop will allow for quick and seamless embarkation. This reduces dwell times at stations, improves reliability, and enhances punctuality, all of which contribute to reduced overall travel times. The frequency of departures enabled by the system’s high throughput further enhances its convenience and utility for passengers.

The tables below compare hyperloop travel times to existing modes of transport for selected routes demonstrate its time-saving potential. However, it is important to highlight that the table reflects the current state of infrastructure and does not consider the planned investments outlined in the TEN-T.

Table 38: Travel times projections from hyperloop promoter 2

Route	State-of-play transport modes used	Travel time	Travel time with hyperloop
Amsterdam to Zaragoza	Coaches, two flights or one flight and train connections	Circa 7 hours and 15 minutes	4 hours and 19 minutes
Brussels to Munich	Coaches, one flight or two trains	Between 5 hours and 6 hours and 57 minutes	2 hours and 43 minutes
Rotterdam to Berlin	Car or coach, train and one flight	Car: 6 hours and 31 minutes Coach, train and one flight: 5 hours and 18 minutes	4 hours and 19 minutes

Source: Hyperloop promoter 2

Table 39: Travel times projections from Hyperloop promoter 7

Travel times (minutes)	Car	Railway (2023)	hyperloop
Zurich-Bern	96	57	16
Zurich-Lausanne	156	135	22
Zurich-Geneva	195	163	26
Bern-Lausanne	77	73	15
Bern-Geneva	117	117	18
Lausanne-Geneva	58	37	12

Source: Hyperloop promoter 7

In conclusion, hyperloop systems promise a paradigm shift in travel efficiency by combining unprecedented speeds, reduced ancillary times, and high-frequency operations. These features make it a game-changing option for Europe's long-distance transport network, aligning with the EU's objectives to enhance mobility while reducing environmental impacts.

9.2 Analysis of safety features across transport modes

Safety is a critical consideration for the development and operation of hyperloop systems, as it underpins the reliability and public acceptance of this innovative transport mode. Transport safety is a key determinant of societal trust and economic efficiency, particularly for a mode envisioned to handle large passenger volumes at high speeds. To enable hyperloop to become a truly transformative technology within the transport sector, it is imperative to establish a comprehensive and efficient safety and security management system. These elements must be closely interlinked to ensure the viability, public acceptance and long-term integration of hyperloop into the EU transport ecosystem. Any transport system must be designed with the utmost attention to safety protocols to protect passengers and the general public. This is particularly critical for hyperloop, given its unprecedented speeds and unique operational characteristics. The potential risks associated with high-speed, low-pressure travel require robust engineering, emergency response systems and clear operational protocols. By prioritising high safety standards, a (semi-)regulatory framework at EU level can instil public confidence in hyperloop as a safe mode of transport. Moreover, the transnational nature of hyperloop infrastructure underscores the need for a consistent, harmonised safety framework across the EU. Learning from safety practices in existing transport sectors provides a strong foundation for this approach.

Lessons from existing transport safety measures

The EU railway network maintains a consistently high safety level and ranks among the safest in the world. In a multimodal comparison, rail emerged as the safest form of land transport in the EU, with a passenger fatality rate comparable to that of air travel. Nevertheless, railway safety levels vary across Member States. This is mainly due to differences in infrastructure safety. Accident reports suggest that sharing knowledge and best practices across the EU could further enhance safety[185].

Differently, the EU aviation safety system is based on a set of shared safety rules overseen by the European Commission, EASA and National Aviation Authorities. These rules are uniformly applied across all EU Member States and cover crucial aspects of aviation, including airworthiness, aircrew, aerodromes, air operations and air navigation services[186]. To further strengthen safety management in aviation, the EU places emphasis on occurrence reporting, a process involving meticulous reporting, analysis and follow-up of safety-related incidents in civil aviation. This robust approach

[185] European Union Agency for Railways (2024). Report on Railway Safety and Interoperability in the EU. https://www.era.europa.eu/content/report-railway-safety-and-interoperability-eu-2024

[186] European Commission, DG MOVE, "Aviation Safety Policy in Europe". https://transport.ec.europa.eu/transport-modes/air/aviation-safety-policy-europe_en.

aims to maintain a secure and reliable environment for air travel throughout the EU[187]. Safety-related measures in aviation are ensured through the establishment of Safety Performance Indicators (SPIs) and Safety Performance Targets (SPTs). EASA Member States are entrusted with devising indicators that align with the specific time, aviation sector and safety issues at hand[188]. In addition, in light of the diverse risks that need addressing and the multitude of safety actions to be measured and monitored, EASA encourages its Member States to develop individual safety objectives and their corresponding level of safety performance rather than devising an aggregate level of safety performance planning[189].

By comparison, hyperloop presents key design advantages: it operates within fully enclosed tubes, eliminating track intrusion and external risks. Unlike conventional rail, including high-speed lines, hyperloop's infrastructure is entirely sealed, preventing unauthorised access and minimising potential disruptions. While rail transport could also be fully autonomous in the future, hyperloop’s design inherently reduces exposure to external hazards, offering a controlled and secure operating environment.

Nevertheless, hyperloop systems must still prepare for high-speed contingencies such as emergency braking, subsystem failure, or external tube damage. Safety protocols must enable safe pod deceleration and evacuation procedures.

Comparative safety benefits of hyperloop

Hyperloop offers substantial safety advantages compared to road and rail transport. In 2021 alone, road accidents resulted in thousands of fatalities across the EU, while railway transport saw 683 fatalities[190]. More than half of such fatalities involved unauthorised persons on the tracks (59%), and more than one-third occurred at level crossings (34%)[191]. At EU level, there has been a gradual decline in the number of fatalities resulting from railway accidents over the past decade, with a 45% reduction rate between 2010 and 2021. According to the 2022 Railway Safety and Interoperability Report published by the European Union Agency for Railways (ERA), the main precursors to accidents in the EU-27 between 2016 and 2020 were track buckles[192], followed by incidents caused by broken rails, signals passed at danger, wrong-side signalling failures and broken wheels and axles.

Hyperloop systems, by design, eliminate these risk factors through fully enclosed infrastructure and automated operations, ensuring that external access is restricted, and operational risks are minimised. Furthermore, by facilitating a modal shift from road to hyperloop, the system could indirectly reduce road accidents, delivering broader safety benefits, as highlighted by hyperloop promoter 2.

Hyperloop operators agree that hyperloop systems are also projected to achieve safety standards comparable to or exceeding those of aviation. Aviation, which is one of the safest modes of transport, operates with accident rates as low as 10^{-10} per flight hour.

[187] European Commission, DG MOVE, “Aviation Safety Policy in Europe”. https://transport.ec.europa.eu/transport-modes/air/aviation-safety-policy-europe_en.

[188] EASA (May 2021) “Acceptable Level of Safety Performance (AloSP) Implementation guidance within the European Union framework”, p 15.

[189] *Ibid*.

[190] Eurostat (January 2021) “Railway safety statistics in the EU”, available at < https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Railway_safety_statistics_in_the_EU>.

