

Hyperloop

Accelerating progress toward

Europe's goal of sustainable transport

HDP Vision Paper I December 11th, 2024

CONTENT

Executive Summary	3
1. What is hyperloop?	4
2. What can hyperloop offer?	5
3. Alignment with EU policies	7
4. Hyperloop allows to address other mobility problems	8
5. Status of hyperloop development	9
6. CAPEX and OPEX	10
7. A standard is needed!	11
8. A European regulatory framework to ensure safety, connectivity and interoperability is needed!	12
9. Timeline toward commercial implementation	13
10. How would the transition look like?	14
11. Addressing challenges	15
Conclusion	16
Annex 1	i
Annex 2	ii



Figure 1 - Render of elevated hyperloop infrastructure adjacent to a motorway

EXECUTIVE SUMMARY

The Hyperloop Development Program proposes a roadmap for the further development of hyperloop leading up to commercial implementation. It offers a comprehensive overview of hyperloop's potential impact, benefits and costs. It addresses questions about the technology's performance, safety, and environmental impact as well as the impact on passengers. It outlines the current state of hyperloop, identifies gaps, and concludes with a proposal for its realization as a complementary transport mode.

It shows that hyperloop supports the EU's aims by offering a high-speed, energy-efficient, and economically viable transport mode, enhancing citizens' well-being with faster and more convenient travel. Its low carbon emissions contribute to the EU's policy objectives on sustainability, i.e., the European Green Deal's goal of a 90% reduction in transport-related greenhouse gas emissions. Improved connectivity across the TEN-T network fosters cohesion and economic integration among EU countries.

Adopting hyperloop strengthens the EU's leadership in innovative technologies and boosts global competitiveness. Hyperloop offers shorter travel times than aviation and a larger capacity than high-speed rail. It does so with lower operating and maintenance costs and with little impact on the environment due to minimum carbon emissions, low noise and little use of space with lower costs of construction and operation. With minimal air resistance and no mechanical friction on the guideway, hyperloop can achieve airplane-like speeds while using less energy than a traditional train.

Hyperloop consists of driverless, autonomous vehicles moving with magnetic levitation and guidance inside a near-vacuum tube environment. Hyperloop leverages

existing, proven technologies from rail and aviation, there is international cooperation, and growing technological alignment. All components are being tested. Hyperloop mainly requires system integration and further engineering and testing to fully demonstrate its viability and passenger safety.

Given the potential of the technology, as well as the need for an interoperable system, public authorities are urged to provide political backing and financial support through a publicly funded hyperloop development ecosystem. This commitment is essential to advance hyperloop technology and to integrate it effectively into the EU's transport infrastructure.



Ursula von der Leyen
President of the European Commission



I also want Europe to take the lead on the innovation and transportation of the future.

*As part of this, you should propose a strategy for the promotion and development of cutting-edge technologies such as **hyperloop technologies**, including a timetable and an investment strategy.*

September 17th 2024 - mission letter to Apostolos Tzitzikostas (European Commission for Sustainable Transport and Tourism) [LINK](#)



Europe's Rail
European partnership for railways innovation



*Emerging tech. for guided transport systems could be a complementary solution for the increased demand, increasing also the availability of sustainable transportation solutions. **Hyperloop technologies** could be a promising alternative, since it promises very high-speed travel with low energy needs while relying on electricity.*

December 5th 2023 - in ANNEX to GB decision n°16/2023 ERJU Work Programme 2024 [LINK](#)



Mario Draghi
On behalf of the European Commission



*In the future, transport is set to experience major green and digital transformations. The transport fleet will increasingly rely on new technology, (...) (e.g. **hyperloop trains**) to deliver greater speed, efficiency and cost savings.*

September 9th 2024 - The future of European Competitiveness – In-depth analysis and recommendations [LINK](#)



TEN-T regulation
Guidelines for a European transport network



*The Commission (...) should encourage projects of common interests which aim to promote and deploy sustainable emerging technologies (...). These could cover(...) **new railway technologies such as hyperloop.***

June 13th 2024 - in the regulation on Union guidelines for the development of the trans-European transport network. [LINK](#)

1. WHAT IS HYPERLOOP?

Hyperloop is a new transport mode consisting of driverless vehicles that move by magnetic propulsion in a near-vacuum tube environment. The vehicles are propelled electrically. It has no mechanical friction and very small air and magnetic drag. That is why hyperloop can be operated with a very low input of energy and does not cause emissions but travels at speeds like airplanes.

Hyperloop is therefore very distinct from all existing transport modes.



Figure 2 - Render of hyperloop infrastructure in a mountainous region

2. WHAT CAN HYPERLOOP OFFER?

The main value proposition of hyperloop lies in its ability to provide competitive or shorter travel times compared to aviation, while simultaneously offering the capacity, comfort, and sustainability of rail travel. This innovative technology fosters seamless connectivity across the continent, enabling passengers to reach 90% of EU destinations in three hours or less, and access any location within a country in under an hour, all while significantly reducing energy consumption compared to traditional air travel. Its inherent multi-country and cross-border nature aligns perfectly with the EU's vision for a well-connected TEN-T network.

That means in more detail:

1. An increase in speed to replace short-haul flights over distances up to approximately 2,000 km with a faster and more sustainable ground transport alternative, simultaneously freeing up airport capacity for economically vital long-haul connections.

2. A big leap in the convenience and attractiveness of public transport. This is achievable with hyperloop network design principles. By deploying multiple smaller vehicles, the hyperloop system enables seamless, 'single seat' journeys without stops between major transport hubs. The resulting reduction in intercity travel time, along with integration into local transit networks positions public transport as a more competitive, efficient choice for travelers.

