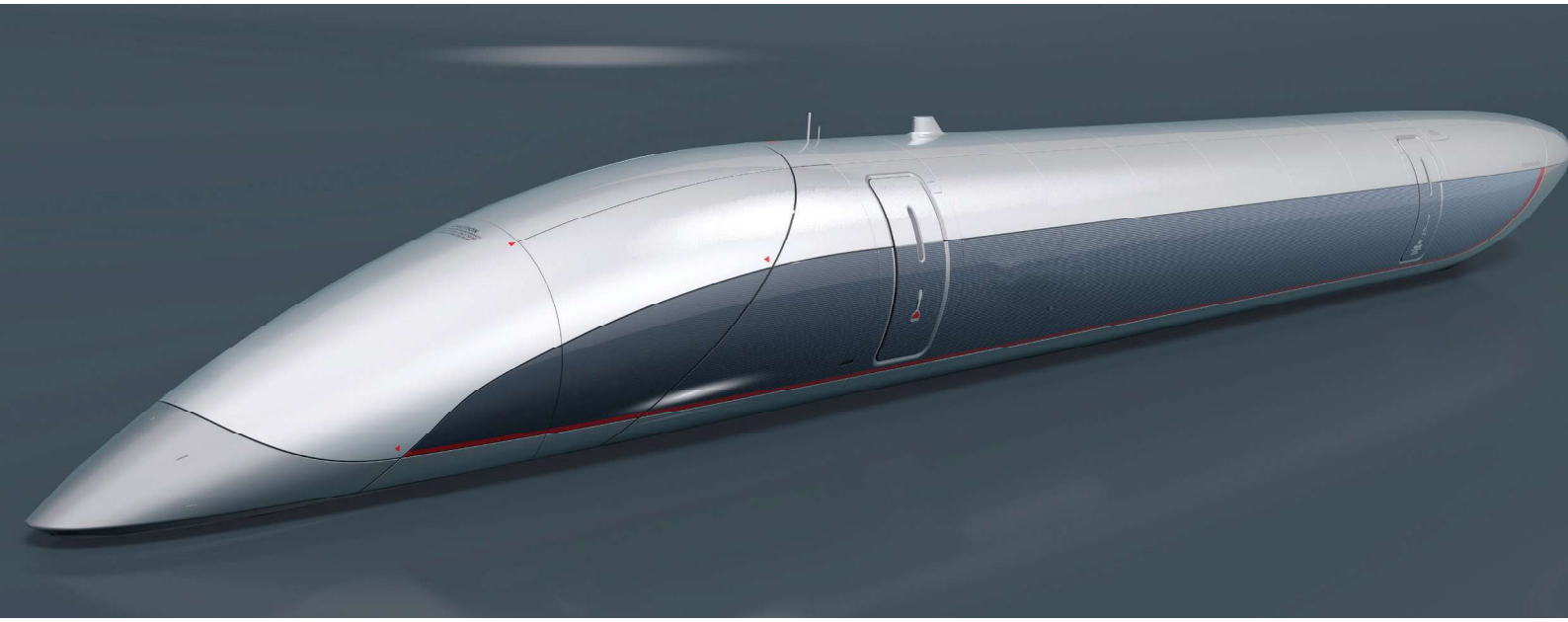
HYPERLOOP: FAST FORWARD TO THE FUTURE

The term 'Hyperloop' has created quite a buzz in the transportation sector.



Hyperloop consists of a sealed tube or a system of tubes with very low air pressure inside, through which a pod can travel at large speeds for transporting passengers or cargo. In today's fast-paced world, the transportation sector is facing challenges to keep up with the growing requirements and expectations while trying to find a balance between speed, efficiency, and environmental sustainability. Hence, many contributors, as well as institutions all around the globe, are striving to make the newly proposed solution of Hyperloop a reality. Due to its unique features, it has been often looked upon as the 5th mode of transportation.

Hyperloop can strongly compete with the other conventional transportation means on multiple verticals of speed, energy, and economic costs. However, the infrastructural and other complexities do not restrict India to be outside the viable zone. Hyperloop can have potential implementations for freight as well as passenger transport in the country. In fact, Hyperloop can play a significant role in handling the inter-city passenger transport load much better. Indeed, Hyperloop will be the "inter-city metro".

The development of Hyperloop technology requires high tech research and engineering to a great extent, considering various challenges that the tube structure and the travelling pod have to handle. The tube structures should meet all the infrastructural and operational requirements for facilitating a high-speed travelling pod across the different landscapes and throughout the year. The pod will require a lot of multi-disciplinary innovations to put together all the subsystems of propulsion, braking, power systems, controls, communications, structures, and suspension. The safety and comfort of the passengers hosted inside the passenger cabin area of utmost priority.