[191] Eurostat

[192] ERA (July 2022) “Railway Safety and Interoperability: the 2022 Report”, p 49.

To ensure operational safety, hyperloop systems are designed with robust engineering parameters and emergency protocols. These measures are tailored to handle the unique challenges posed by high-speed travel in a low-pressure environment.

Table 40: Safety parameters provided by Hyperloop promoter 8

Parameter	Value
Maximum time to reach a hub in case of emergencies	13 *minutes*.
Maximum allowable distance between hubs to facilitate evacuation:	109,327 *meters*
Required emergency track length for safe deceleration	3,684 *meters*
Emergency acceleration capacity for rapid response	8,00 m/s^2.
Emergency braking length[193]	1,736 *meters*
Duration of emergency braking	20,8 *seconds*
Maximum number of pods affected during a sudden system collapse at maximum speed	6,9 *pods*
Maximum number of passengers potentially affected in such scenarios	147 *passengers*

Source: Hyperloop promoter 8

However, it is important to note that disruptions resulting from vacuum-related incidents or accidents represent a specific operational risk inherent to hyperloop systems, a risk that does not exist in conventional rail or air transport. These potential disruptions could have significant implications for service reliability and safety and must therefore be carefully considered in future feasibility assessment.

In conclusion, by integrating advanced safety features and adopting standards aligned with those of the aviation sector, hyperloop systems have the potential to deliver a high level of safety in high-speed transport. While their design eliminates several key risk factors present in existing modes of transport, it is also important to acknowledge that new, mode-specific risks, such as those related to vacuum system failures, may introduce operational vulnerabilities that must be thoroughly addressed to ensure overall system resilience and passenger protection.

Security considerations

In contrast with transport safety, which focuses on unintentional accidents, transport security is concerned with safeguarding the transport systems from intentional threats, such as terrorism, sabotage and other criminal activities. Given the potential of hyperloop pods to transport over 3,000 passengers per hour through high-frequency pod departures[194], a comprehensive framework can effectively safeguard this substantial number of people from intentional threats.

The considerable passenger capacity of hyperloop and its autonomous nature, which minimises the need for excessive personnel onboard, will necessitate the implementation of robust passenger security screening at hyperloop stations. These screenings would prevent passengers from carrying hazardous items onto the pods, thereby ensuring the utmost safety and integrity of the hyperloop system during its operations[195]. Nevertheless, it is still unclear whether hyperloop transport would demand similar security screening procedures as what is currently employed in air travel since, unlike air transport where planes can be hijacked and weaponised, hyperloop travels on fixed

[193] The *emergency braking length* refers to the distance required to bring the hyperloop pod to a full stop when applying maximum emergency braking. In contrast, the required *emergency track length for safe deceleration* includes not only the emergency braking length but also additional distance for safety margins, system reaction time, and controlled deceleration. This ensures a smooth stop while minimising excessive forces on passengers and infrastructure.

[194] Taylor et al. (2016). Hyperloop Commercial Feasibility Analysis: High Level Overview. NASA p 15. https://rosap.ntl.bts.gov/view/dot/12308

[195] Hyperloop Connected (2022). A hyperloop Handbook for Public and Private Stakeholders, p 51.

routes, limiting potential damage to the system itself[196]. As a result, the distinct features of hyperloop may necessitate a reassessment of security protocols to ensure a suitable and effective approach to addressing potential security risks. In addition, a more in-depth risk safety assessment would be required in order to ensure the safe integration of hyperloop systems with other transport modes, namely in the connection to airports.

Furthermore, transport security standards within the EU differ significantly from transport safety standards, particularly when it comes to land transport. Currently, there is no specific EU legislation that directly addresses land transport security (except for the transport of dangerous goods)[197]. The primary reason behind this stance is likely the highly diverse nature of security needs in land transport. Different regions and cities in Europe face varying threats and risks, making a prescriptive approach to security rules potentially counterproductive or overly rigid. Furthermore, the topic of transport security is complex and encompasses both passenger and cargo aspects. Solutions to security issues are often better addressed on a sector-by-sector basis, acknowledging the unique characteristics and demands of each mode of transport[198].

For what concerns aviation security, the European Commission has implemented standardised regulations in civil aviation security since 2002, aimed at protecting individuals and goods from any illicit interference with civil aircraft. As a matter of fact, aviation security is identified as one of the key risk areas on the basis of the European Risk Classification Scheme (ERCS)[199], (a scheme measuring risks utilising a 2-dimensional matrix). In the ERCS's matrix, the rows assess the potential severity of an occurrence if it had escalated into a fatal accident. This evaluation considers the size of the aircraft involved and the worst likely type of accident outcome. On the other hand, the columns gauge the probability of such an occurrence leading to a fatal accident outcome. This assessment is based on a model that considers how close the occurrence was to such an outcome. It is noteworthy that no safety issue was found to be associated with the key risk area of security either for the data portfolio of large aeroplanes[200], or for the data portfolio for aerodromes and ground-handling[201]. This indicates that aviation security has become one of the most comprehensively safeguarded areas within the entire transport sector, providing a best practice for the management of security requirements within hyperloop transport.

Implications of hyperloop safety standards on EU institutions and other relevant stakeholders

Ensuring a very high level of safety in hyperloop transport would significantly impact various EU institutions involved in the transport sector. Firstly, the Directorate-General for Mobility and Transport (DG MOVE) lays down the foundation for ensuring a high level of safety. Likewise, EASA and ERA could contribute with their technical expertise in hyperloop transport, offering insights into risk assessment, enforcement measures and performance-based planning. This approach prioritises the attainment of measurable safety objectives, leading to a sharper focus on critical safety

[196] Taylor et al. (2016). Hyperloop Commercial Feasibility Analysis: High Level Overview. NASA p 9. https://rosap.ntl.bts.gov/view/dot/12308.

[197] European Commission, DG MOVE (n.d.). Land Transport Security. https://transport.ec.europa.eu/transport-themes/security-safety/land-transport-security_en.

[198] European Commission, SWD(2012) 143 final, p 4; PROTECTION OF PUBLIC SPACES - EU Action Plan on rail security: achievements and outlook

[199] Regulation (EU) No 376/2014 of the European Parliament and of the Council of 3 April 2014 on the reporting, analysis and follow-up of occurrences in civil aviation, amending Regulation (EU) No 996/2010 of the European Parliament and of the Council and repealing Directive 2003/42/EC of the European Parliament and of the Council and Commission Regulations (EC) No 1321/2007 and (EC) No 1330/2007.

[200] Defined by EASA as commercial air transport airlines, air-taxi and non-commercial business operations.

