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Hyperloop: The innovative logistic technology

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A R T I C L E I N F O

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A B S T R A C T

Railroads, roads, rivers, and airways are the most common modes of transportation for people and commodities. The cost of different ways of transportation varies according to distance, luxury, size, fragility, and other factors. When the following factors are accounted for, the vehicle might become prohibitively expensive for many individuals. A new means of conveyance has been developed. Elon Musk initially proposed it as the fifth mode of transportation in 2012. For commuters and goods, Hyperloop offers a quick and cost-effective way of transportation. The Hyperloop is essentially a vacuum tube train that transports people or products at incredible speeds while efficiently. Compared to traditional forms of transportation, the Hyperloop is ideal since it is highly energy-efficient, quiet, and self-contained. Increased cargo delivery speeds will be the most evident benefit of this idea to the industry. Hyperloop also has the potential to make a significant contribution to green supply chains. It is a carbon-free form of transportation that has changed inland freight transportation and maritime and air freight transit. It can move freight below, above ground, and under-water. The aim of this paper is to explain this new innovative technology as a development for logistic concepts.

1. Introduction

In the last several years, new technology in transportation systems has advanced at a breakneck pace throughout the world. According to some analysts, a new mode of transportation is becoming competitive with existing modes of transportation such as vehicles, trains, aircraft, and boat (Rathore & Kumar, 2018; Siegfried 2021). The usage of an ultrafast Hyperloop vacuum train, which travels on air or magnetic cushion within tubes with low internal air pressure to decrease resistance to movement, is a new fifth mode of transportation (Dharmeshkumar & Samir, 2021.).

The hyperloop is characterized as a high-speed, autonomous means of land transportation in which a vehicle is directed through a low-pressure tube or set of lines for people and goods (Mitropoulos et al., 2021). It is a revolutionary means of intercity transportation that uses a fixed guideway tube-based infrastructure to connect cities securely, efficiently, and sustainably (Rathore & Kumar, 2018).

The hyperloop is a high-speed passenger and freight transportation system that can reach up to 1200 km/h (Dudnikov, 2017). The capsules are supported by an air pad that includes pressurized air as well as an aerodynamic lift (Yang et al., 2017). The pills are accelerated using a magnetic linear accelerator with rotors in each capsule connected to different stations on the low-pressure tube (Rob et al., 2019). Passengers can enter and depart the Hyperloop at stations located at the tube's ends or branching throughout its length (Inamdar & Panchal, 2018.)

It may alternatively be defined as a pod- and magnetic-levitation-based method of transportation in a low-pressure-sealed tube or series of lines that work in a low-pressure environment to minimize drag and boost efficiency, resulting in much shorter journey times (Chin & Gray, 2015). The effective deployment of the hyperloop and its safe integration into the present transportation system would need a confluence of modern technology utilized in high-speed railway (HSR), aviation, aerospace, and magnetic levitation applications (van Goeverden et al., 2018).

A large amount of research and patent activity on numerous hyperloop system components has been emphasized since the original conceptualization of the hyperloop. While various means of transportation with similar elements can be employed in hyperloop construction, specific hyperloop components are very different (Nøland, 2021). The hyperloop, for example, moves at faster speeds than maglev trains and uses a comparable propulsion technology. Furthermore, the pressure value supported by the pod is similar to that of airplanes (Decker et al., 2017). Several papers give descriptions of the hyperloop system's components.

Others focus on other hyperloop technology, such as pneumatic tube and tunnel systems, while others focus on technical performance concerns, such as aerodynamics and energy (Yang et al., 2017). Certain technologies' system operation has been demonstrated at a sub-scale level and low speeds; however, the compatibility of the different systems in subsonic speed ranges and on a genuine scale has yet to be proved (Mahalakshmi, 2018)

Multiple public and private stakeholders in North America, Asia, and Europe have been involved in researching and developing the hyperloop system (Mitropoulos et al., 2021). The amount of scientific research that is publicly available is still somewhat restricted. Researchers concentrate on specific aspects of the Hyperloop, like the design and simulation of the electro-magnetic levitation force via a short-stator linear synchronous motor, aerodynamic design of the vehicle and simulation dynamics of the tube structure and vehicle interaction(Opgenoord & Caplan, 2018), sizing models for the passenger pod, sizing and feasibility study for a magnetic plane concept, impact on bridge dynamics, and other technical, operational, economic, social/environmental issues (Hansen, 2020).