Early Beginnings of Tube Transportation

In 1799, designer George Medhurst proposed a plan to move products through cast-iron lines utilizing gaseous tension. In 1844, he

fabricated a railroad station (for traveller carriages) in London that depended on pneumatics until 1847. All through the mid-1850s, a few more pneumatic railroads were implicit in Dublin, London, and Paris. The London Pneumatic Despatch framework was intended to ship packages, yet it was huge enough to convey individuals, as well. To check its opening, the Duke of Buckingham went through it in 1865.[2]

During the 1860s, South London developed the Crystal Palace climatic railroad, which went through a recreation centre. A fan, which estimated 11 feet in radius, propelled the train. On return voyages, the fan's sharp blades reversed, sucking the freight backwards. The Pneumatic Transit Beach, which worked in Manhattan from 1870 to 1873, was New York City's soonest subway archetype. Planned by Alfred Ely Beach, it had one stop and a one-vehicle transport that utilized compressed air to move riders.[2]

In 1904, in Worcester, Massachusetts, the pioneer of the present-day rocket plan, Robert H. Goddard, composed an article investigating transport in 1945. He portrayed a frictionless framework utilizing tunnels with reduced air pressure to minimize friction and achieve high speeds. 'Vacuum trains' were conceived. The concept was created and was patented in 1950. In 1997, the US firm called ET3 recorded a patent on "evacuated tube transport" (ETT), which is based on 100% evacuated tubes, and MAGLEV drive and levitation. The ETT patents expired in 2017.

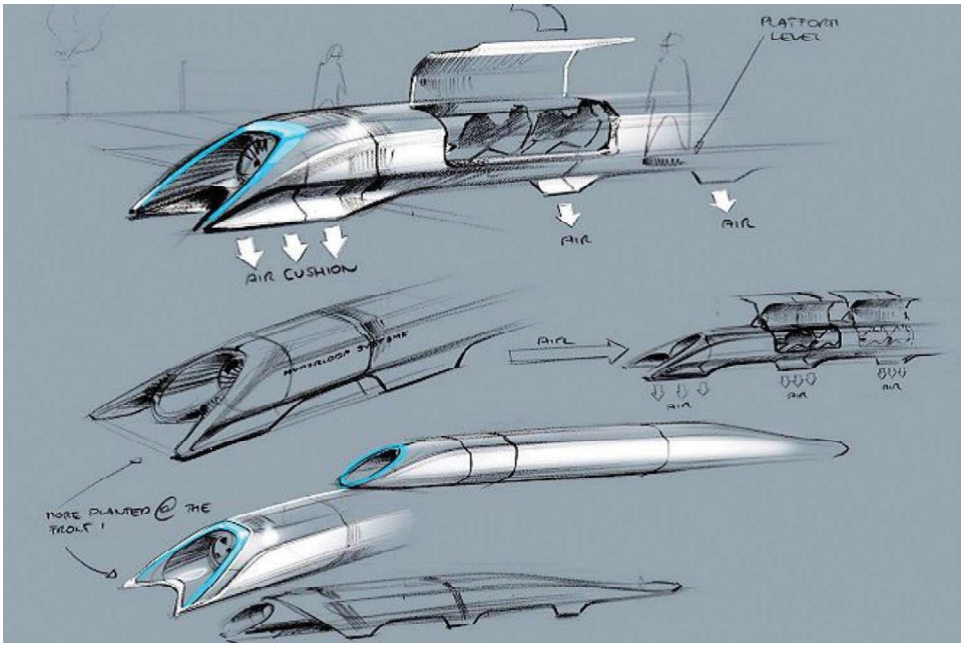
Hyperloop

Hyperloop alludes to the idea portrayed by Elon Musk in his paper, Hyperloop Alpha, distributed in 2013 and includes either traveller or cargo conveying vehicles that operate inside tubes with air evacuated to create a low-pressure environment. The decreased air opposition coming about because of the low-pressure environment could empower the vehicles to reach extremely high speeds, 2-3 times quicker than high-speed trains. It is also claimed that the system can enable direct, on-demand travel, instead of a scheduled service as given by different types of public transport, could be more environmentally friendly than other transportation modes and could be less expensive than the others.

In order to promote this new transportation system, SpaceX has been organizing an annual design and speed competition called SpaceX Hyperloop Pod Competition for Hyperloop pods built by student teams from all over the world. The competition is held at the SpaceX Headquarters, Los Angeles, where they have built a one-mile-long test tube with a reduced diameter of 1.5m, in which the teams that qualify all the safety tests place their subscale prototype of Hyperloop Pod to test it.