3. Current transport modes fall short of delivering the decarbonization targets required by law, which mandate a 90% reduction in emissions by 2050. Sustainably produced electricity, green hydrogen and sustainable aircraft fuels are not likely to be available in sufficient quantities to meet the



Figure 3 - Interior of a hyperloop test vehicle (Munich, DE)

demand that reaching these targets would generate. An additional transport mode with lower energy consumption can help to achieve the transition.

4. An opportunity to develop a transport system which will have the lowest emissions per passenger-km traveled. 100% powered by electricity, some of which can be generated by renewables mounting solar panels on its own infrastructure and regenerated from decelerating vehicles, hyperloop has the potential to operate with zero emissions.

5. An increase in transport capacity to address the projected growth of passenger and freight transport demand. It is economically, environmentally and commercially impossible to accommodate this growth by extending or expanding railways, motorways and airports. Hyperloop trains can dynamically form and detach autonomously, providing a transport capacity of up to 20.000 passengers per hour per direction (pphpd). This system allows passengers to enjoy point-to-point seamless journeys without additional stops in between.

6. Hyperloop could relieve the pressure on overloaded infrastructures: short-haul flight congests airports, freight congests roads for passenger transport, high-speed rail does not allow freight trains to use the infrastructure, and dedicated networks are difficult to realize.

7. A maximum improvement in reliability; a transport mode which is almost totally protected from external disturbances such as (extreme) weather conditions and intersecting traffic.

8. Disruptive effect on growth of large agglomerations and revitalisation of less accessible regions. Instead of cities sprawling out into the countryside, commuters could live in smaller cities further away from the main centres, where accommodation is often less costly. This can be easily done by hyperloop connections to smaller cities without slowing down traffic on the long distance. Commuting times could be shorter over longer distances due to the point-to-point connectivity.

9. Because hyperloop requires less land, it can be built alongside existing linear infrastructures. Furthermore, its design is compact and does not require replacement of the infrastructure as rapidly as high-speed rail. As a result, capital expenditures (CAPEX) are expected to be lower, and operating and maintenance costs will also be reduced. This efficiency paves the way for a faster return on investment and makes operations economically viable.

10. Therefore, it can be an attractive proposition for PPP (Public Private Partnership) financing. Due to high capacities and low operational costs (vehicles operate without on-board staff), hyperloop projects are expected to be at minimum partly privately financed. Studies by various parties, including Roland Berger and InnoEnergy, indicate that hyperloop is financially viable. After implementing a full-size test line to demonstrate safety and functionality, and establishing a regulatory framework, the commercial lines could be developed as a PPP with limited public funding.

11. A once-in-a-century opportunity to establish a leading new industry on the development, planning, and delivery of this new transport system. Hyperloop could become a European export product on a large scale. Other regions around the world are actively pursuing hyperloop

development as well, making it not a question of if but rather when and who will be the first to bring the technology to market. Europe has a unique chance to lead this global movement, positioning itself as a primary innovator and exporter in the hyperloop industry.

12. In conclusion: hyperloop offers a high-speed, point-to-point, high-capacity, environmentally friendly, transportation system with low maintenance and operational costs:

- Average speeds of 500 km/h, or faster, ultimately reaching to 1,000 km/h
- Can provide direct connections on an entire continent without intermediate stops
- A capacity to transport 20.000 persons per hour per direction
- 50% tighter curve radii than traditional rail infrastructure
- 50% lower land use than traditional rail infrastructure
- No noise, no vibrations, no direct emissions

Most of these benefits would already apply as soon as some first lines exist and do not depend on the existence of a full network!



Figure 4 - Render of a hyperloop station

3. ALIGNMENT WITH EU POLICIES

Hyperloop aligns well with – and is already embedded into – European policy. The EU's Trans-European Transport Network (TEN-T) policy, described by the European Commission as “a key instrument for planning and developing a coherent, efficient, multimodal, and high-quality transport infrastructure across the EU,” seeks to optimize transport efficiency for both people and goods. It facilitates access to jobs and essential services, promotes trade and economic growth, and bolsters the EU's economic, social, and territorial cohesion.

By creating seamless, cross-border transport systems without gaps, bottlenecks, or missing links, TEN-T lays the foundation for a unified European network. Notably, the 2024 policy revision, which recognizes hyperloop as an emerging railway technology, prioritizes reducing the environmental and climate impact of transportation while enhancing network safety and resilience. Specifically, hyperloop could enhance 3 of 6 requirements of the TEN-T Network, setting new benchmarks for transportation infrastructure in Europe, as outlined below.

The development of hyperloop is supported by the European Commission through a grant and investment of the European Innovation Council and through Europe's Rail Joint Undertaking (ERJU) Flagship Area 7: Innovation on new approaches for guided transport modes. ERJU's 2024 work programme mentions: “The objective of FA7 is to explore non-traditional and emerging flexible and/or high-speed guided transport systems [...]. This will provide socio-economically efficient and long-term sustainable transport for citizens and businesses throughout Europe. The main aspects for such systems are the reduction of energy consumption, noise and pollutant emissions and land consumption [...]. New approaches foreseen under FA7, like [...] pods, magnetic levitation, [...] and vacuum tube technique bring a lot of advantages and can be an important and possibly unavoidable component of the mobility of the future”. The consortium Hyper4Rail led by the Hyperloop Development Program has been granted €2.3M by the European Commission to develop a roadmap towards industrialisation and harmonized implementable concept.

Hyperloop is the best option available to extend and complement the TEN-T Network.