[201] EASA (May 2021) "Acceptable Level of Safety Performance (AloSP) Implementation guidance within the European Union framework", p 52.

outcomes. EASA, as mentioned in Section 4.3.4, frequently employs performance-based regulations to supplement prescriptive rules in the European aviation sector. This wealth of experience and expertise makes EASA a highly suitable agency to consider for involvement in the regulation of hyperloop technology. Europe’s Rail and potentially other institutions like the European Institute of Innovation and Technology (EIT) and the Joint Research Centre (JRC) could foster innovation and research in the field of hyperloop safety.[202] EIT InnoEnergy, a hub and knowledge community dedicated to sustainable energy innovation under the EIT umbrella, is already engaged in multiple initiatives concerning hyperloop. Additionally, the need to ensure a high level of safety in hyperloop transport would impact hyperloop developers in several ways. The primary impact would stem from the establishment of safety requirements, irrespective of their specific legal form or binding nature, which hyperloop developers must adhere to. Achieving compliance can present challenges, necessitating additional resources and specialised expertise. By ensuring a robust and comprehensive approach to safety and security, the framework would minimise risks and potential liabilities for hyperloop developers, while also aligning the technology with the EU's sustainability objectives, making it more attractive to environmentally conscious customers and stakeholders. Acting as the primary point of contact with hyperloop developers, public authorities and national bodies would also bear the responsibility of overseeing the monitoring of operations conducted within their countries.

Certification and standardisation bodies would also be impacted. These bodies would collaborate with the authorities and industry experts to develop comprehensive guidelines and standards for safety in hyperloop transport. They would address key aspects such as infrastructure design, operational procedures, emergency protocols, and system reliability.

Lastly, the emphasis on ensuring a high level of safety in hyperloop transport would also have implications for European-wide associations involved in the transport sector. As entities representing various stakeholders in the transport sectors, these associations would likely engage in policy-making discussions to influence safety-related decisions and advocate for the interests of their members. For instance, the Community of European Railways and Infrastructure Managers (CER) and the European Rail Freight Association (ERFA), which represent, respectively, the interests of railway undertaking and infrastructure managers, and those of European rail freight transport stakeholders, may assess the potential impact of hyperloop transport on their operations and safety practices. They might advocate for fair competition and collaboration between hyperloop and existing rail systems while ensuring seamless integration and interoperability. Differently, associations like the European Disability Forum (EDF) and the European Passenger Federation (EPF) would be particularly concerned with ensuring that the safety standards for hyperloop transport cater to the needs of passengers, including individuals with disabilities. They would work to promote accessibility, equal treatment, and safety for all passengers using hyperloop services. Finally, associations representing transport workers, such as the European Transport Federation (ETF), would advocate for the interests of their members, including by encouraging the adoption of measures that safeguard the health and security of those engaged in the construction, operation, and maintenance of hyperloop systems.

[202] For instance, there is the ongoing EU-Rail project which will be further expanded in 2026 with the pilot project. In addition, there is JTC20 which is now lunching a Working Group on safety

10. CONCLUSIONS

Below, firstly, the key insights gathered through this study are summarised. This is followed by a discussion of a set of limitations related to the work carried out under this study. Finally, we present a set of recommendations for next steps that could be taken.

10.1 Summary of key insights

Below, the main strengths, weaknesses, opportunities and threats of the European hyperloop sector are discussed based on other parts of the report (and cross-references are included as relevant).

The main strengths of the European hyperloop sector could be summarised as follows:

- **Technological innovation**: if all the claims from developers are put into practice, hyperloop technology offers the potential for a unique combination of speed, efficiency and sustainability that differentiates it from traditional transport modes such as rail, road, air and waterborne. Moreover, the use of magnetic levitation and low-pressure tubes has the potential to significantly reduce travel times while minimising noise pollution. Finally, hyperloop's closed system design enhances operational efficiency and could lead to energy savings (for more details, see Section 3.1.1)
- **Environmental benefits**: if the technology put all of its promises into practice, the hyperloop system aligns well with EU sustainability goals, particularly those outlined in the European Green Deal and Fit for-55, which aim for a 90% reduction in transport emissions by 2050. Hyperloop has the potential to cut greenhouse gas emissions by offering an energy-efficient alternative transport mode. With the ability to run on renewable energy sources, hyperloop could significantly contribute to the EU's decarbonisation targets. At the same time, material sourcing and lifecycle emissions remain areas of concern, as well as the fact that most electricity is currently not based on renewable source although this is expected to become more and more the case (for more details, see Section 8)
- **Assess opportunities on the TEN-T's extended European transport corridors:** hyperloop development should focus on routes where high-speed rail is not yet planned to provide the maximum value added possible. Therefore, hyperloop is positioned as a complementary addition, connecting cross-border cities where no competitive rail links exist and bridging gaps where high-speed rail cannot offer solutions or are too difficult to implement. Hyperloop can also connect smaller cities not connected to the HSR network to the large agglomerations. This way, it can contribute to closing gaps from the existing TEN-T extended network and provide highest added value in terms of disclosing unconnected or poorly connected areas

The main weaknesses of the European hyperloop sector could be summarised as follows:

- **Uncertain business case:** although some business cases are evidence-based, there is still a lack of a common goal on the way forward, with cross-border integration being further challenged by diverging national priorities and varying Member State readiness. More detailed feasibility studies, focused on particular contexts at a regional, national and cross-border scale are still necessary to meet the common standards and access to funding required for other transport modes, and to determine a more harmonised network vision. In fact, the financial feasibility of large-scale implementation remains uncertain, with varying projections from different stakeholders. Yet, this scenario may change as developments evolve(for more details, see Section 4.3.2)
- **High capital costs:** infrastructure costs for hyperloop are significant, with estimates ranging around EUR 17.5-36.6 million per kilometre. Yet, these can be similar, but potentially lower than high-speed rail, for instance. The upfront investment required to

build the network presents a significant barrier to entry, with uncertainty around funding availability and potential returns for early projects. At the same time, hyperloop's modular design could allow for scalability and phased deployment to mitigate high initial capital costs. Another caveat is that these cost estimates are based on limited data, remain uncertain at this stage and could be further reduced depending on the specific technology used and the location. In addition, the estimated costs for hyperloop are based on an EU average, without considering any differences between Member States. As costs vary greatly among countries, this may be an element worth assessing further before any particular conclusions (for more details, see Section 7.1)

- **Technological readiness:** in terms of technological readiness of hyperloop technology, according to developers, no fundamental technological breakthroughs are needed, as its core components already exist at high Technology Readiness Levels (TRLs) in other industries. Key subsystems, such as infrastructure, traction, and control systems, are derived from rail transport, while elements like the fuselage, cabin, and life support systems are adapted from aviation. Nevertheless, there is no full agreement with stakeholders other than developers on whether all of these technologies can be reused directly or should be adapted (significantly) for the specific purpose of hyperloop. Moreover, despite the progress made, challenges remain, particularly in integrating these technologies into a fully functional and commercially viable system. While certain technical components, such as magnetic propulsion, have been demonstrated at high TRLs, others are still in the early stages of development. The integration of all components in a single system thus still needs to be proven, whilst hyperloop technology over long distances also still needs to be tested, which is a crucial step toward commercialisation (for more details, see Section 3.2.2)
- **Gaps in EU manufacturing capacity:** Europe will face significant challenges in scaling up hyperloop development, including supply chain vulnerabilities for batteries as well as lithium and rare earth elements, and localised grid capacity limitations. However, the EU’s strong manufacturing base in steel, aluminium, and composites, along with a growing battery sector and advanced workforce expertise, provides a solid foundation to progress further. Strategic investments in domestic material sourcing, renewable energy infrastructure and targeted skills development could further help to overcome these challenges and position Europe as a leader in Hyperloop technology