After the release of Hyperloop Alpha in 2013, between 2013 and 2016, three companies were formed to work on the implementation of the concept proposed: Virgin Hyperloop, Hyperloop Transportation Technologies, and Transpod.

Recently, few student teams that took part in the SpaceX Hyperloop Pod Competition have decided to go further and are incorporating their businesses in order to develop their own versions of the Hyperloop pods and infrastructure. With a lot of parties involved in the business, there are a few ongoing implementation projects and many more in the planning stage across the globe.



Hyperloop Alpha, as proposed by Elon Musk

(Source: Hyperloop White Paper)

While this seems like taking the best of existing technologies, it did attract a lot of criticism for being ambitious and several other challenges such as Infrastructure, planning, overarching capability needs, construction, operations, safety, and a few others. Nevertheless, several players in the market have brought in their own ways to deal with each of these concerns.

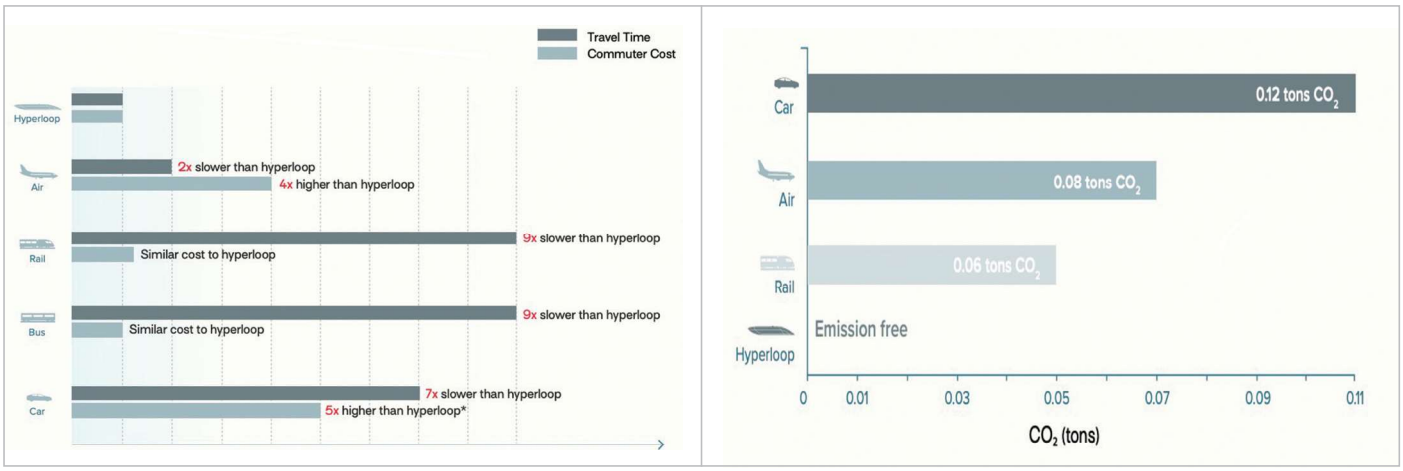
Comparison with other modes

Currently, there are four well-known transportation systems – Roadways, Railways, Airways, and Waterways for both passenger and freight movement. Here, many countries are involved in looking for some smart transportation solution, which will not only accelerate the mass movement but also reduce the travel time and cost. Over the last few years, several countries across the globe have been experimenting and innovating with high-speed rails, Bullet Trains, and Maglev too. However, the need for a real solution did not end. Eventually, Hyperloop was proposed as the Fifth Mode of Transportation. The ideation of a novel transportation system with extensive features naturally requires considerable reasons to believe in. It has often been quoted as "The fifth mode of transportation," "Energy self-sufficient, Fast and cheap for people and goods" (Elon Musk) and "On-demand, energy-efficient, safe" (Virgin Hyperloop One).

The below charts compare the various transportation modes. The first one shows how Hyperloop gains an edge based on time and cost. The second figure compares Hyperloop with other transportation modes based on CO2 emission levels and clearly has an advantage.

Looking at the applications, they could broadly be classified into Goods and Passenger Transportation. As for goods transportation, the current alternatives are to transport by air, truck, rail, or by ship. However, Hyperloop is fairly competitive and shows a combined advantage.

Based on passenger travel, a comparison of Hyperloop transportation with other existing systems has been reflected in the below table. Commute by ships is neglected due to access and volume of transportation by that means.