Table 1 - Potential enhancement of TEN-T requirements

Requirements	Current benchmarks	Potential benchmarks with hyperloop
Rail travel speed	By 2040, passenger railway lines on the core and extended core network must support trains traveling at speeds of 160 km/h or faster.	By 2060, hyperloop lines on the core network must support vehicles traveling at speeds of 500 km/h or faster.
European Rail Traffic Management System (ERTMS)	The single European signalling system will be deployed across the entire TEN-T network, enhancing rail safety and efficiency. National systems will be phased out.	A single European hyperloop signalling system is developed and deployed across the entire TEN-T hyperloop network, ensuring interoperability and digital from day one.
Airport connectivity	Major airports with over 12 million passengers annually must be connected by long-distance rail, making rail a competitive alternative to domestic feeder flights.	Major airports with over 12 million passengers annually must be connected by hyperloop, making hyperloop a competitive alternative to intra-European flights.



4. HYPERLOOP ALLOWS TO ADDRESS OTHER MOBILITY PROBLEMS

Studies indicate that freight transport demand will at minimum triple by 2050, largely due to globalization, e-commerce, and supply chain complexities. The politically desired shift to rail is not advancing. Policy measures, investments in infrastructure, and technological advancements are expected to drive this shift, reducing the reliance on road transport and lowering greenhouse gas emissions. However, the desired shift towards more sustainability in freight transport is currently limited by a number of factors, one of them availability of rail capacity. Especially where high-speed trains and freight trains share the same infrastructure. Other problems are congestion of motorways and airports. Expanding these infrastructures becomes more and more difficult. Hyperloop is well positioned to reduce the demand for short-haul flights and complement or replace high-speed rail on long distances. This shift could free up rail capacity for freight and alleviate congestion on railways, motorways and airports for passengers.

Building new infrastructures for current transport modes takes very long

The development and implementation of new infrastructure projects in Europe faces significant time constraints. Approval times for new linear infrastructure, such as railways and motorways, typically take no less than 10 years. This lengthy process includes environmental impact assessments, public consultations, and securing necessary permits. Land acquisition is a critical component of infrastructure projects and can consume approximately 5 years. The design and construction phases of new infrastructure projects can take around 10 years. This includes detailed engineering, procurement, and actual construction activities. Considering these timelines, any new infrastructure planned today may not be available until 2050. Due to the lengthy duration, new linear infrastructure projects are considered generational undertakings.

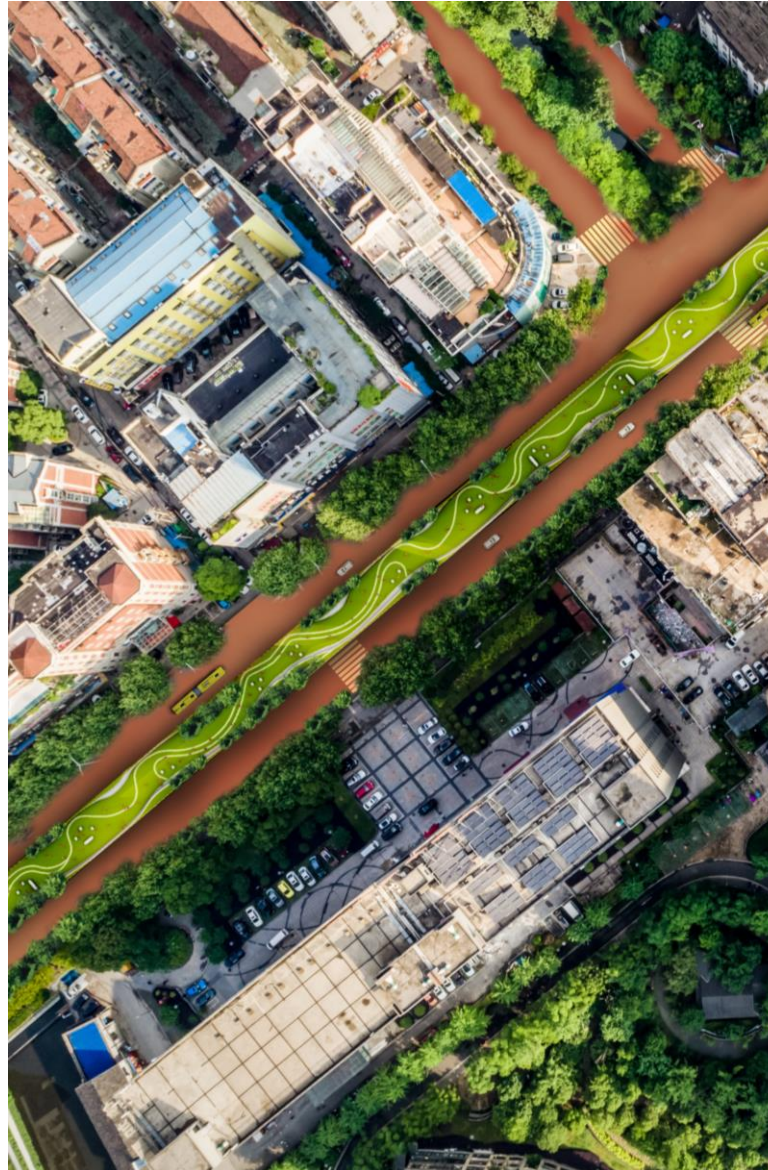


Figure 5 - Render of hyperloop infrastructure with a park on top, located alongside a city avenue

In addition, maintaining and upgrading the existing road and rail infrastructure requires substantial public budgets in all countries where infrastructure is paid for by public sources. This financial burden leaves little room for additional significant transport spending, hindering the ability to address future demand and sustainability goals effectively.

Hyperloop can be built faster if existing infrastructure such as motorways are followed. Given that there is an existing infrastructure, there can be a shorter approval process, the building process is shorter than for high-speed rail and the investment will offer faster pay-back than for new high-speed rail.