Following many studies, it has been discovered that using Hyperloop as the fifth form of transportation can reduce trip times by half or more than half (Dudnikov, 2017; Siegfried & Strak 2021). The concept of the Hyperloop appears to be science fiction. Still, it is on the verge of becoming a reality, with a growing number of companies developing new concepts every day (Decker et al., 2017). Companies such as Virgin Hyperloop One are beginning to build their own designed Hyperloop in countries like the United Arab Emirates and India.

2. Concept and basic elements of Hyperloop logistic technology

The present progress status for the hyperloop system is offered based on the literature results by concentrating on the system's components.

The vehicle (also known as pod or capsule) consists of an aerodynamic fuselage similar to the design of a commercial airplane; an interior and an electric subsystem. Hyperloop capsules travel in low-pressure tubes between pre-determined trajectories and point-to-point stations (Station A and Station B) (Figure 1).

The infrastructure consists of the tube, the substructure, and the stations. The tube encloses and maintains the low-pressure environment, allowing for the least amount of air loss. The infrastructure also includes the pressure maintenance system and power substations, which significantly reduce air drag and enable the pod to move at speeds of up to 1200 km/h. The parameters of the infrastructure are determined by the type of levitation and propulsion system used (Tavsanoglu et al., 2021).

The communication system establishes a self-contained environment, transfers data, and organizes operations to ensure safety and comfort.

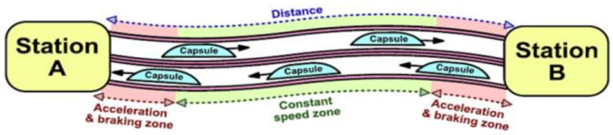

Figure 1: The conceptual Hyperloop diagram. (Nøland, 2021)

2.1 The pod

The pod is the main structural structure of the system and is comparable to an airplane airframe (Figure 2). The hyperloop pod is essentially a pressure vessel that can endure pressure variations and, more crucially, transport people and goods. Its design blends aerodynamics, materials technology, and production procedures, emphasizing performance, reliability, and cost.

The pod is meant to be as light as feasible to handle external low-pressure circumstances, design speed, and contain:

- -On-board technologies and interior furnishings.
- -Enhancing passenger safety.
- -Travel experience.
- -Comfort inside a tube-based environment.

The pod design has a considerable impact on the tube infrastructure design, which is determined by the loading pad arrangement and the development of dispersed or concentrated loads and static, dynamic, and thermal stresses. The aerodynamic drag and operating energy consumption of the tube may be affected by the frontal surface and form of the pod. The Kantrowitz limit, blockage ratio, drag coefficient, and pod length are all aspects to consider while maximizing aerodynamic performance and pod speeds.

Inside a pod, passenger safety and comfort are based on a blend of rail and aviation best practices, with verified components from established technology. Passengers will enjoy comfort, information, and entertainment thanks to a human-centric interior design that includes augmented reality windows, lighting, brilliant colors, texture, and sound level control.

Two power system approaches are identified one employs a guideway as a propulsor, resulting in a lightweight pod with high infrastructure costs, and the other uses an energy-autonomous pod that stores vast quantities of onboard energy, cutting infrastructure costs dramatically.

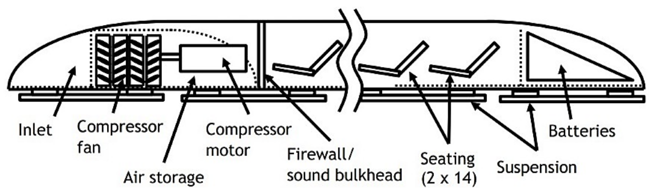

Figure 2 : Hyperloop Passenger capsule subsystem notional locations. (Joshi, 2016)

2.2 Compositions

Tube: The tube creates a low-pressure travel-guideway environment and shields the pod from any outside influences. It is airtight to preserve the low-pressure environment, sturdy enough to avoid failures, and constructed following the pod's shape and aerodynamic needs (Figure 3). The system's operational pressure level determines the tube geometry. Furthermore, the tube must be grade-separated from other types of transportation. Concrete towers of varying heights are expected to support the tube system, depending on the layout of the guideway. Elevated, on-ground, and subsurface guideway infrastructures are being investigated. The elevated guideway is safer since it eliminates the requirement for crossing control devices at traffic crossings and has a smaller land footprint than a railway track.