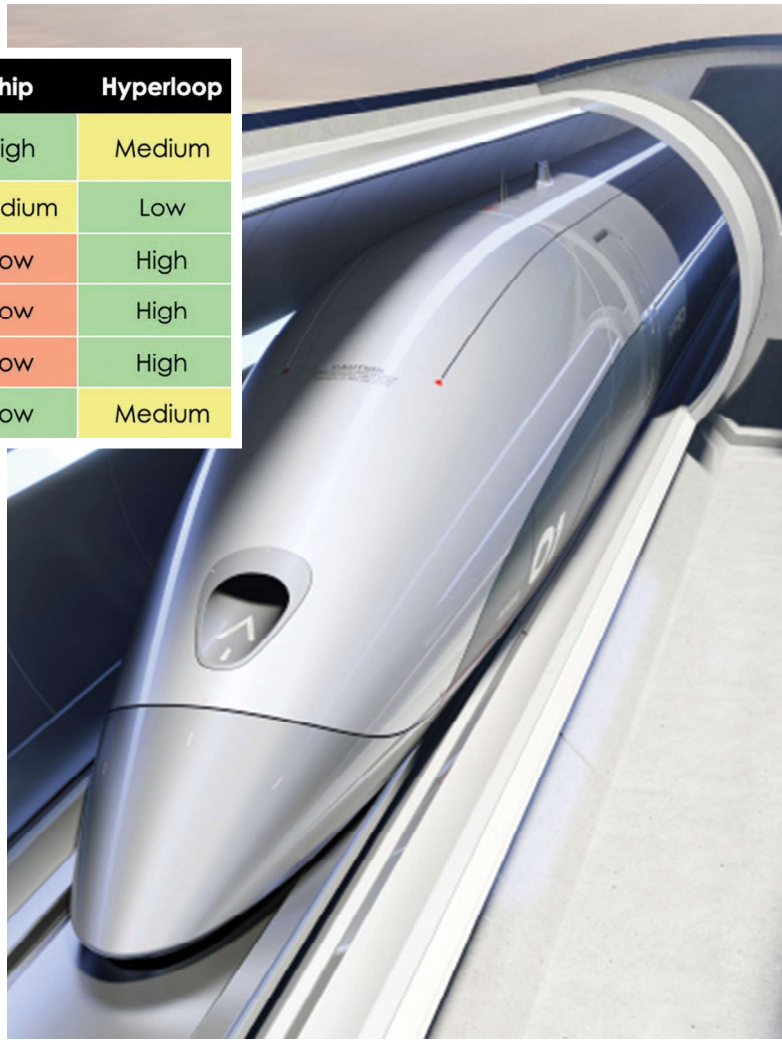
Comparison of Hyperloop with other modes of transportation

(Source: Great Lakes Hyperloop Feasibility Study by Hyperloop TT)

COVER Story

(Ref: Hyperloop in Thailand report by Transpod)

Categories	Air	Truck	Rail	Ship	Hyperloop
Payload Capacity (Tons)	Low	Medium	High	High	Medium
GHG Emission	High	High	Medium	Medium	Low
Frequency	High	High	Low	Low	High
Speed	High	Medium	Medium	Low	High
Weather Resistance	Low	Low	Medium	Low	High
Cost per ton	High	Low	Low	Low	Medium



Based on the above points, Hyperloop transportation definitely has key advantages over other systems which will help in achieving the objective of a rapid mass movement with cheaper and faster technology.

Scope in India

India is one of the fastest-growing economies in the world. India being the seventh-largest country by area and the second-most populous country, various initiatives are needed in the transport sector to meet the demands of such a large population over large distances. Hyperloop is definitely a step in the right direction. India has a good reputation for managing land transportation with the fourth largest railway network and the second largest road network in the world. Despite this, there is a lot of time spent on travel by each individual keeping in mind the population. In fact, it has been several years since the Indian Transportation System has seen a major breakthrough.

Currently, the fastest train operational in India, the Vande Bharat, has speeds of up to 180 kmph. With Hyperloop aiming to achieve speeds greater than 1000 kmph, it will reduce the average travel spent by an individual by a huge scale. The Indian government has been contacted by a few Hyperloop companies and some routes have been proposed as well for immediate implementation of this in India. With a reasonable price, it would allow for people to work in one city while residing in another. This could help a lot the decongestion of major cities.