The main opportunities of the European hyperloop sector could be summarised as follows:

- **Policy and funding support**: EU transport priorities, especially linked to further greening and decarbonisation, present significant opportunities for hyperloop development. As discussed, regulatory support and financial incentives at EU level act as a catalyst for private investment and accelerate research efforts. The potential strategic use of public-private partnerships could further accelerate the development of the European hyperloop sector. As a concreter idea for the short term, a regulatory sandbox can be used to help the sector develop further. This can be linked to existing initiatives, such as for example the European Hyperloop Centre in Netherlands. At a later stage, further advancement can be made at policy level, for instance, by moving forward to action plan and testing of regulatory environment (for more details, see Section 3.2.3)
- **Safety features**: hyperloop's enclosed infrastructure minimises the risk of external interference and accidents caused by human error, offering a potentially safer alternative to conventional transport modes. In fact, hyperloop’s automated operations reduce operational risks. However, the lack of full-scale testing means safety claims remain largely theoretical, and extensive trials are required to validate these benefits (for more details, see Section 9)

- **Economic potential**: hyperloop has the potential to stimulate economic growth through job creation and enhanced connectivity between key urban centres. In particular, there are opportunities for regional development, particularly in underserved areas. Nevertheless, significant uncertainties remain regarding the long-term economic viability of the technology, as also discussed under the business case above. This will require gathering more concrete data to support investment decisions (for more details, see Section 4.2)
- **Larger socio-economic benefits:** some additional indirect socio-economic benefits are expected from hyperloop. For instance, land value appreciation as the development of hyperloop infrastructure has the potential to increase property values in areas surrounding stations and corridors, as improved connectivity makes these locations more attractive for businesses, residential areas, and commercial activities. This can drive economic growth, boost investment, and encourage urban expansion in previously less accessible regions. Yet, this would need to be fully corroborated by in-depth demand studies for the different routes
- **Market growth and related social benefits:** hyperloop has the potential to capture a relevant market share in both passenger and freight transport. The potential demand growth it would bring up on top of this share of the existing transport could also have several social benefits such as enhancing regional and cross-border connectivity, enhancing opportunities that already exist in terms of cross-border and regional connectivity, tourism, and freight efficiency (for more details, see Section 4.2)
- **Technological convergence:** collaborations between hyperloop developers, research institutions and industry stakeholders can drive standardisation and innovation. In fact, there are already several ongoing efforts in establishing technical frameworks and interoperability standards that could facilitate the seamless integration of hyperloop systems across Europe (for more details, see Section 3.2.2)

The main threats to the European hyperloop sector could be summarised as follows:

- **Regulatory fragmentation** inconsistent regulatory approaches across EU member states could hinder hyperloop deployment (as, for example, happened previously in the rail sector). Moreover, a lack of harmonised standards may result in operational inefficiencies and increased compliance costs, potentially slowing adoption (for more details, see Section 4.3.4)
- **Investment risks**: uncertainties surrounding hyperloop's economic feasibility and long-term viability pose significant investment risks. In fact, potential investors may be hesitant without clearer indications of expected market demand as well as the regulatory uncertainty as described above (for more details, see Section 4.3.4)
- **Existing transport modes**: hyperloop needs to clearly improve it advantages over strongly established transport modes such as high-speed rail and air travel. This is why hyperloop must demonstrate clear cost and efficiency advantages to prevail, particularly in regions with existing, robust transport networks (for more details, see Section 8.4 and 9.1
- **Technical and social acceptance**: public perception and acceptance of hyperloop technology remain uncertain. This is largely due to concerns linked to passenger comfort, safety and ticket affordability. Effective public engagement and awareness campaigns will thus be crucial to overcoming these barriers and gaining widespread support (for more details, see Section 4.2)

10.2 Main study limitations

Despite the comprehensive approach taken in this fact-finding study, several limitations can be identified that may affect the robustness and applicability of the findings. One significant limitation is the **limited stakeholder consultation**, which primarily focused on hyperloop developers and selected industry stakeholders. As we had to concentrate our efforts on collating all existing evidence available with them, the perspectives of broader stakeholders, such as policymakers, potential end-users and environmental groups, were not sufficiently incorporated. The lack of prior reference for this new transport mode limited the ability to effectively engage with stakeholders, whereas consulting a broader range of stakeholders could have provided more unbiased data on hyperloop. As a starting point, topics like socio-economic and regulatory challenges that could impact the deployment and adoption of hyperloop technology across Europe has been discussed with a broader range of stakeholders during the final Workshop organised during the study in February 2025.

Another critical limitation is the **limited availability of quantitative data and reliable estimates**. Hyperloop is an emerging technology, and there is a scarcity of empirical data to support precise modelling and forecasting efforts. Many of the projections related to cost, demand and operational efficiency are based on assumptions and extrapolations from early-stage feasibility studies rather than real-world deployments. Even though we made every effort to achieve the best possible outcome, this data gap introduces a degree of uncertainty in the financial and environmental viability of hyperloop systems, potentially affecting investment decisions and policy formulation.

Additionally, the study encountered **divergence of opinion between stakeholders**, which has complicated the formulation of consistent conclusions. Various stakeholders, including hyperloop developers, national governments and industry experts, hold differing views on critical aspects such as technological readiness, regulatory needs and business models. This diversity of opinions underscores the challenges in achieving a unified approach to hyperloop standardisation and implementation, which could slow down progress and create fragmented regulatory landscapes.

Moreover, the study faced **challenges related to technological uncertainties and the evolving regulatory framework**, which add complexity to the findings. Given the rapid pace of technological innovation, certain aspects of the hyperloop system, such as safety protocols and energy efficiency, remain speculative.

Lastly, **geographical and contextual variations** across Europe pose a challenge in generalising the study's findings. Differences in infrastructure, economic conditions and political priorities across Member States may require tailored approaches to hyperloop development, which were not fully explored within the study's scope. This is reflected by the fact that in some counties, significant steps have been taken to develop and test the strategy, other counties have not developed any projects related to the technology so far. This also leads to the fact that the former countries have started thinking about strategies for standardisation and a possible regulatory framework already, whilst the latter counties have not yet done so. As a result, the findings may not fully capture the specific challenges and opportunities unique to different regions within the EU.

Addressing these limitations in future research efforts will be crucial to ensuring a more comprehensive and actionable understanding of hyperloop's potential in Europe. Expanding stakeholder engagement, improving data collection methods, and fostering greater alignment among industry participants will contribute to more robust policy recommendations and investment strategies.

