Design of a European Hyperloop Large Scale Technology and Research Infrastructure

Prof. Dr. rer. nat. Walter Neu[*1,2], Dr. Ralf Effenberger[3],
B.Eng. Lukas Eschment[1,2], Prof. Dr.-Ing. Thomas Schüning[1,2]

[1] University of Applied Sciences Emden/Leer, Institute of Hyperloop Technologies, Constantiaplatz 4, 26723 Emden, Germany

[2] Carl von Ossietzky University of Oldenburg, School of Mathematics and Science, Carl-von-Ossietzky-Str. 9 – 11, 26129 Oldenburg, Germany

[3] Integrated Infrastructure Solutions GmbH & Transrapid Versuchsanlage Emsland (MagLev test facility Emsland), Hermann-Kemper-Str. 23, 49762 Lathen, Germany

Large-Scale Research Infrastructure, Hyperloop, research hub network, system design, safety, magnetic levitation, magnetic suspension

Introduction

A European multidisciplinary Large-Scale Research Infrastructure (LSRI) for Hyperloop enables both academia and industry to assess relevant technical performances of such a novel transport system, as well as to design and develop innovative concepts and technologies that will support a fast, high-capacity, carbon-free long-distance mobility in line with the European strategic goals on sustainable transport. The proposed work will design a multidisciplinary infrastructure where researchers of various backgrounds will work towards advancing scientific efforts to extract relevant and practical information aiming to boost innovative processes in future mobility industry.

A substantial share of the high standard of living in the modern world is attributable to the availability of excellent transport infrastructure. It grants access to goods, services, employment, recreation and interconnection. While the transport sector fulfils a pivotal socio-economic role, the sector is simultaneously one of the largest energy consumers, responsible for about 25% of the global CO_2 emissions. Unless immediate measures are taken, the global transport emissions will grow by another 60% by 2050, causing the international community to fall dramatically short of the Paris Agreement from 2015 as well as the recent goal of Europe to become a CO_2 neutral continent by 2050. Therefore, the transport sector has a large responsibility in implementing clean transportation alternatives to combat climate change.

One of the most promising concepts that has received extensive attention since 2013 as a sustainable alternative for high-speed transportation is the Hyperloop. With the potential speed of an aircraft and possibly even lower energy consumption compared to current High-Speed Rail (HSR), it may very well be one of the best solutions we have to sustainably improve and disrupt our European-wide mobility. But it is not only the distances where aviation dominates the market and Hyperloop will thrive. Its expected high transport capacity, tiny infrastructure footprint and the unique possibility to connect cities along a line without disrupting long-distance travelers, make the Hyperloop an exceptional solution. Furthermore, Hyperloop will be independent of outside factors like weather for example. This makes Hyperloop an alternative to rail and aviation that people will be more likely to use, as reliability and speed increase while the carbon footprint decreases.

As transport infrastructure plays a substantial role in the high standard of living of modern societies, technological progress in vehicles, in infrastructures and in Information and Communication Technology (ICT) solutions have facilitated the globalization of the world economy, reduced trip times and provided more comfort at a cheaper price. However, it has become apparent that the contemporary transportation system also has severe drawbacks related to increased air pollution, noise nuisance and traffic congestion that can deteriorate the quality of life they are meant to support instead[1,2]. One possible way to address these concerns in the long term is to develop new and

[*] Corresponding author: walter.neu@hs-emden-leer.de

advanced modes of transportation that satisfy environmental compatibility through minimal carbon footprints on the one hand, while on the other hand accommodate future high-capacity and high-speed throughput to support societal future needs.

In order to accelerate the development of Hyperloop many research organizations, startups and non-profits have started to plan and construct test tracks to test and develop different subsystems which are necessary for the realization of Hyperloop as a new mode of transport. Up until now, none of these existing or planned Hyperloop facilities fulfills the purpose of a full-scale research infrastructure to identify the most efficient Hyperloop technology from many different concepts. An independent assessment of all applicable technologies that constitute the Hyperloop needs to occur in order to converge towards a system that allows for interoperability among different actors while still achieving the same levels of safety as well as performance. This will set the foundation for the European Hyperloop technology, which at the same time will contribute to the establishment of a clear set of standards as well as regulation.