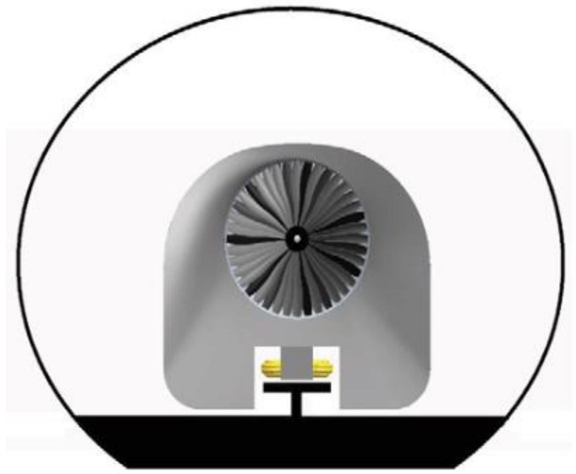

Figure 3: Front view showing the capsule with the tube cross-section (Hodaib & Fattah, 2016).

Switches with a High-Frequency Operation: The switches are track-changing devices that allow pods to move from one track to the next, creating point-to-point connectivity in a tube network and connecting cities. Two significant possibilities have been proposed for switching. The first envisions tubes diverging and heading in various directions. The second split the main pipe two kilometers away from a destination, allowing for more capacity during the acceleration and deceleration periods. If actual pod quantities are close to forecasts, more portals (terminal entrance or departure points) will be required. The ability of the pods to switch between tubes is likely to improve as changing technological advances. The number of needed switches heavily influences the cost of a hyperloop system. The high-speed controls must also be maintained and monitored to guarantee lateral steering and safety, preventing unforeseen accidents.

Airlocks: The airlocks are devices with gate valves that allow hyperloop pods to be loaded and unloaded inside the evacuated tube without re-pressurizing the entire line, making the transition from atmospheric to low pressure and vice versa easier. To maximize the speed and efficiency of (dis)embarking when the pod frequency is high, a configuration of multiple parallel working airlocks is necessary. The evolution of airlocks may be classified into two categories: The pressure in an airlock chamber is likely to vary. The airlock chamber serves as a pressure regulator, ensuring a smooth transition from atmospheric pressure to a low-pressure tube environment and back; once the pod is shut, depressurization happens. The platform will include bridge doors that lock onto the pod doors, allowing the pod to be exposed exclusively to a low-pressure environment while still connected to the station atmosphere.

System for Maintaining Pressure (PMS): The PMS is in charge of the initial air evacuation (pump down) and the maintenance of steady-state conditions, and air leakage management. PMS may rely on various pressure levels, with some functioning at pressures comparable to civil aviation and others at pressures close to space. The power necessary to sustain pressure vs. the energy required to overcome aerodynamic drag is a trade-off when determining an appropriate pressure level.

Interfaces—Levitation: The earliest hyperloop design advocated using air bearings for levitation combined with a linear induction motor, which involves a lot of maintenance, tight integration between the track and the pod, and dramatically increasing the pod weight with fans, motors, and hover-pads (Figure 4). Following that, work concentrated on magnetic levitation (maglev), combined with electromagnetic propulsion for increased efficiency

Interfaces—Propulsion: The propulsion subsystem's primary duties include:

- Accelerating the pod, braking or decelerating it.
- Maintaining the goal speed between the acceleration and deceleration zones.
- Combating drag forces.
- Providing safe magnetic field levels and comfort in the passenger cabin.

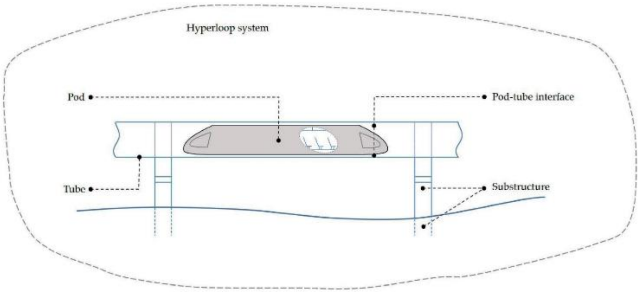

Figure 4: Hyperloop system decomposition (Gkoumas & Christou, 2020)

Axial compressors and linear motors are the two types of propulsion technologies currently being considered.

2.3 System of Communication

Several communication systems are required, including (1) transmission of the pod's sensor data to and from a centralized data processor and (2) communication between the pod and the tube relevant to the pod's position. There are several difficulties with pod communication and data collecting and the high-speed connection between pods and infrastructure. Wireless communication between antennas using radio waves is now possible thanks to a new type of optical fiber. Although the GSM-R (Global System for Mobile Communications-Railway) is the central communication system for HSR, the LTE-R (Long-Term Evolution-Railway) may be employed in communication systems owing to specific restrictions (Zhang et al., 2020).Data transfer, Internet access, and high-quality voice or mobile video streaming are all possible with the LTE-R. Radio and fiber networks, with particular antennas located at intervals and the hyperloop system and hardware put on the pod using the newest 802.11 Wi-Fi standards, have also been built (Mitropoulos et al., 2021).