10.3 Recommendations for next steps

Based on the key findings and conclusions of this report, as well main EU policy goals in the transport field, we have identified a set of main recommendations:

- **Alignment with long-term objectives of the TEN-T network**, particularly considering the comprehensive coverage of high-speed rail by 2050 across Europe. By positioning hyperloop as an alternative to very high-speed polluting transport modes and low carbon-freight, promoters can support the EU's goals of reducing greenhouse gas emissions, improving connectivity and enhancing the efficiency of transport sector across Member States. To achieve this, a key strategy for the European hyperloop sector should be the identification of potential gaps in the TEN-T plan where hyperloop could address unmet transport needs or provide an economically viable solution. For example, certain high-demand corridors lack direct connections, forcing passengers and goods to rely on less efficient, multimodal options. In such cases, hyperloop could offer a faster, more sustainable alternative, reducing travel times and increasing network efficiency. Additionally, hyperloop could target corridors with challenging geographical or urban constraints, where the high capital expenditure of high-speed rail could be a limiting factor. Moreover, previous sections have highlighted the significant variability in high-speed rail's capital expenditure across Europe, as seen in, for instance, Section 7.1.1. This variability opens opportunities for hyperloop to serve as a cost-competitive solution in certain regions. By focusing on high-demand corridors, hyperloop promoters can demonstrate the technology's economic and operational viability while addressing bottlenecks and gaps in the TEN-T network, such as congested rail corridors, high-congested air routes, or regions where high-speed rail development faces technical or economic challenges. By doing so, the hyperloop technology could position itself as a transformative yet complementary technology in Europe

Moreover, the Draghi report (*The Future of European Competitiveness*)[203] provides several insights and recommendations that can be adapted for the hyperloop sector in Europe:

- Firstly, it **encourages increased R&D investment in hyperloop technology**, including in infrastructure, energy efficiency and operational systems. The hyperloop sector should collaborate with public and private stakeholders to benefit from EU funding mechanisms, such as the Horizon Europe programme
- This recommendation is strongly aligned with other points aligned in the report, to share financial risk and attract private investment. The Draghi report further emphasises the leveraging of private capital alongside public funding to foster large-scale infrastructure projects. Moreover, the financial analyses from many developers underline that public investment might be necessary to de-risk early hyperloop projects and attract private investors. Once hyperloop technology has proven its commercial viability, mechanisms such as **guarantee schemes and launch aid**, similar to those used in the aviation industry (e.g. Airbus), were proposed as ways to provide initial financial support
- Another point underlined in the report is the relevance of creating a **coherent regulatory environment** to accelerate market entry to innovative sectors while ensure safety, economic competitiveness and sustainability. Therefore, hyperloop promoters shall work closely with DG MOVE, as well Europe's Rail Joint Undertaking, other services of the Commission and the European Union Agency for Railways (ERA) to establish clear safety, environmental, and operational standards for hyperloop systems

[203] European Commission, *The future of European competitiveness – In-depth analysis and recommendations*, 2024.

Appendix 1. ANALYTICAL METHODS USED

This annex presents the methodology for and results of the analysis of the market analysis. The market analysis consisted of a stepwise approach to model the data from the hyperloop transport sector in 2050. The quantitative data analysed distinguished indicators considering the following quantitative elements: i) Passenger transport activity; ii) Freight transport activity; iii) Economic and operational analysis; iv) Analysis of Environmental Impacts; v) Performance and safety. The data was presented at EU-27 level. This annex presents the methodological approach that was adopted and the main results.

Methodological approach

The analytical work underpinning this Fact-Finding study uses the data provided by hyperloop promotes, which was extrapolated using the European Commission's PRIMES-TREMOVE model EU Reference Scenario (drawing from the Support Study for an Impact Assessment of the Passenger Rights Framework[204]), on the evolution of demand for passenger and freight transport as a proxy to estimate and calibrate projections on economic and operational analysis, as well as the analysis of environmental impacts.

The following table presents the list of variables used throughout this report, together with the source.

Table 41: List of variables used in the report

Group	Indicator	Source	Rationale
Transport Activity	Kilometres of operational network (2035-2060)	Hyperloop promoter 2	
	European hyperloop in 2050 (covering 8 Member States)	Hyperloop promoter 2, Hyperloop promoter 1 and Hyperloop promoter 5	We drafted a potential network map based on the inputs from hyperloop promoters.
	Measurement in kilometres of the three scenarios	hyperloop promoter 2 and TENtec Map	
	Modal share trends for long-distance passenger transport	Hyperloop promoter 2, Hyperloop promoter 1	
	Share of high-speed rail services	Statistical Pocketbook: EU Transport in figures 2024	
	Number of passengers in each scenario	Hyperloop promoter 1 (market share), PRIMES-TREMOVE EU Reference Scenario, Eurostat	Based on Hyperloop promoter 1's market shares, Eurostat's historical and PRIMES-TREMOVE, we estimated the passenger demand for the different scenarios.
	Share of induced demand (both passenger and freight)	Hyperloop promoter 4	
	Freight demand in 2050	Hyperloop promoter 2 (market share), PRIMES-TREMOVE	Based on hyperloop promoter 2 market shares and PRIMES-TREMOVE, we estimated the freight demand for the different scenarios

[204] *Support study for an impact assessment on new rules for making the passenger rights framework resilient and future proof*, 2024, available at: https://op.europa.eu/en/publication-detail/-/publication/1ad56c92-3366-11ef-b441-01aa75ed71a1/language-en

Group	Indicator	Source	Rationale
Economic and operational analysis	Capital expenditure (EUR/km)	Hyperloop promoter 2, Hyperloop promoter 6, Hyperloop promoter 7	Due to the similarity between the figures provided, we have used an average of these figures.
	hyperloop infrastructure costs per category	Hyperloop promoter 7	
	Total infrastructure capital costs under the three scenarios	Hyperloop promoter 2, Hyperloop promoter 6, Hyperloop promoter 7	Based on the measurement in kilometres of the three scenarios estimated in the transport activity section, and the average value of capital expenditure, we estimated the total infrastructure capital costs for the three scenarios.
	Number of hyperloop vehicles	Hyperloop promoter 2	
	Passengers per vehicles	Hyperloop promoter 2	
	hyperloop Vehicles Cost, EUR/Passengers	Hyperloop promoter 6	
	Vehicle capital costs under the three scenarios	Hyperloop promoter 6, hyperloop promoter 2	Our estimations based on the figure provided by Hyperloop promoter 6 to estimated vehicles costs and hyperloop promoter 2's number of vehicles and passengers per vehicles (which is an approximated value to the figure provided by Hyperloop promoter 6).
	Capital expenditures estimations according to non-hyperloop promoters	A non-hyperloop promoter from another mode of transport	Our estimations based on the projected passenger demand and the kEUR/km figures provided by a non-hyperloop promoter from another mode of transport
	Infrastructure maintenance costs projections	Hyperloop promoter 6	Projections based on the infrastructure maintenance costs provided by Hyperloop promoter 6 and the measurement in kilometres of the three scenarios estimated in the transport activity section.
	Infrastructure maintenance costs projections according to non-hyperloop promoters	A non-hyperloop promoter from another mode of transport	Projections based on the infrastructure maintenance costs provided by a non-Hyperloop promoter from another mode of transport and the measurement in kilometres of the three scenarios estimated in the transport activity section.
	Vehicle maintenance costs projections	Hyperloop promoter 6, hyperloop promoter 2, Hyperloop promoter 5	Projections based on the vehicle maintenance costs provided by Hyperloop promoter 6 and the measurement in kilometres of the three scenarios estimated in the transport activity section.
	Vehicle maintenance costs projections according to non-hyperloop promoters	A non-hyperloop promoter from another mode of transport	Projections based on the vehicle maintenance costs provided by a Non-Hyperloop promoter from another mode of transport and the measurement in kilometres of the three scenarios estimated in the transport activity section.
	Operational expenses related with staff	Hyperloop promoter 6	Projections based on the staff-related costs provided by Hyperloop promoter 6 and the measurement in kilometres of the three scenarios estimated in the transport activity section.