Sustainability targets are difficult to meet with the current mix of transport modes

Current transport modes are falling short of meeting the legally mandated decarbonization targets, which require a 90% reduction in emissions by 2050. Even if sustainably produced electricity and green hydrogen become available in large quantities to meet the demand generated by emission reduction targets, the high energy consumption for producing sustainable aviation fuels would be disproportionate to the renewable energy requirements of the rest of society. Furthermore, aviation will likely continue to impact climate and air quality negatively due to the effects of aerosols. Additionally, as the ever-increasing number of cars and trucks transition to electric power, they will still contribute to motorway congestion and exacerbate environmental concerns.

Hyperloop uses much less energy and operates without emissions. If it becomes part of the transport mix, it will facilitate to reach decarbonization targets.

5. STATUS OF HYPERLOOP DEVELOPMENT

Hyperloop does not require major technological breakthroughs to become viable. Each necessary system already exists at TRL9 in other industries, with many subsystems having been demonstrated at TRL5-6 in relevant environments for hyperloop, and others currently at TRL2-4. The closest analogues are rail for infrastructure, traction, and control systems, and aviation for fuselage, cabin, and life support systems. Significant investment has already gone into demonstrating the core principles of these technologies for Hyperloop. The most critical next step is to harmonize the hyperloop system, ensure that all key subsystems are demonstrated at TRL4, and then move towards industrialization.

Industrializing and going through the certification process is costly and time-consuming, and will require more elaborate test and certification facilities, which is only feasible once a harmonized concept is defined, and all key subsystems are sufficiently de-risked. These efforts are currently being performed in the Hyper4Rail project financed by the EU, which will deliver a roadmap for further development and deployment of hyperloop technology by the end of 2026. It is now crucial to build momentum by involving a critical mass of public and private stakeholders in developing this roadmap and the subsequent program for industrialization.

An extended paper on the technological status will be made available as an early deliverable of the Hyper4Rail project.

International cooperation

Hyperloop development is ongoing in the US, China, India, South Korea, Turkey, Canada and in several European countries. European Hyperloop developers, infrastructure companies, rail operators and others cooperate through the Hyperloop Development Program (see Annex 1) a

foundation under Dutch law with a mandate to promote hyperloop at a European level. There is also increasing cooperation and exchange between developers inside and outside Europe. The European Hyperloop Week organises competitions of university teams to bring the technology forward. Similar competitions exist in other parts of the world.

Start of a European Industrial Hyperloop Cluster

As soon as larger test infrastructures and pilot applications will be built, there will be a new market in construction, steel, concrete and battery production; electronics and vacuum pumps will be needed. A number of companies in these sectors are already associated or interested. A first project of more than fifty-kilometre length will create a volume exceeding one billion euros!

Role of governments

A number of governments are following the development, some are already contributing financially. The European Union has brought forward the hyperloop as an opportunity through various policy initiatives, including by the European Commission, the European Parliament and Europe's Rail. Strong government support is necessary for any infrastructure project, even if privately financed. Governments also need to address and manage citizens' concerns and provide assurances that safety standards are met.

To ensure, that Europe fully benefits from the development of hyperloop, it is suggested to create shared cooperative testing facilities and a financial framework between the EU and its Member States to ensure mutual benefit.



Figure 6 - HDP Partners Day 2024 (Dübendorf, CH)

6. CAPEX AND OPEX

Studies indicate that the capital expenditure for hyperloop construction is expected to be lower than that of high-speed rail, with average costs estimated at around € 30 million per kilometer compared to € 37 million per kilometer for high-speed rail. Because hyperloop uses non-wheeled electromagnetic propulsion (linear motor), it is not reliant on adhesion to climb gradients. A 10% (1-in-10) gradient is possible for Hyperloop, whereas freight rail is typically limited to 1.5% and high-speed rail to 2.5% – 4%. This is a fundamental hyperloop advantage. Maximizing the advantage of elevated construction to enable hyperloop routes to 'smooth out' landscape undulations. This significantly reduces the need for costly earthworks in cuttings and embankments, eliminates much of the requirement for very costly bridges or viaducts, and can significantly remove the need for tunnelling on most routes.

Several other factors will also play out in favor of lower CAPEX for hyperloop:

- When the route is elevated, it only requires some 2 m² of land per linear meter, while a TGV-style rail alignment needs 12-16 m². In addition, the land underneath remains usable for its original purpose in many cases, in particular in the case of agricultural use. This reduces the cost of land acquisition.
- Another capex-reducing advantage of elevated construction is that the alignment can traverse most existing infrastructure (roads, railways and waterways) without expensive civil works such as tunnels or long viaducts.

When looking at Operation and maintenance costs, the following elements can be considered:

- Fully automated operation means no drivers, personnel costs can be concentrated on providing services to the passengers
- The shorter round-trip time of a hyperloop line means fewer vehicles in use, therefore less maintenance
- Energy consumption is much lower, and lines could be used to produce excess energy for other purposes. Therefore, energy costs are projected to be much lower
- Maintenance of the guideway is minimal due to the fact, that the train does not touch the guideway

Operational expenditure per passenger seat is projected to be much lower than that of high-speed rail. That means that hyperloop connections cannot only be operated in a financially viable way, they could be financed and operated privately as build and operate schemes or availability schemes as is already the case in some rail projects.

The maintenance of current modalities will exert extreme pressure on public budgets with growing costs, while hyperloop has the potential to be largely operated on a profitable basis.

Hyperloop has the potential to be built and operated on a largely private basis.

