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HYPERLOOP

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ABSTRACT: In today's date travelling is defined by rail, road, air and water. These are mostly available in world with very common sets of problem like safety, security of structure, environmental crisis, space, time for travelling, etc. And most important problems are that even best of these has high cost or slow speed or in sad cases both of them. Hyperloop is a concept that is believed to be originated from 20th century's sci-fi, which shifts paradigm of transport. Hyperloop is theoretically most safe, eco-friendly, relatively cheap, and the future face of transportation.

I. INTRODUCTION

Railways structured urban geographies for most of the 19th and 20th century. They brought prosperity and decline to towns depending on the location of the stations. By the end of the 20th century, the railway's impact on urban form waned considerably due to the proliferation of the automobile and air travel in many parts of the world. Therefore, companies have been trying to alter existing public ground transportation systems to maximize public transportation benefits. At the beginning of the 21st century, the second railway revolution had emerged called high-speed rail (HSR), operational in numerous parts of the world, including Japan, western and northern Europe, Korea and China. In 2013, the CEO of SpaceX, Elon Musk, proposed a concept of ultra-high-speed rail (UHSR) called hyperloop and open-sourced it. The technology significantly builds on a much older idea variously known as "gravity vacuum tube," "gravity vacuum transit," or "high-speed tube transportation," which dates originally back to 1865.

Since 2013 several companies have been actively promoting hyperloop's development in various locations around the world. Hyperloop is the newest HS ground transport system currently in the early stage of testing. The concept works on electromagnetic attraction forces with travel pods operating in a very low-pressure environment with almost no air resistance or friction, thus enabling the theoretical speed of 1,200 km/h. The technology has an ambitious goal to result in a time-space shrinkage, which will increase the accessibility of cities through very low travel times over long distances. The main selling point used by Musk in his proposal for UHSR is cutting carbon emissions through very high energy efficiency and efficiently managing urban growth. UHSR claims to be superior to other HS transport in operational, economic, environmental and social performance. However, due to the hyperloop's very recent nature, its actual effects on cities and people are largely speculative. This paper therefore attempts to investigate the current state of knowledge about the technology and to identify some knowledge gaps in this new mode of transport.

II. LITERATURE REVIEW

└ Ahmed Hodaib, Samar F. Abdel Fattah (May 2016), discussed the "Design of a hyperloop capsule with linear induction propulsion system" which is used to accelerate and decelerate the capsule. They studied that like rotary synchronous motors; linear motors run on 3-phase power and can support very high speeds. However, there are end effects that reduce the motor's thrust force. Linear induction motors are thus less energy efficient than normal rotary motors for any required force output. They also discussed about the manufacturing of linear induction motor in this paper.

└ Jeffrey C. Chin, Justin S. Gray, Scott M. Jones, Jeffrey J. Berton, they discussed about the "Open-Source Conceptual Sizing Models for the Hyperloop Passenger Pod" in this paper. They concluded that the refined analysis illuminates several interdisciplinary couplings that alter two major aspects of the initial concept. First, the pod travel speed and the tube cross sectional area are linked, forcing the tube size to be to be roughly twice the diameter of the original specification, in order for the pod to reach Mach 0.8. Second, the steady-state tube temperature is dominated by ambient thermal interactions unrelated to the heat generated by the pod compression system.

III. COMPOSITION AND CONSTRUCTION OF HYPERLOOP.

- **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. 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.
- **Pod:** The pod is the main structural structure of the system and is comparable to an airplane airframe. 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.
- **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 splits 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.
 - Axial compressors and linear motors are the two types of propulsion technologies currently being considered.

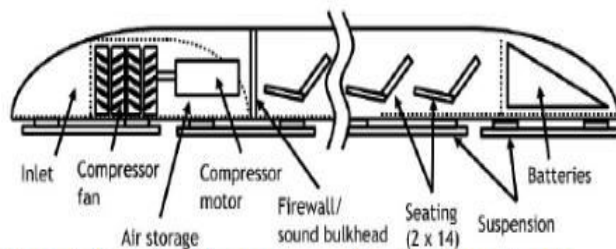


Figure 2 : Hyperloop Passenger capsule subsystem notional locations. (Joshi, 2016)

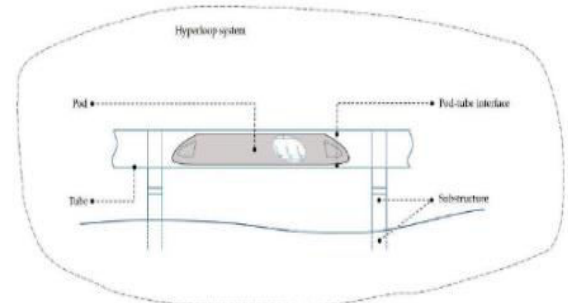


Figure 4: Hyperloop system decomposition (Gkoumas & Christou, 2020)

Pod or Capsule

Hyperloop system

1. Working

Here's a step-by-step overview of how the Hyperloop system is envisioned to work:

- **Low-Pressure Tube:** Hyperloop operates within a sealed tube or tunnel with low air pressure. By reducing air resistance, the system minimizes energy consumption and allows for higher speeds.
- **Pods:** Passenger or cargo pods travel through the tube. These pods are designed to be aerodynamic and are propelled using various methods such as magnetic levitation (maglev) or air compression.
- **Magnetic Levitation (Maglev):** Maglev technology utilizes powerful magnets to levitate the pods above the track, eliminating friction and allowing for smoother, faster travel. Linear induction motors propel the pods forward by interacting with the magnetic fields.
- **Vacuum Environment:** The tube is maintained at a near-vacuum condition to reduce air resistance. This enables the pods to travel at high speeds with minimal air resistance, similar to an aircraft flying at high altitudes.
- **Propulsion System:** Hyperloop pods are accelerated using either linear induction motors or a system of air compressors. Linear induction motors provide propulsion by generating electromagnetic fields that push and pull the pods along the track. Alternatively, air compressors can create a cushion of air in front of the pod, propelling it forward.
- **Passenger/Cargo Loading:** Passengers or cargo are loaded into the pods at stations located at various points along the Hyperloop route. The stations serve as entry and exit points for travelers and provide facilities for boarding, ticketing, and security checks.
- **Computerized Control System:** The Hyperloop system is controlled by a sophisticated computerized system that manages pod movement, maintains optimal conditions within the tube, and ensures safety and efficiency. This system monitors pod speed, position, and environmental conditions in real-time, adjusting parameters as needed.
- **Safety Measures:** Safety is a paramount concern in Hyperloop design. Emergency braking systems, redundancy in propulsion systems, and automated collision avoidance technologies are integrated to ensure passenger safety.
- **Energy Efficiency:** Hyperloop aims to be an energy-efficient mode of transportation. Renewable energy sources such as solar power can be utilized to generate the electricity needed to operate the system. Additionally, regenerative braking systems can capture and store kinetic energy from decelerating pods, which can be reused to power acceleration.

- **Hyperloop Network:** The Hyperloop system can potentially connect cities and regions, revolutionizing transportation and reducing travel times significantly. By linking major urban centers and transportation hubs, Hyperloop has the potential to transform the way people and goods are transported over long distances.

Overall, the Hyperloop concept combines various cutting-edge technologies to create a high-speed, energy-efficient mode of transportation that promises to revolutionize long-distance travel. While several companies are actively developing Hyperloop prototypes and conducting feasibility studies, widespread implementation of the technology is still in the early stages and faces various technical, regulatory, and economic challenges.

2. Advantages and Potential Impact

The Hyperloop concept offers several potential advantages that could revolutionize transportation:

- **Speed:** Hyperloop pods have the potential to reach incredibly high speeds, potentially exceeding 600 miles per hour (965 kilometers per hour). This could significantly reduce travel times between distant cities.
- **Energy Efficiency:** Because the system operates within low-pressure tubes and reduces air resistance, the energy required for propulsion is much lower compared to traditional transportation methods.
- **Environmental Benefits:** With its minimal carbon footprint, the Hyperloop has the potential to be one of the most environmentally friendly transportation systems, particularly if powered by renewable energy sources.
- **Reduced Congestion:** By enabling fast travel between cities, the Hyperloop could alleviate congestion on highways and at airports, leading to more efficient transportation networks.
- **Weather Independence:** The enclosed nature of the tubes would render the system less susceptible to weather-related disruptions, making it a reliable mode of transportation.
- **Economic Growth:** The implementation of Hyperloop systems could spur economic growth by fostering closer connections between cities and regions.

3. CHALLENGES AND CONSIDERATIONS

While the Hyperloop concept holds immense promise, there are several challenges that need to be addressed:

- **Infrastructure:** Constructing the necessary infrastructure, including the low-pressure tubes and supporting pylons or tunnels, requires significant investment and coordination.
- **Regulation and Safety:** Developing regulations and safety standards for a novel transportation system poses regulatory challenges.
- **Technological Hurdles:** Overcoming technical obstacles, such as maintaining a low-pressure environment and ensuring the safety of passengers and cargo, is critical.
- **Cost:** Despite its potential benefits, the upfront costs of building Hyperloop systems could be substantial.

4. 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.

IV. FUTURE SCOPE

The future scope of Hyperloop is vast and holds promise for revolutionizing transportation on a global scale. With its potential to propel passengers and cargo at near-supersonic speeds within low-pressure tubes, Hyperloop stands as a beacon of innovation in the transportation sector. Beyond merely reducing travel times between cities, Hyperloop networks offer the prospect of seamlessly connecting regions, fostering economic growth, and alleviating congestion and pollution. As urbanization continues to accelerate and populations grow, the demand for efficient and sustainable transportation solutions becomes increasingly urgent. Hyperloop presents an opportunity to meet this demand while also driving technological innovation in areas such as propulsion, materials science, and automation. Moreover, its potential to integrate with renewable energy sources and minimize environmental impact underscores its significance in the transition towards a more sustainable future. As research and development efforts progress and regulatory hurdles are addressed, the vision of Hyperloop as a transformative mode of transportation draws closer to realization, promising to reshape economies, societies, and the way we move people and goods across the globe.

V. CONCLUSIONS

In conclusion, Hyperloop represents a groundbreaking leap forward in transportation technology, offering the potential to revolutionize the way we travel and transport goods. With its ability to propel passengers and cargo at incredibly high speeds through low-pressure tubes, Hyperloop has the capacity to significantly reduce travel times, alleviate congestion, and promote economic growth. The vision of Hyperloop extends beyond mere efficiency; it embodies a commitment to sustainability, innovation, and interconnectedness. As research and development efforts



continue and regulatory challenges are addressed, Hyperloop moves closer to becoming a viable and transformative mode of transportation. While there are hurdles to overcome, the promise of Hyperloop as a catalyst for positive change in transportation and beyond is undeniable. As we look to the future, Hyperloop represents not just a mode of transportation, but a symbol of human ingenuity, collaboration, and the relentless pursuit of progress.

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