Group	Indicator	Source	Rationale
	Energy usage costs	Hyperloop promoter 6, hyperloop promoter 2	Projections based on the energy usage-related costs provided by Hyperloop promoter 6 and the measurement in kilometres of the three scenarios estimated in the transport activity section.
	Other fixed facilities	Hyperloop promoter 2	
	Ticket fare per kilometre	Hyperloop promoter 2, Hyperloop promoter 6, Hyperloop promoter 7	
	Estimation of ticket fare for potential routes	Hyperloop promoter 2, Hyperloop promoter 6, Hyperloop promoter 7, TENtec Map	
	Potential ticket fare revenue for the three scenarios	Hyperloop promoter 2, Hyperloop promoter 6, Hyperloop promoter 7	Our estimations based on the projected passenger demand of the three scenarios estimated in the transport activity section and the ticket fare per kilometre.
	Potential revenue generated by hyperloop freight services	Hyperloop promoter 2	Our estimations based on the freight passenger demand estimated in the transport activity section and the fare per kilometre.
Analysis of environmental impacts	Greenhouse gases (CO_2, CH_4, N_2O stated in CO2s equivalents)	A non-hyperloop promoter from another mode of transport	
	Greenhouse gases estimations for air, rail and hyperloop under the three scenarios	A non-hyperloop promoter from another mode of transport	Projections based on GHG emissions estimations from a non-hyperloop promoter from another mode of transport and the passenger transport demand estimated in the dedicated sessions.
	Energy consumption (kWh/pkm)	Hyperloop promoter 7	
	hyperloop energy consumption under the three scenarios	Hyperloop promoter 7	Projections based on energy consumption estimations from Hyperloop promoter 7 and the passenger transport demand estimated in the dedicated sessions.
	Life-cycle Assessment for hyperloop components (gCO_2-eq./pkm)	Hyperloop promoter 7	
	Life-cycle Assessment for hyperloop components under the three scenarios		Projections based on life-cycle assessment estimations from Hyperloop promoter 7 and the passenger transport demand estimated in the dedicated sessions.
Performance and safety	Average speed, Access/egress time for hyperloop	Hyperloop promoter 6	
	Maximum speed, nominal cruising speed, throughput on main lanes during peak times	Hyperloop promoter 8	
	Travel times projections	Hyperloop promoter 2, Hyperloop promoter 7	

Group	Indicator	Source	Rationale
	Safety parameters (emergency response, braking systems, indecent containment)	Hyperloop promoter 8	

Source: elaboration of the Partnership (2025)

Data Inputs

In early 2024, hyperloop promoters received a formal request from the European Commission **for additional data required to support the ongoing analysis. Specifically, the requested data points focused on key areas critical to ensuring the robustness and accuracy of the study:**

Table 42: Data indicators requested

Data indicators	
hyperloop deployment year ***Distinguishing freight and passenger activity***	*Besides the deployment year, it would be valuable to understand the evolving network coverage at five-year intervals following hyperloop implementation.* *Moreover, it would be useful a list of cities connected by hyperloop and their routes.*
Passenger activity and modal share of the different long-distance modes of transport	*Considering the development of hyperloop technology and how its development can impact the share of other transport modes.*
Additional demand	*We aim further clarification on whether additional demand is estimated arising from the implementation of hyperloop, or if it will solely result in the substitution of existing transport modes. Furthermore, if hyperloop developers anticipate additional demand, it would be useful if they could provide a range for estimating such additional demand.*
Main hyperloop competitor	*It would be beneficial to clarify whether the main competitors for hyperloop are intra-EU short-haul flights or high-speed rail.*
Freight activity and modal share of the different transport modes	
Number of journeys per mode	*For passenger and freight transport*
Travel time across transport modes	
Safety: Accidents per transport mode	
CAPEX and OPEX for hyperloop implementation	*For passenger and freight transport*
Passenger fares	
Employment for hyperloop	*Employment needs for ensuring the operation of hyperloop transport.*
Environmental indicators for hyperloop transport	*Greenhouse gas emissions; Energy demand; Fuel consumption; Noise pollution.*

Source: elaboration of the Partnership (2025)

To facilitate better alignment and address any ambiguities in the data requirements, a workshop was held in early summer 2024. This workshop provided an opportunity for direct dialogue between the Partnership and hyperloop promoters, allowing for the clarification of specific data needs and expectations. As a result of these discussions, the hyperloop promoters shared supplementary data that was more closely tailored to the study’s objectives and requirements. This newly provided data served as a main resource for the analysis presented in this study.

In addition to the data provided by the hyperloop promoters, we used historical data from official EU sources, such as Eurostat and the Statistical Pocketbook: EU Transport in figures 2024. Furthermore, data from Support study for an impact assessment on new rules for making the passenger rights framework resilient and future proof[205] and EU Reference Scenario 2020, particularly regarding passenger numbers for the 2015-2050 period, was incorporated to project demand. These sources, aligned with the EU Reference Scenario, served as the foundation for the projections.

[205] European Commission, *Support study for an impact assessment on new rules for making the passenger rights framework resilient and future proof*, 2024, available at: https://op.europa.eu/en/publication-detail/-/publication/1ad56c92-3366-11ef-b441-01aa75ed71a1/language-en

Table 43: Baseline for passenger transport demand (2015-2050)

	2015	2019	2020	2025	2030	2040	2045	2050
Total air, bus and coach, rail and waterborne passenger transport								
Total number of passenger services (million)	97,7	107,0	56,8	95,9	109,1	120,7	127,6	133,8
Growth rate relative to 2019	-	-	-47%	-10%	2%	13%	19%	25%
Total number of passengers (million)	11 034	13 402	7 400	13 990	15 391	17 863	18 931	19 846
Growth rate relative to 2019			-45%	4%	15%	33%	41%	48%
Air transport								
Air services (million)	6,6	7,5	2,7	7,5	8,6	10,3	11,2	12,0
Growth rate relative to 2019	-	-	-63%	0%	14%	38%	50%	61%
Passengers travelling by air (million)	664	970	210	970	1 058	1 231	1 292	1 367
Growth rate relative to 2019	-	-	-78%	0%	9%	27%	33%	41%
Bus and coach								
Bus and coach services (million)	65,5	66,4	36,5	53,7	63,2	64,9	67,9	71,0
Growth rate relative to 2019	-	-	-45%	-19%	-5%	-2%	2%	7%
of which, services above 250 km	7,4	7,3	2,6	7,4	7,4	6,8	7,3	7,0
Passengers travelling by bus and coach (million)	3 302	3 345	2 390	3 514	4 137	4 246	4 444	4 645
Growth rate relative to 2019	-	-	-29%	5%	24%	27%	33%	39%
of which, passengers travelling above 250 km	372	369	259	381	449	460	482	504
Rail transport								
Rail services (million)	25,6	33,2	17,5	34,7	37,3	45,4	48,4	50,8
Growth rate relative to 2019	-	-	-47%	5%	12%	37%	46%	53%
Passengers travelling by rail (million)	6 699	8 668	4 570	9 067	9 737	11 872	12 652	13 264
Growth rate relative to 2019	-	-	-47%	5%	12%	37%	46%	53%
Waterborne transport								
Passengers travelling by waterborne transport (million)	368	418	230	438	459	514	543	569
Growth rate relative to 2019	-	-	-45%	5%	10%	23%	30%	36%