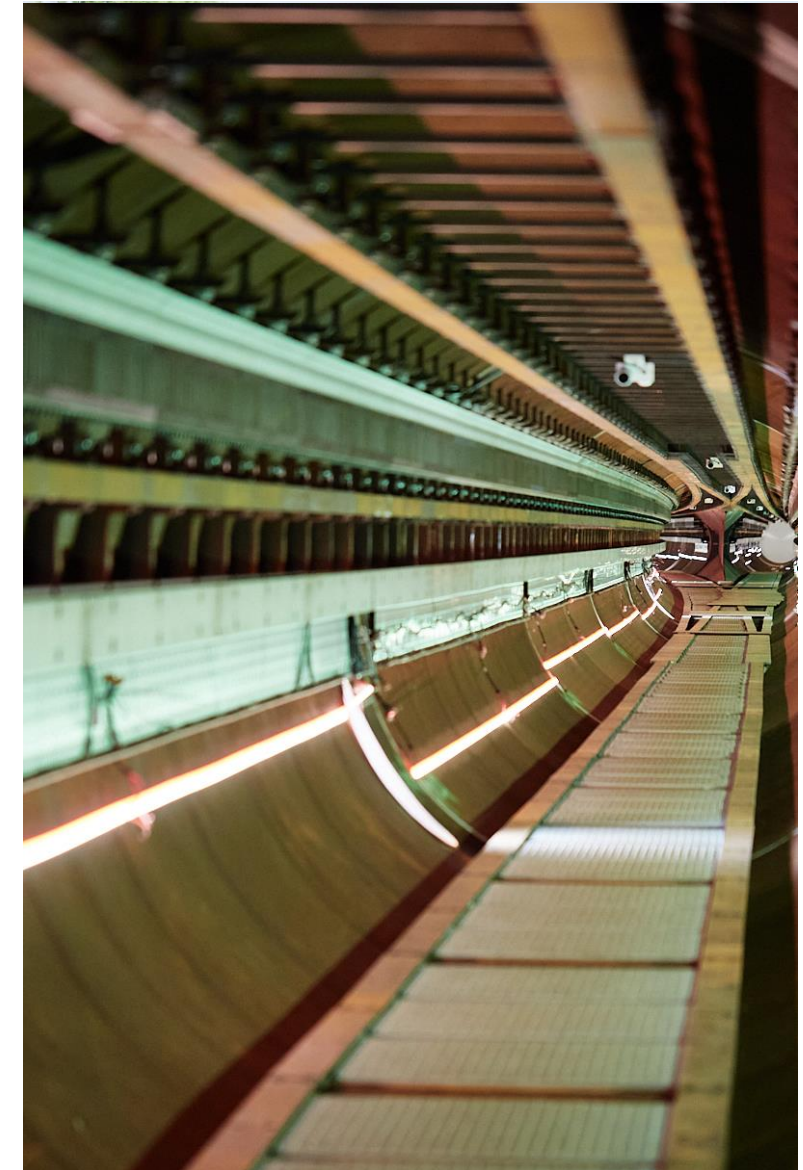


Figure 7 - Photo of hyperloop test infrastructure (Veendam, NL)

7. A STANDARD IS NEEDED

The development of the European Standard (EN) of all systems, products, services and applications related to the hyperloop transport system is covered by CEN-CLC/JTC 20 – Hyperloop systems. A common EU-wide standard must be established, not only to guarantee safe, reliable and resilient operations, but also to enable open and competitive access to the EU's future hyperloop networks, both for operators of standards-compliant vehicle fleets, and for suppliers of standards-compliant hardware, software, and services. This requires cross-country coordination at EU level and beyond. An EU Hyperloop Standard is crucial for successful implementation of commercial hyperloop systems to:

- Avoid the cross-border incompatibilities between gauges, physical and digital control systems, electrification standards, and operating rules which hamper coherent development of legacy rail systems on an EU-wide scale;
- Provide an EU-wide assurance of safe, reliable, resilient, redundant operation of hyperloop in normal service and in case of emergency;
- Create an enforceable set of quality standards to which infrastructure owners and hyperloop service providers must adhere;
- Avoid vendor lock-in and improve competitiveness on the hyperloop supplier market.