Large-Scale European Hyperloop Research Infrastructure

Research infrastructures are key investments in all areas of research, and they meet both the demand of the scientific community for state-of-the-art resources for supporting excellent science, but also the demand of knowledge transfer for innovation at social and economic level. Furthermore, research infrastructures are a key component of the European Research Area (ERA) as they have the ability to bring together a wide variety of stakeholders to search for solutions to the scientific problems being faced by society today.

Research infrastructures can enable research and provide the proper environments for leading researchers and scientists to conduct innovative science at European and international levels, thus increasing the productivity of the EU industry in the long term. As a result, research infrastructures can provide unique opportunities for all scientists, while facilitating knowledge transfer and innovation and thus, creating the basis for technological developments which will lead to the creation of highly skilled jobs – and the birth of several start-ups in very diverse fields that can lead the way to new technologies and markets. In line with this, it has been proven that "extreme" scientific and technological research projects and infrastructures are significant in terms of economic and social returns. Moreover, research infrastructures stimulate research environments and attract researchers from different countries, regions and disciplines. Thousands of researchers and students from universities, research institutions and industry from Europe and from outside Europe use research infrastructures each year.

Magnetic Levitation (MagLev) and the Hyperloop concept are future technologies that could support the conceptual and technical design for new research infrastructures in the transport domain. Discussing the engineering demands of a Hyperloop infrastructure also relates to cost considerations, building needs, interoperability of different technologies and long-term testing as well as the application of real life conditions at full-scale. Leveraging an existing LSRI as a possible location under assessment is the former Magnetic Levitation Transrapid test facility (Transrapid Versuchsanlage Emsland -TVE) in Lathen, Germany (Figure 1).

Figure 1: 32km MagLev Transrapid test facility Emsland, Lathen, Germany (TVE)

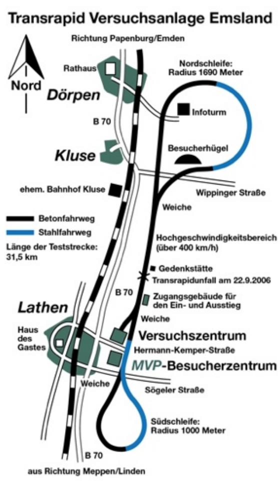

Figure 2: Overview of the existing 32km TVE[3]

The setup of a Large-Scale European Hyperloop Research Infrastructure is based on operational and planned test tracks in Europe and around the world to foster a full-scale system integration. Thus, long term operational test cases are possible under real life conditions. This includes different levitation systems, guiding, suspension and navigation as well as fluid dynamics and structural components. Some variants for these technologies might not be suitable for high speeds or prove other challenges like the integration into an operational Hyperloop system. On the other hand, these satellites in Europe allow for strategic testing of different technologies, so that proven and operational technologies can be implemented in a full-scale European test track. There the focus should be on improving and comparing those technologies based on their performance in continuous testing and interaction with other systems.

A Large-Scale European Hyperloop Research Infrastructure has the potential of proving different subsystems in one system as a whole. Testing might involve heat dissipation, pressure levels, power and energy requirements and communication. This includes the investigation of energy losses in the system, such as remaining air friction due to pressure buildup in front of the pod and electromagnetic losses in the levitation and propulsion systems. Only these tests on a large-scale test track can answer those questions well and specify further design choices. Key parameters for tests are continuous operation, scalability and interoperability regarding a full-scale system and realistic application.

Figure 3:
TVE in Lathen with existing support structure and uninterrupted 32km test track

Upgraded and additional technologies in a Large-Scale Research Infrastructure

The MagLev test track in Lathen will provide a time saving and cost-efficient implementation of a Large-Scale European Hyperloop Research Infrastructure. The availability of a continuous test track and foundations on which tube elements can be placed without interrupting existing trainlines, roads and other linear infrastructure offers an additional advantage. Furthermore, existing knowledge of the Transrapid's Electromagnetic Suspension (EMS) technology will help an accelerated development of magnetic levitation and wireless power transfer for the Hyperloop system. Additionally, previous approvals for test operations of the TVE and contracts with surrounding parties allow for an accelerated land use planning procedure and planning permission hearings.