Source: Support study for an impact assessment on new rules for making the passenger rights framework resilient and future proof

Passenger transport activity: all scenarios

As presented in 5.3, we have developed various scenarios to assess the impact of hyperloop operations on passenger demand, given the uncertainties regarding the impact of hyperloop deployment in the entire transport system.

The four scenarios considered are as follows:

1. Excluding extra-EU flights (i.e. considering that hyperloop transport will only substitute intra-EU air transport, as abovementioned)
2. Excluding conventional rail transport, as it is not foreseen that hyperloop will substitute conventional rail, which covers mostly regional services. In this second scenario, we used the share of high-speed rail services for all Europe, as reported in the Statistical Pocketbook: EU Transport in figures 2024206. Under this scenario, conventional rail is excluded entirely from the baseline passenger total and is therefore not considered in the analysis.
3. "Conservative" scenario. The specific assumptions underlying these scenarios will be detailed in subsequent sections.
4. Induced demand scenario

In addition, and for each of these scenarios, we have outlined three micro-scenarios:

1. The first scenario foresees that hyperloop transport will have an impact on transport demand (for passenger and freight) at an EU-27 level by 2050.
2. The second scenario considers that hyperloop transport will only have an impact in transport demand in eight EU-27 Members States (Netherlands, Luxembourg, Belgium, Germany, France, Italy, Austria and Poland) in the same year.
3. In the third scenario, we consider that hyperloop operations will only be limited to the Netherlands, Belgium and Luxembourg in 2050.

Scenario 1: No-policy change scenario considering substitution market share provided for hyperloop to replace all rail passengers and air passengers (excluding extra-EU Flights)

Table 44: No-policy change scenario considering substitution market share provided for hyperloop to replace all rail passengers and air passengers (excluding extra-EU Flights)[207]

	EU-level		8 Member States		BENELUX	
Mode	Number of passengers (2050)	Final Share	Number of passengers (2050)	Final Share	Number of passengers (2050)	Final Share
Air	173	1%	398	3%	442	3%
Rail	7,330	53%	9,212	67%	11,380	85%
Hyperloop	6,254	45%	4,147	30%	1,936	15%

Source: elaboration of the Partnership (2025)

[206] European Commission, Statistical Pocketbook: EU Transport in figures 2024.

[207] The sources for all tables going forward in this Appendix are elaboration of the Partnership (2025), based on the various data sources described in this Appendix

Table 45: Passenger number projections in a 10-year series for 1.1 Sub-scenario 1: hyperloop network covering the EU27

Mode	2050 Number of passengers per mode (million)	2055 Number of passengers per mode (million)	2060 Number of passengers per mode (million)
Intra-EU air	173	181	189
Rail	7,330	7,812	8,190
hyperloop	6,254	6,605	6,914
Total number of passengers in the modes considered	13,757	14,597	15,293

Source: elaboration of the Partnership (2025)

Table 46: Passenger number projections in a 10-year series for 1.2 Sub-scenario 2: hyperloop network only covering 8 Member States (Austria, Belgium, France, Germany, Italy, Luxembourg, the Netherlands, Poland)

Mode	2050 Number of passengers per mode (million)	2055 Number of passengers per mode (million)	2060 Number of passengers per mode (million)
Intra-EU air	398	417	435
Rail	9,212	9,641	10,108
hyperloop	4,147	4,340	4,543
Total number of passengers in the modes considered	13,757	14,398	15,087

Source: elaboration of the Partnership (2025)

Table 47: Passenger number projections in a 10-year series for 1.3 Sub-scenario 3: hyperloop network only covering Benelux

Mode	2050 Number of passengers per mode (million)	2055 Number of passengers per mode (million)	2060 Number of passengers per mode (million)
Intra-EU air	442	463	484
Rail	11,380	11,910	12,486
hyperloop	1,936	2,026	2,121
Total number of passengers in the modes considered	13,757	14,398	15,090

Source: elaboration of the Partnership (2025)

Scenario 2: No-policy change scenario considering substitution market share provided for hyperloop to replace high-speed rail passengers (excl. conventional rail) and air passengers (excluding extra-EU Flights)

Table 48: No-policy change scenario considering substitution market share provided for hyperloop to replace high-speed rail passengers (excl. conventional rail) and air passengers (excluding extra-EU Flights)

	EU-level		8 Member States		BENELUX	
Mode	Number of passengers (2050)	Final Share	Number of passengers (2050)	Final Share	Number of passengers (2050)	Final Share
Air	173	4%	318	7%	473	10%
Rail	2,390	50%	3,255	68%	3,914	82%
Hyperloop	2,254	47%	1,245	26%	369	8%

Source: elaboration of the Partnership (2025)

Table 49: Passenger number projections in a 10-year series for 2.1 Sub0-scenario 1: hyperloop network covering the EU27

Mode	2050 Number of passengers per mode (million)	2055 Number of passengers per mode (million)	2060 Number of passengers per mode (million)
Intra-EU air	173	181	189
Rail	2,390	2,547	2,670
hyperloop	2,254	2,381	2,492
Total number of passengers in the modes considered	4,817	5,108	5,351

Source: elaboration of the Partnership (2025)

Table 50: Passenger number projections in a 10-year series for 2.2 Sub-scenario 2: hyperloop network only covering 8 Member States (Austria, Belgium, France, Germany, Italy, Luxembourg, the Netherlands, Poland)

Mode	2050 Number of passengers per mode (million)	2055 Number of passengers per mode (million)	2060 Number of passengers per mode (million)
Intra-EU air	318	332	347
Rail	3,255	3,406	3,571
hyperloop	1,245	1,303	1,364
Total number of passengers in the modes considered	4,817	5,041	5,282

Source: elaboration of the Partnership (2025)

Table 51: Passenger number projections in a 10-year series for 2.3 Sub-scenario 3: hyperloop network only covering Benelux

Mode	2050 Number of passengers per mode (million)	2055 Number of passengers per mode (million)	2060 Number of passengers per mode (million)
Intra-EU air	473	495	517
Rail	3,914	4,097	4,295
hyperloop	369	386	404
Total number of passengers in the modes considered	4,756	4,977	5,216