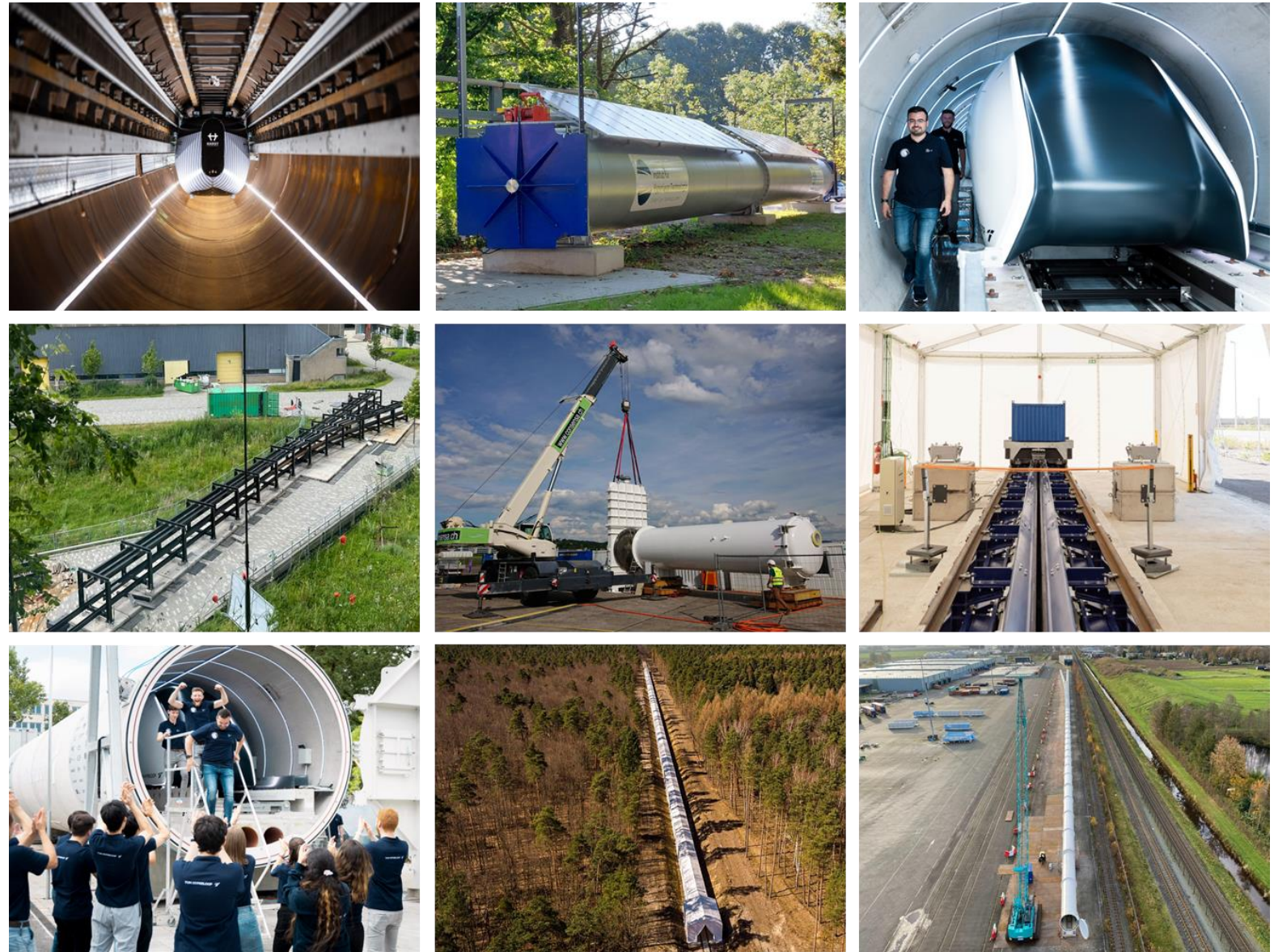


Figure 8 - Photos of test infrastructure across Europe

8. A EUROPEAN REGULATORY FRAMEWORK TO ENSURE SAFETY, CONNECTIVITY AND INTEROPERABILITY IS REQUIRED

For hyperloop to be implemented at network scale in the EU, it is also important that a comprehensive regulatory framework is defined. This is essential for successful implementation of hyperloop to:

- Ensure safe, robust, reliable and resilient open access hyperloop operations;
- Ensure public safety in hyperloop operations;
- Provide a clear focus for Europe's innovation and industrialization effort in the field;
- Establish EU hyperloop standards as the go-to international standard in the global market;
- Define a regulatory and market framework for free, open, and competitive investment and access to EU hyperloop infrastructure and for future fleet operators.

Passenger and freight vehicles will conform to the same general standards – diverging only in their equipment and fit-out for human or freight use. It is critical to mandate freight/passenger vehicle uniformity, in particular to ensure that passenger and freight units accelerate, cruise, decelerate, bank and switch in exactly the same manner as passenger units. This ensures that both types of traffic pass through the system at the same speed and flow rate. This is essential to avoid the clash of 'express' and 'slow' traffic which heavily reduces the overall capacity of rail bound transport systems.

An EU Regulatory Framework will de-risk investments by private investors and attract more funds to the project.



Figure 9 - Render of the hyperloop vehicle's interior

9. TIMELINE TOWARD COMMERCIAL IMPLEMENTATION

After a decade of international R&D, various hyperloop concepts and subsystems have been developed and tested. The following phases outline the pathway going forward:

1) 2025-2026 - Maximize value of current and planned R&D facilities

The objective of Phase 1 is to achieve a harmonized preliminary system integration specification by utilizing existing and proposed European hyperloop R&D facilities. This stage focuses on demonstrating and derisking the core operational aspects of hyperloop and aligning technology development with future EU standards. Phase 1 is performed through the Hyper4Rail project, in which final prototypes of key missing subsystems will be delivered, the overall concept will be harmonized, and the roadmap to industrialization will be created. The main facilities in question are (and not limited to):

1. The existing European Hyperloop Center (EHC) in the Netherlands
2. The DemoTube facility under construction in Switzerland
3. The realized TU Munich facility in Germany
4. The realized HS Emden/Leer facility in Germany
5. The proposed Zeleros facility in Spain
6. The proposed Hyperloop R&D Tunnel at TÜBİTAK Gebze Campus in Türkiye
7. Any other test facility willing to participate in this endeavour

2) 2025-2029 - Full system prototype, proof of concept

The main objective in Phase 2, that partly coincides with Phase 1, is the physical construction of a 3-5 km 1:1 scale demonstrator at TRL7. By the end of Phase 2, the aim is to have collected sufficient empirical data from testing operations to inform publication of a 'draft for agreement' of the EU Standard. Indicatively, once the demonstrator is physically completed, this stage of the programme could be completed in 18-24 months.

3) 2030-2034 - Minimum Viable System

Phase 3 extends the 3-5 km to form a 30-50 km twin tube Minimum Viable System (MVS) facility in which real-world, real-life hyperloop operations can be developed, demonstrated and certified for public service. This MVS is envisioned to possess several key characteristics:

- Equipped from the outset for service-like passenger operations
- Walk-on / walk-off stations at both ends of the route
- Twin-tube infrastructure permitting bi-directional operations between both stations
- A range of curves built in, to demonstrate g-compensation at operating speed
- Switches at both ends of the route to permit vehicles to travel in both directions
- High speed switch at the centre point of the route, enabling demonstration of both single vehicle high-speed switching, but also multi-vehicle 'splitting and joining' (if it is decided to adopt this principle)
- Capable of demonstrating at least 500 km/h (and ultimately up to 1000 km/h) maximum speed in human-

in-vehicle operations

The MVS could be realized either in a remote area where it can function as a certification facility for the long-term, or it could make sense to build MVS on a route where demand for high intensity transport exists for future revenue services. A link from a major city center to a remote airport would be such an example.