Of the many routes proposed, a few were found to be viable for the implementation of the concept of Hyperloop in the Indian Subcontinent. A few other routes

Categories	Passenger Flight	Rail	Bus	Hyperloop
Speed Performance	Medium	Low	Low	High
Frequency of departure	Medium	Medium	Medium	High
Fuel Efficiency	Low	Medium	Medium	High
Energy Efficiency	Low	High	Low	High
Weather Resistance	Low	Medium	Low	High
Motion Sickness Prevention	Medium	Medium	Medium	High
Passenger Comfort	High	Medium	Medium	High

(Ref: Hyperloop in Thailand report by Transpod)

are also being checked for feasibility. Here are some of the routes with their expected travel time:

- Mumbai to Pune – 160 km in 16 minutes
- Bengaluru to Chennai – 334 km in 28 minutes
- Mumbai to Chennai – 1100 km in 78 minutes
- Bengaluru to Thiruvananthapuram – 736 km in 55 minutes
- Delhi to Mumbai – 1317 km in 93 minutes
- Vijayawada to Amravathi – 42 km in 8 minutes

For a country like India, the goal of affordable high-speed transportation would do a great deal. Definitely, easier said than done. Coming with a huge infrastructure cost, Hyperloop attracts a lot of critical eyes. But what comes along is a lot of savings, in terms of money, human efforts, time, and energy. This holds true for all the stakeholders of Private Companies, Government of India, and the commuters too.

Hence, India stands as a great market for the commercial players looking at developing the 5th mode of transportation for the people at large.

Major Players

The global market for Hyperloop technology is estimated to be around US $1.35 billion in 2022 and is predicted to reach US $6 billion by 2026, growing at a compound annual growth rate of 45.2% from 2023 to 2026. The rise in demand for a fast and affordable mode of transportation has driven the demand for Hyperloop technology. Furthermore, the technology being energy-efficient & environment-friendly naturally fuels the growth of the market.[1]

The market being relatively untapped and in its early stages has prompted many companies to enter the market and try to come on top with the first working demonstration of the technology. AECOM, Dinclix GroundWorks, Virgin Hyperloop One, Hyperloop Transportation Technologies, TransPod Inc., Zerelos, Uwashington Hyperloop, and Hardt Hyperloop are some of the main players operating in the worldwide Hyperloop technology market.[1]

Virgin Hyperloop One has taken huge leaps in terms of Hyperloop development by having multiple projects going on. These include India (Mumbai - Pune was called off; Amritsar - Chandigarh still in talks) and the UAE. The company had started the construction of a 5-mile Hyperloop track in 2017. Recently in November 2020, Virgin Hyperloop One also completed the test of the first Hyperloop Pod with passengers on-board.

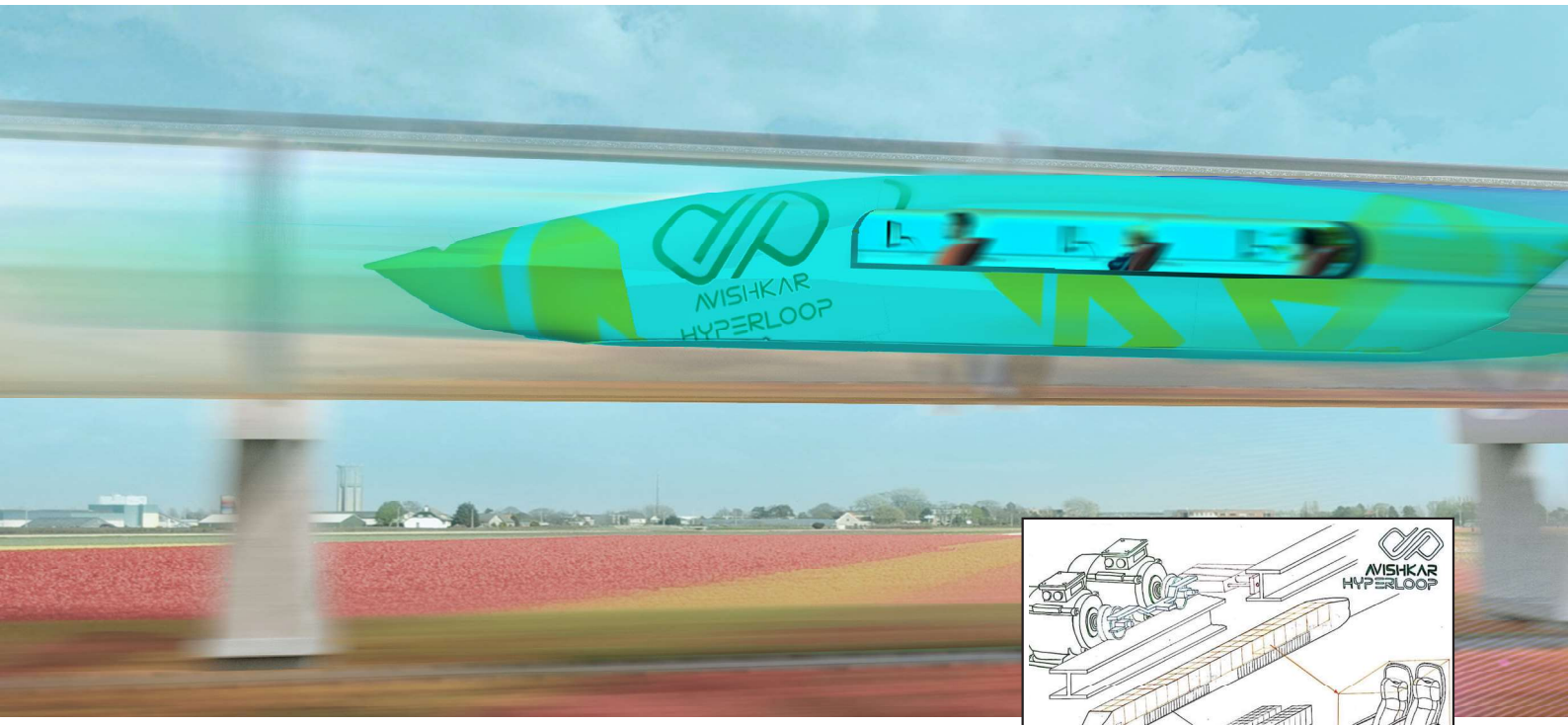
Hyperloop Vs Other ground-based high-speed transportation systems