An extensive list[4] of technologies required for the evolution of the TVE to a LSRI for Hyperloop includes:

- Vacuum equipment
- Levitation and guidance systems
- Propulsion and braking systems
- Bogies and suspension
- Pod motion physics
- Power generation and distribution
- Network communication and control
- Environmental control and life support systems (ECLSS)
- Emergency braking system
- Emergency management
- Power supply system
- Control systems
- Air docks

Additionally, there can be further expertise involved, such as logistics and distribution partners to demonstrate freight transport and intermodal connectivity for the Hyperloop system as well as specialized technologies such as cryo technology for Superconductor Magnetic Levitation (SML).

Technologies that need to be developed for a LSRI include e.g. large-scale vacuum technology with high volumes of throughput and tube technology. There are already prototypes in development for most of these questions, that have been posed, which will face additional challenges when being implemented in a large-scale Hyperloop track. Figure 4&5 show tube segments from concrete and steel. Different challenges such as vacuum-tightness with very small leakage rates, balancing of different expansion coefficients from superstructure, tube and levitation system as well as overall structural integrity have to be investigated before constructing a LSRI.

Figure 4:
Concrete Hyperloop-Tube[5]


Figure 5:
Hyperloop Tube from Steel[6]

Technological aspects: magnetic levitation

The Hyperloop system constitutes in part technologies that are established and emerging technologies e.g. levitation technologies including High Temperature Superconductors (HTS) systems, and composite materials. Matured technologies with proof of operational compatibility can be integrated in the main LSRI to be tested under real life continuous operation. Not only could there be different technologies for the same subsystems, like a pod suspended with an EMS system from the top of the tube, an Electrodynamic Suspension (EDS) system with suspension from the bottom or a Superconductor Magnetic Levitation (SML) system (Vehicles with different types of levitation in Figure 6-8), but also multiple different geometric designs to test one system, e.g. different versions of the inductrack technology. The research infrastructure therefore has to be designed with a modular approach to accommodate for different designs.


Figure 6:
Shanghai EMS MagLev Transrapid train[7]


Figure 7:
Superconducting EDS Shinkansen L0 Series[8]


Figure 8:
Superconductor SML prototype[9]

Hyperloop Research Network and Hubs in Europe[4]

HYPERION[4] (HYPerloop European Research Infrastructure & Open Network) envisions a European Hyperloop Research Network with a central European LSRI and several hubs functioning as satellites for the LSRI. The network includes universities, industries, SMEs, public stakeholders and EU platforms and projects. Figure 9 shows a potential concept for a framework to shape the collaboration of the partners.

HYPERION envisages to specify and design a research infrastructure and network, that will cause important change in cross- domain and collaborative research related to high-speed transportation sciences. The HYPERION project shall contribute to the simplification of experiments for data collection through the design of a novel data sharing infrastructure and also on the basis of the virtual experimentation environment. These two components are envisaged as key elements for boosting cross domain research, and to utilize data derived through specialized experiments of other researchers. Moreover, these will also be key elements for strengthening junior research groups, young scientists and startups who can apply for “flight time” thus providing an open infrastructure for the initial tests of novel ideas on existing data that can sufficiently cover their needs.

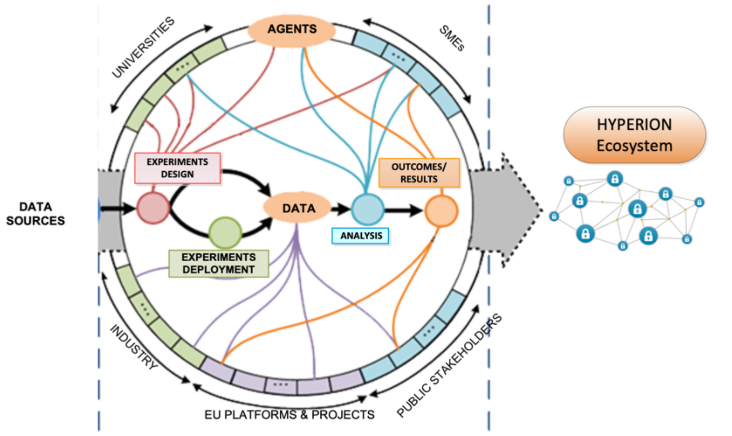

Figure 9: HYPERION system interfaces, embedded data models, automation, intelligence and field applications[4]

As such, the project will allow for the integration of analysis methodologies under its framework and the straightforward sharing of approaches within the scientific community.