By the end of Phase 3, the aim is to have collected sufficient empirical data from POC and MVS operations to publish the definitive EN standards, by demonstrating reliable, robust, resilient high-speed hyperloop operation in service-like conditions over a 30-50 km route.

4) 2035 > - Network roll out

Phase 4 is enabled by the implementation of a regulatory framework and EN standard. This standard allows for the development of the first tranche of commercial hyperloop route(s) to an agreed and enforceable standard. As a logical and cost-effective approach, the first of these routes would ideally extend from Phase 3 - Minimal Viable System. Consequently, the first commercial line could be established or under construction by the end of Phase 3, projected to conclude in nine years. Meanwhile, planning for larger network construction could proceed in parallel during the later stages of Phase 3.

10. HOW WOULD THE TRANSITION LOOK LIKE?

By 2040, the first commercially viable hyperloop lines are expected to have been realized. A decade later, by 2050, some of these lines will be interconnected, with the potential of resulting in a full European hyperloop network by 2060. Historically, new transport modes and their respective infrastructures grew in an incremental way (motorways, high-speed rail, aviation) over long periods given the capital intensity. It can be expected that the same will happen for hyperloop. Each hyperloop line can be profitable on a stand-alone basis. Therefore, the roll-out can be started by individual projects that can be developed into a network later. It is expected that the construction of lines can be financed by private sources or PPPs, reducing the already high pressure on public budgets. Each line running in a profitable way will facilitate the construction of new lines. These can be airport to airport, city to city connections. Links could be created

Table 2 - Socio-economic impact of modal shift

Socio-economic impact in 2060	Value (B€)
Revenue	170
Time	15
Climate	14
Accidents	11
Well-to-tank emissions	6
Noise	4
Air pollution	3
Congestion	1
Net annual impact	224



between agglomerations where today there is a lack of connections (see for example Amsterdam-Berlin, today 8-10 hours by train).

The possibility to connect smaller centres along a longer line without slowing down travel times can allow to increase connectivity for smaller centres. The stations of hyperloop lines can be located in connecting hubs of other infrastructures, such as urban public transport. A network can grow gradually taking as a point of departure connections where other infrastructures are overloaded.

The application of hyperloop on a European scale of 25,000 km would lead to an expected modal shift from European aviation to hyperloop of as much as 66%, with annual demand reaching 800 billion passenger-km . Up to distances of 2.000 km, hyperloop could be the preferred mode of transport compared to aviation; beyond that, aviation becomes the more likely choice.

Table 2 shows the total expected socio-economic impacts of such a modal shift, including 440 billion passenger-km shifted away from aviation and 220 billion passenger-km shifted away from road transport. These values were calculated based on the Handbook on the external costs of transport from the European Commission.

Hyperloop’s connectivity benefits would open up choices for individuals on where to live and work, improving housing choices, potentially revitalizing rural areas and reducing housing pressure on densely urbanized economic clusters. It could enhance quality of life and support EU policies on social inclusion and tourism development by providing accessible affordable travel between countries. More convenient travel

would allow business travelers to travel more frequently to meet face to face, attend trade fairs or to provide client support enhancing economic cohesion among EU countries. Finally, hyperloop can satisfy demand for perishable goods and the growing e-commerce sector, making the logistics system more efficient and reducing the need for duplication of warehousing, stock and processes.

The Hyperloop Development Program (see Annex 1) can play a useful role during the testing and standardization phase and provide a platform for exchange between all actors.



Figure 10 - A potential European hyperloop network

11. ADDRESSING CHALLENGES

Each new large project, especially in infrastructure, prompts citizens to raise their concerns.

The construction of the hyperloop system is expected to increase greenhouse gas emissions temporarily, due to the intensive use of materials like steel and concrete, which are CO₂-intensive to produce. To address this, the development and use of low-carbon concrete and steel is of particular interest. LCAs from third parties show that the construction emissions are relatively small (~20%) of total lifetime emissions when divided over a lifetime of 50 years.

The significant cost for hyperloop infrastructure could lead to increased social inequality, if not managed correctly. If access to hyperloop is priced out of reach for lower-income individuals, it could exacerbate economic disparities. Previous studies show that - if operational expenses can be kept low due to the low energy consumption, low maintenance requirements, and driverless operations - there is sufficient demand on a European scale to provide ticket prices between €0.10-0.15/km travelled, which is similar to rail and aviation. Furthermore, partnerships with existing public transportation systems could integrate services and pricing, making travel more equitable.

As with all new technologies, safety will be a major concern. As the engineering proceeds, safety is already addressed as an integral part of the development of an integrated system. The experience from air traffic, from European safety standards for tunnels and high-speed rail will provide a solid basis to draw upon. Once Phase 3 of the afore-mentioned timeline is reached, passengers will be able to experience the new technology.

Regulatory and legal challenges are normal in a new technology. However, standardization, and a European Regulatory Framework can help to mitigate these challenges. Permitting and planning challenges are always a major issue when it comes to new infrastructures. One promising approach to handle these will be to follow as much as possible existing alignments, especially motorways. The planning and permitting process would be shortened considerably.

Since hyperloop lines do not emit emissions and very little noise, public concerns should be less. Land use is smaller than with other infrastructures. Visual impact will need to be managed, but the smaller size of hyperloop lines as opposed to high-speed rail or motorways will facilitate this.

Hyperloop is not more difficult to implement than other transport modes.