Source: elaboration of the Partnership (2025)

Scenario 3: New Substitution Market Share (conservative) for hyperloop to replace high-speed rail and intra-EU air passengers considering no-policy change scenario

Lower Bound (90% of the factor provided)

Table 52: New Substitution Market Share (conservative) for hyperloop to replace high-speed rail and intra-EU air passengers considering no-policy change scenario (Lower bound)

	EU-level		8 Member States		BENELUX	
Mode	Number of passengers (2050)	Final Share	Number of passengers (2050)	Final Share	Number of passengers (2050)	Final Share
Air	461	10%	475	10%	489	10%
Rail	4,131	86%	4,217	88%	4,291	89%
hyperloop	225	5%	124	3%	37	0,8%

Source: elaboration of the Partnership (2025)

Table 53: Passenger number projections in a 10-year series for 3.1 Sub-scenario 1: hyperloop network covering the EU27 (Lower bound)

Mode	2050 Number of passengers per mode (million)	2055 Number of passengers per mode (million)	2060 Number of passengers per mode (million)
Intra-EU air	461	482	504
Rail	4,131	4,402	4,615
hyperloop	225	238	249
Total number of passengers in the modes considered	4,817	5,122	5,368

Source: elaboration of the Partnership (2025)

Table 54: Passenger number projections in a 10-year series for 3.2 Sub-scenario 2: hyperloop network only covering 8 Member States (Austria, Belgium, France, Germany, Italy, Luxembourg, the Netherlands, Poland) (Lower bound)

Mode	2050 Number of passengers per mode (million)	2055 Number of passengers per mode (million)	2060 Number of passengers per mode (million)
Intra-EU air	475	497	520
Rail	4 217	4 494	4,712
hyperloop	124	131	138
Total number of passengers in the modes considered	4,817	5,123	5,369

Source: elaboration of the Partnership (2025)

Table 55: Passenger number projections in a 10-year series for 3.3 Sub-scenario 3: hyperloop network only covering Benelux (Lower bound)

Mode	2050 Number of passengers per mode (million)	2055 Number of passengers per mode (million)	2060 Number of passengers per mode (million)
Intra-EU air	489	512	535
Rail	4,291	4,573	4,794
hyperloop	37	39	41
Total number of passengers in the modes considered	4,817	5,124	5,370

Source: elaboration of the Partnership (2025)

Upper bound (70% of the factor provided)

Table 56: New Substitution Market Share (conservative) for hyperloop to replace high-speed rail and intra-EU air passengers considering no-policy change scenario (Upper bound)

	EU-level		8 Member States		BENELUX	
Mode	Number of passengers (2050)	Final Share	Number of passengers (2050)	Final Share	Number of passengers (2050)	Final Share
Air	397	8%	440	9%	482	10%
Rail	3,744	78%	4,003	83%	4 225	88%
hyperloop	676	14%	373	8%	111	2,3%

Source: elaboration of the Partnership (2025)

Table 57: Passenger number projections in a 10-year series for 3.1 Sub-scenario 1: hyperloop network covering the EU27 (Upper bound)

Mode	2050 Number of passengers per mode (million)	2055 Number of passengers per mode (million)	2060 Number of passengers per mode (million)
Intra-EU air	397	415	434
Rail	3,744	3,990	4,183
hyperloop	676	714	748
Total number of passengers in the modes considered	4,817	5,119	5,365

Source: elaboration of the Partnership (2025)

Table 58: Passenger number projections in a 10-year series for 3.2 Sub-scenario 2: hyperloop network only covering 8 Member States (Austria, Belgium, France, Germany, Italy, Luxembourg, the Netherlands, Poland) (Upper bound)

Mode	2050 Number of passengers per mode (million)	2055 Number of passengers per mode (million)	2060 Number of passengers per mode (million)
Intra-EU air	440	461	482
Rail	4 003	4 266	4 473
hyperloop	373	394	413
Total number of passengers in the modes considered	4 817	5 121	5 367

Source: elaboration of the Partnership (2025)

Table 59: Passenger number projections in a 10-year series for 3.3 Sub-scenario 3: hyperloop network only covering Benelux (Upper bound)

Mode	2050 Number of passengers per mode (million)	2055 Number of passengers per mode (million)	2060 Number of passengers per mode (million)
Intra-EU air	482	504	527
Rail	4,225	4,502	4,720
hyperloop	111	117	122
Total number of passengers in the modes considered	4,817	5,123	5,369

Source: elaboration of the Partnership (2025)

Scenario 4: Substitution market share provided for hyperloop to replace high-speed rail passengers (excl. conventional rail) and air passengers (excluding extra-EU Flights) and additional 5% of induced demand relative to the baseline scenario

Table 60: Substitution market share provided for hyperloop to replace high-speed rail passengers (excl. conventional rail) and air passengers (excluding extra-EU Flights) and additional 5% of induced demand relative to the baseline scenario

	EU-level		8 Member States		BENELUX	
Mode	Number of passengers (2050)	Final Share	Number of passengers (2050)	Final Share	Number of passengers (2050)	Final Share
Air	182	4%	333	7%	478	9,5%
Rail	2,509	50%	3,418	68%	4,192	82,9%
hyperloop	2,367	47%	1,307	26%	388	7,7%

Source: elaboration of the Partnership (2025)

Table 61: Passenger number projections in a 10-year series for 4.1 Sub-scenario 1: hyperloop network covering the EU27

Mode	2050 Number of passengers per mode (million)	2055 Number of passengers per mode (million)	2060 Number of passengers per mode (million)
Intra-EU air	182	190	199
Rail	2,509	2,674	2,803
hyperloop	2,367	2,500	2,617
Total number of passengers in the modes considered	5,058	5,364	5,619

Source: elaboration of the Partnership (2025)

Table 62: Passenger number projections in a 10-year series for 4.2 Sub-scenario 2: hyperloop network only covering 8 Member States (Austria, Belgium, France, Germany, Italy, Luxembourg, the Netherlands, Poland)

Mode	2050 Number of passengers per mode (million)	2055 Number of passengers per mode (million)	2060 Number of passengers per mode (million)
Intra-EU air	333	349	365
Rail	3,418	3,642	3,818
hyperloop	1,307	1,380	1,445
Total number of passengers in the modes considered	5,058	5,371	5,628

Source: elaboration of the Partnership (2025)

Table 63: Passenger number projections in a 10-year series for 4.3 Sub-scenario 3: hyperloop network only covering Benelux

Mode	2050 Number of passengers per mode (million)	2055 Number of passengers per mode (million)	2060 Number of passengers per mode (million)
Intra-EU air	478	500	523
Rail	4,192	4,467	4,684
hyperloop	388	409	428
Total number of passengers in the modes considered	5,058	5,377	5,635

Source: elaboration of the Partnership (2025)

Economic, operational and environmental impacts

Due to the lack of more detailed and granular data, the projections under these sections have been limited to the year 2050, rather than covering a more extended time series or providing insights for additional years beyond this reference point.

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