The two major high-speed ground-based transportation systems are Maglev and High-speed rail. Maglev is an arrangement of train transportation that utilizes two arrangements of magnets: the first set to repel and elevate the train above the track, and the second set to move the lifted train ahead, exploiting the absence of contact.[3] High-speed rail is a kind of rail transport that runs fundamentally quicker than customary rail traffic, utilizing an incorporated arrangement of specialized rolling stock and dedicated tracks. Hyperloop is a sealed tube with very low air pressure through which a pod may travel substantially free of air resistance or friction.

Both Maglev and Hyperloop are quite ingenious, with Hyperloop being a relatively recent one. While Maglev has been in use for over a decade in a few countries, Hyperloop is still getting off the rails, with quite a few major players like SpaceX and Virgin Hyperloop One diving deep into the R & D of this technology.

Maglev vehicles have set up a couple of speed points of reference, and maglev trains can quicken and decelerate significantly snappier than standard trains; the fundamental sound judgment imperative is the security and comfort of the passengers. The power needed for levitation is ordinarily not an immense degree of the overall energy use of a quick maglev system; that honour goes to the component which needs to stimulate the trains to such high speeds while beating the drag powers.

COVER Story



[3] Maglev infrastructure has been essentially more exorbitant to create than normal train infrastructure, even though the less difficult development of maglev vehicles makes them more affordable to make and keep up.

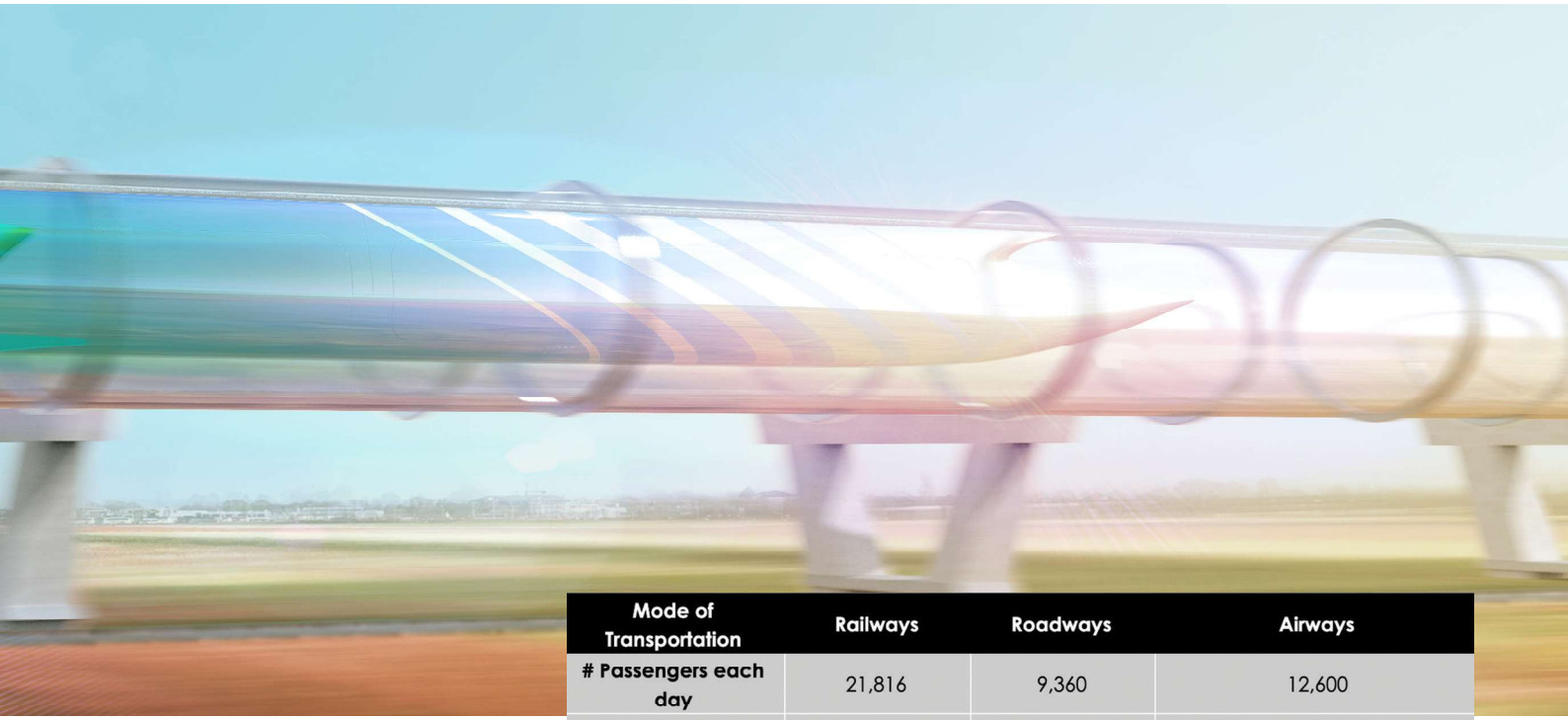
The estimated cost per km of the Hyperloop is much lesser than that of the Maglev and High-speed train, though. The gradual advantages of maglev innovation have frequently been viewed as difficult to justify against cost and danger, particularly where there is a current or proposed traditional fast train line with spare passenger carrying capacity, as in high-speed rail in Europe, the High Speed 2 in the UK and Shinkansen in Japan.