Standardization is an additional outcome of the process of testing technologies in many different hubs in Europe, as well as from results of a LSRI. Especially for Hyperloop which has the potential of being a continent spanning transportation system, standardization is a major benefit that can be gained from a LSRI.

Conclusion

A short-term implementation of existing, as well as new technologies into a LSRI is essential in order to setup a common European standard and quick realization of an ultra-high-speed transportation system to extend the high living standards and ensure the challenging requirements to obey the Paris Agreement. Nevertheless, research needs to be conducted regarding all possible technologies existing today to maximize economic operability and compatibility with the environment in the future.

Time to market shouldn’t be the only concern for a Hyperloop system, which will require a completely new infrastructure to be built. That is why the European research community is urgently needed to pursue Hyperloop (subsystems) with all its possible solutions. At the end Hyperloop is a new mode of transportation with drastically new approaches to the way we travel which is why the development should not stop at a point of possible realization, but rather when all available technologies have been tested.

Taking best practice knowledge of CERN’s ideas to the HYPERION facility is a challenging approach but fits very well into the scope of today’s demands and needs on innovative transportation and future mobility. Environmental and societies expectations cannot be tackled on a national scale but require a pan European or even a global approach. Science, engineering, ecological, economic, and social aspects are interwoven and have to be disentangled only on a common base with a common understanding best taken by a model like CERN. HYPERION could be the ultimate and best practice example of a large-scale high-speed transportation research facility with also a huge impact on industrial development.

Acknowledgements

This work is supported in part by a grant from the Ministry of Science and Culture of Lower Saxony, Germany. We gratefully acknowledge the support from both Presidential Boards of the University of Applied Sciences Emden/Leer and the University of Oldenburg.

References

1: Graham D., Pena, E.d.l., Vasallo, J.M., Acciaro, M., European Comission - Directorate-General for Research and Innovation Directorate H – Transport - Unit H.1- Transport strategy. 2017. Transport Infrastructure - Expert group report. Luxembourg: Publications Office of the European Union. https://ec.europa.eu/transparency/regexpert/index.cfm?do=groupDetail.groupDetailDoc&id=34586&no=1

2: Dimitriou, H. T., Gakenheimer, R. A. (2011). Urban Transport in the Developing World: Perspectives from the First Decade of the New Millennium.

3: Maximilian Dörrbecker, M., n.d., Karte der ehemaligen Transrapid-Testrecke im Emsland [graphic]. Retrieved from https://upload.wikimedia.org/wikipedia/commons/c/cc/Karte_Transrapid-Teststrecke_Emsland.png

4: University of Applied Sciences Emden/Leer et. al., 2019, HYPERION EU Funding Proposal for *H2020-INFRADEV-2018-2020* Call- HYPerloop European Research Infrastructure & Open Network, Germany – Emden-26723 – Constantiaplatz 4

5: EuroTube, n.d. EuroTube partners with Creabeton Matériaux, a company of Vigier, to develop next-generation tube technologies. EuroTube Foundation, Dreikönigsstrasse 7, 8002Zürich, Switzerland, Retrieved from: https://eurotube.org/partnership-with-creabeton/

6: Cooper, D. - Engadget, January 26th, 2016, Testbed: City of North Las Vegas, Nevada, Engadget https://www.engadget.com/2016-01-29-what-you-need-to-know-about-hyperloop.html

7: Psytrance, 2015, Shanghai Transrapid Magnetic Levitation Train(MagLev), Wallpaper Abyss, https://wall.alphacoders.com/big.php?i=589122

8: Bloomberg via Getty., 2014, https://www.huffingtonpost.co.uk/2014/09/25/japans-insane-500kph-levi_n_5880366.html

9: Nguyen, C. December 2nd 2014, TechDrive https://techdrive.co/japan-gifts-5b-to-u-s-to-build-its-first-maglev-train/