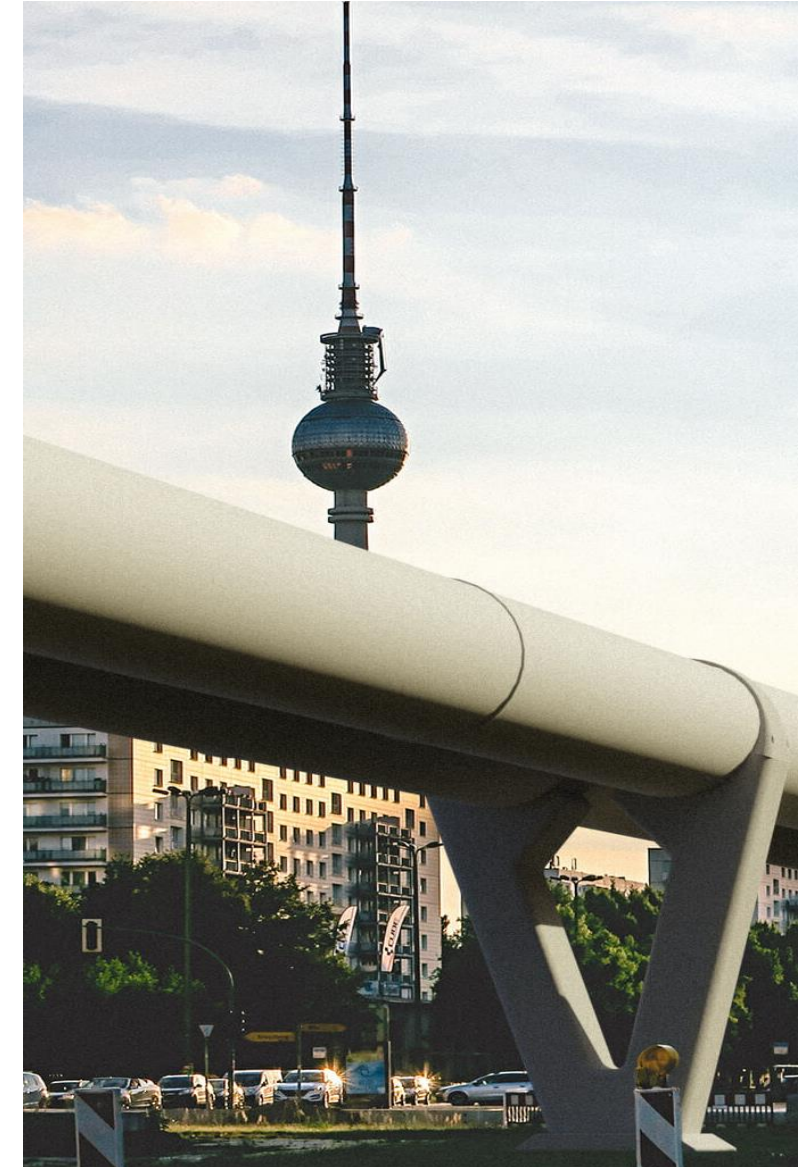


Figure 11 - Render of hyperloop infrastructure in Berlin

CONCLUSION

Hyperloop, if added to the mix of transport modes, can facilitate to address the impact of growth in transport and the achievement of decarbonisation targets within two to three decades.

It can free up motorway and rail capacity for increases in freight transport demand. It can complement the existing infrastructure and reduce the need for expanding it.

It can reduce short-haul aviation by offering faster total travel times, more convenience and near zero emissions as sustainable aviation fuels will be available only gradually on a mass basis.

It therefore fully responds to the objectives of the Trans-European Transport Network policy of the EU and contributes in a very resource-efficient way to its objectives. In particular, it can contribute in a significant way to the modal shift of freight from road to rail or hyperloop.

A high-capacity hyperloop system, capable of following motorways at 400-500 km/h and ultimately capable of up to 1000km/h on optimized-for-hyperloop alignments, can be developed as a sustainable and economically viable transport solution. This system, potentially partially or fully privately financed, could be implemented more quickly than expanding existing transport modes, freeing up resources for the necessary upgrades to current infrastructure.

Hyperloop is the most promising mode to address the challenge of sustainable transport!



Figure 12 - Photo of a hyperloop test track (Colorado, USA)

ANNEX 1: HYPERLOOP DEVELOPMENT PROGRAM

The HDP is a foundation under Dutch law and has the following objectives laid down in its basic act:

- (i) setting up innovation and development programmes and mobilising resources in cooperation with the public sector, industry and research organisations;
- (ii) support for research and development ("R&D") programmes up to and including the level of technical readiness TRL 9 (Technology Readiness Level 9), to be further developed by commercial parties into concrete market propositions;
- (iii) facilitating public acceptance by bringing the developments taking place within the programme to the attention of a wider audience;
- (iv) creating a context in which hyperloop can be realized;
- (v) facilitating various test and demonstration facilities in collaboration with government and industry;
- (vi) gathering knowledge and information to support the implementation and policymaking of hyperloop;
- (vii) stimulating and facilitating R&D activities by start-ups, scale-ups, small and medium-sized enterprises and other companies;
- (viii) stimulating and facilitating research by knowledge institutions, universities, and universities of applied sciences;
- (ix) providing space for the creation of "spin-off" and "spin-in" technologies;
- (x) organising events for the exchange of knowledge;
- (xi) creating and fostering an open ecosystem where all partners can participate with a meaningful contribution to hyperloop development at all levels of technical readiness (Technology Readiness Levels);
- (xii) stimulating European cooperation.

ANNEX 2: OVERVIEW OF ORGANISATIONS THAT ENDORSE THIS PAPER

1) Partners of the Hyperloop Development Program



2) Contributors to this paper (non-HDP Partners)



Hyperloop

Accelerating progress toward Europe's goal of sustainable transport

HDP Vision Paper I December 11th, 2024

www.hyperloopdevelopmentprogram.com