On the other hand, Hyperloop could pass on individuals or objects at the aircraft or hypersonic speeds while being very energy proficient. This would definitely decrease travel times versus trains as well as aeroplanes over separations of under around 1,500 kilometres (930 miles). While the capital expenditure for the Hyperloop Tracks will be on par with Maglev, the maintenance and energy costs will be significantly lower than any Maglev Technology.

Chennai - Bengaluru case study

Briefly, having understood about Hyperloop, its advantages, and relevance in the Indian context, the idea of developing Hyperloop for real, in whatever use case, should be highly considered. With the ultimate aim of passenger commute, the development of Hyperloop can be divided into parts where different subsystems are developed complementing various other applications. This can act as proofs of concept addressing all concerns in regards to the functionality of Hyperloop, while also gathering the trust of the future commuters.

Train	Length of route	Time	Total building cost	Cost per km
Shanghai Maglev (Pudong Airport to Pudong)	30.5 kms	7m	$ 1.33 Billion	$ 43.6 Million
L0 Series Maglev (Tokyo to Nagoya)	286 km	40m	$ 48.6 billion (estimated cost)	$ 169.9 Million
High-speed rail (Mumbai to Ahmedabad)	510 km	110m	$ 15 billion (estimated cost)	$ 29.4 Million
Hyperloop (Chennai to Bengaluru)	350 km	30m	$ 8 billion (estimated cost)	$ 23.1 Million



Mode of Transportation	Railways	Roadways	Airways
# Passengers each day	21,816	9,360	12,600
Average Travel Time	5-6 hours	5-7 hours	3-4 hours (incl. Boarding, Security Check, Travel to/from airports, etc.)
Total Revenue per day	₹ 25,39,440	₹ 76,21,710	₹ 5,49,72,000

The best business case for Hyperloop lies in passenger transport as many people are willing to pay a premium for a faster commute that saves a lot of time. At a later stage, freight transport too can be added as a complementing service. Having weighed several parameters such as population, daily passenger transport volume using different modes, and the average expenditure on transportation, with mutual consensus, Chennai - Bengaluru is taken as the base route for all the comparisons and calculations in this article.

The following table sheds light on some of the important parameters like passenger volume and a few others that affect the revenue of a mode of transport. This data includes transport modes of all classes and types, and the costs have been factored in accordingly. For instance, Railways includes data for chair cars as well as AC coaches. Roadways take into account the peak pricing over the weekends.

Following these calculations, the cost and passenger capacity for Hyperloop can be further optimized based on parameters such as time interval between consecutive pods, individual pod capacity, the total number of pods to be run over the day, etc. The expected time interval, to begin with, is taken as 6 minutes.