3. Discussions

The hyperloop is still in its early phases of development, and boosting technological readiness levels will need actions and cooperation from both the corporate and public sectors.

The nacelle's frontal size and form impact the tube's aerodynamic drag and operating energy consumption. The proper blocking ratio, aerodynamic performance, and material properties may all assist in lightening nacelles and minimizing pain. Tube design still has several restrictions, such as a lack of full-scale test facilities, standardized tube diameter measurements, and materials and proof of concept for dimensional stability. System simulations are needed to determine the best aerodynamic gondola with sufficient passenger capacity and the ability to attain the projected ultra-high speeds.

It has already been demonstrated that well-supported seat designs with safety features protect passengers during rapid accelerations and decelerations; nevertheless, the concept's viability must still be tested at high speeds of operation to determine its viability. Passengers' comfort must be met for the vehicle to accelerate and decelerate in curves and corners, and the best seating configuration must be checked to ensure passenger safety. The hyperloop is an innovative concept that allows you to travel at high speeds.

Infrastructure design takes on new dimensions with Hyperloop. Alignment characteristics such as tilt, horizontal curvature, and allowable rates of change for vertical and horizontal angle and jerk are affected by speed, which is the critical component that varies from traditional means of transportation. There is a growing need to include the needs of hyperloop into the present state of the art in the design of HSR and maglev rail lines. The applied alignment has a direct impact on hyperloop steering.

Elevated, ground and subsurface guideways are all options. In the near term, environment and raised guiding structures may be chosen because to cost savings, but, in the long run, underwater tunnels capable of supporting a hyperloop system may provide a viable alternative to aircraft.

Hyperloop, like design, presents new features in transportation planning because of its revolutionary operational and physical properties. A demand forecasting system must be devised to give practical assessments with other competing modes in different corridors. Hyperloop is evaluated using two primary parameters: time and cost. Because time is inversely related to speed, ticket prices must be weighed against infrastructure costs and the value of time to passengers. Surveys at the national and international levels should also incorporate user perceptions of the value of travel time (VTD) and behavioral factors. The station design (number of tracks, platform size, passenger and freight waiting areas), station type (underground/above ground), and the arrangement of connecting facilities (i.e., hubs) with other modes of transportation will be influenced by the physical characteristics of the hyperloop (e.g., tube, vacuum system, etc.).

Simulation software for a hyperloop system that addresses the following challenges will be required to offer comprehensive and reliable assessments.

Performance is assessed mainly in terms of safety, energy efficiency, and cost. The necessity for stakeholders to show the practicality of hyperloop technology and compare its performance to other modes of transportation is likely driving this interest. Hyperloop is a cutting-edge mobility technology that partially integrates rail and aircraft subsystems, necessitating unique rules to develop and operate.

4. Conclusion

Faster, cheaper, and increasingly safe forms of transportation that can run constantly are required to develop a robust economy. Due to significant population increase, our highways, airports, and seaports are now crowded. The Hyperloop is a suggested solution to all of the current transportation system's difficulties. Hyperloop has emerged as a superior choice to existing transportation systems since it is twice as fast as airplanes, has halved travel times, and has a cost comparable to aviation travel. In addition, the Hyperloop is safer than current routes of transportation. One of the four essential qualities of Hyperloop is its speed, which makes it a superior alternative to existing systems. It's immediate and on-demand. Trains usually have a set timetable with many stops.

The Hyperloop always leaves when you're ready, and units may pull out many times at the moment, carrying commuters and dropping them off immediately at their jobs with no pauses in between. It is environmentally friendly, with a minor natural impact, boosting the efficiency of vitality usage, and no direct emissions. It is cheaper and has a wide range of applications. Magnetic levitation trains, both high-speed and conventional, require more control over the entire length of the track. As a result, the ways are more expensive and need more labor to finish. Hyperloop can provide superior performance at a lower cost.

5. Limitation and study forward

According to its proponents, the hyperloop is a technology that can make a massive impact. It has the potential to minimize air travel between large cities, stimulate economies and commerce, and relieve city housing shortages by letting commuters reside further afield. But none of this has been verified, not even close. Before Hyperloop technologies can comfortably transport passengers in an air tube, let alone alter the world, they must overcome significant technological and commercial challenges.

The next stage for Hyperloop is to go past preliminary tests and feasibility studies and begin testing the technology over greater distances, as well as, most critically, with passengers. Finding business models that operate globally will be another difficulty. We won't know if Hyperloop is a success until all of this is completed.

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