Please note that these predictions are based on the assumption that innovations contribute to the growth and development of the economy. That is, with every passing year, for the given forecast period, until 2030 –

- Hyperloop – Time interval between two consecutive Pods reduces by 0.5 minutes.
- Airways – Increment of 4 airplanes.
- Railways – Increment of 1 train with just upper class (3-tier AC and above).
- Roadways – Increment of 20 buses.

This analysis clearly shows how Hyperloop is capable of individually handling the population increase and the growing commute. Eventually, when Hyperloop is implemented, it would ideally complement all the other modes of commute, and hence together, address the growing demand and ease overall congestion.

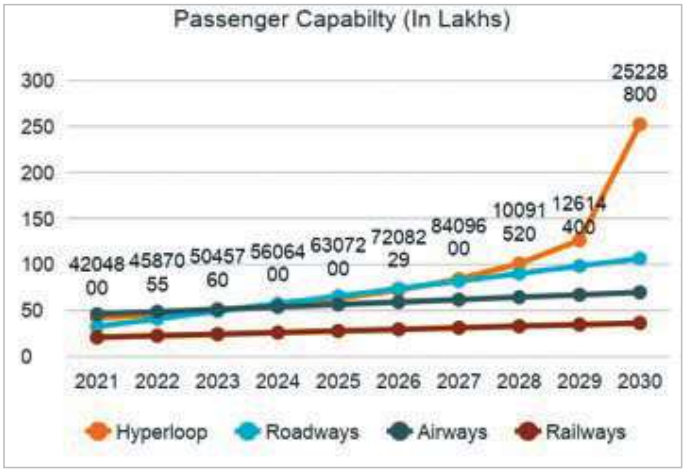
Conclusion

Hyperloop can provide much lesser travel time for comparable costs, in consideration with the other means of transportation. Upon optimizations in the

technology and the business processes, emissions during its operation will be nearly zero, and its energy sustainability benefits over the long run can provide a much greener choice (environmentally) in the transportation sector.

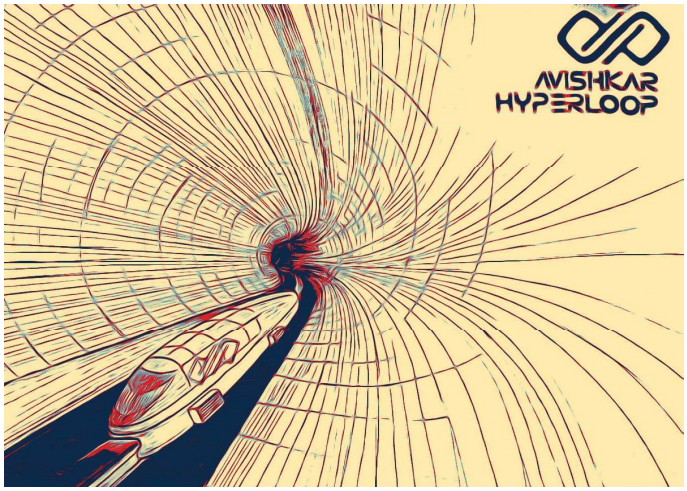
The Global Hyperloop Technology Market is huge and is projected to reach from US $1,350 million in 2022 to US $6,000 million in 2026. Many institutions are working around the globe, from its technological development to agreements with the governments for its testing and construction. Such an intense evolution can make it a better performer even as compared to the Maglev technology.

Hyperloop can offer high-speed transportation at affordable rates in India as well, despite the multi-faceted challenges involved. Upon analysis, it was concluded that Hyperloop could be a finer application for passenger transport, as compared to freight transport.



Year	Hyperloop	Roadways	Airways	Railways
2021	42,04,800	32,76,000	45,99,000	20,76,120
2022	45,87,055	40,95,000	48,61,800	22,49,130
2023	50,45,760	49,14,000	51,24,600	24,22,140
2024	56,06,400	57,33,000	53,87,400	25,95,150
2025	63,07,200	65,52,000	56,50,200	27,68,160
2026	72,08,229	73,71,000	59,13,000	29,41,170
2027	84,09,600	81,90,000	61,75,800	31,14,180
2028	1,00,91,520	90,09,000	64,38,600	32,87,190
2029	1,26,14,400	98,28,000	67,01,400	34,60,200
2030	2,52,28,800	1,06,47,000	69,64,200	36,33,210

Trends in Passenger Transport Capability over the years by different modes



Upon the financial and business analysis, it is estimated that the completion of a full-fledged Chennai - Bengaluru commercial Hyperloop corridor will require up to US $8 billion. A major fraction of this cost will be accounted for the 2-way tube structure and related infrastructural activities. Evaluating a comparable ticket cost of ₹ 4,000 INR while running the system 24 x 7, the break-even point will be reached in approximately 18 years, considering all factors and assuming full costs without any cost optimization, support, and subsidy.

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