HYPERLOOP HIGH SPEED OF TRANSPORTATION

Abhishek Kumar, Abhishek Kumar, Abdul Bashit Khan

Department of Civil Engineering, IIMT College of Engineering. Greater Noida (India)

BACKGROUND

There are truly a new mode of transport – a fifth mode after planes, trains, cars and boats – that meets those criteria and is practical to implement? Many ideas for a system with most of those properties have been proposed and should be acknowledged, reaching as far back as Robert Goddard's to proposals in recent decades by the Rand Corporation and ET3.

Unfortunately, none of these have panned out. As things stand today, there is not even a short distance demonstration system operating in test pilot mode anywhere in the world, let alone something that is robust enough for public transit. They all possess, it would seem, one or more fatal flaws that prevent them from coming to fruition.

WHAT IS HYPERLOOP

The Hyperloop is basically a capsule hovering in a low pressure tube above ground for hundreds of miles between cities. This high speed system would allow people to travel 760 mph, as fast as the speed of sound. The goal is to travel from Delhi to Mumbai in about 1hour instead of a 18-19hour drive. Although all the details are being worked out, there is talk of it becoming a reality in 2018. Short of figuring out real teleportation, which would of course be awesome (someone please do this), the only option for super fast travel is to build a tube over or under the ground that contains a special environment. This is where things get tricky. However, a low pressure (vs. almost no pressure) system set to a level where standard commercial pumps could easily overcome an air leak and the transport pods could handle variable air density would be inherently robust. Unfortunately, this means that there is a non- trivial amount of air in the tube and leads us straight into another problem. A new high speed mode of transport is desired between Delhi and Mumbai. This preliminary design study proposes a new mode of high speed transport that reduces both the travel time and travel cost between Delhi and Mumbai. Options are also included to increase the transportation system to other major population centers across Mumbai. It is also worth noting the energy cost of this system is less than any currently existing mode of transport.

ABSTRACT

Current transport (rail, road, water, air), are either slow, expensive, or both. Hyperloop is both fast and cheap. It is being developed as an open source project. Hyperloop is the concept for very high-speed, fixed-guideway, surface transportation. Hyperloop is a new mode of transport that seeks to change this paradigm by being both fast and inexpensive for people and goods. Hyperloop is also unique in that it is an open design concept, similar to Linux. Feedback is desired from the community that can help advance the Hyperloop design and bring it from concept to reality. Hyperloop consists of a low pressure tube with capsules that are

transported at both low and high speeds throughout the length of the tube. The capsules are supported on a cushion of air, featuring pressurized air and aerodynamic lift. The capsules are accelerated via a magnetic linear accelerator affixed at various stations on the low pressure tube with rotors contained in each capsule. Passengers may enter and exit Hyperloop at stations located either at the ends of the tube, or branches along the tube length.

I. HYPERLOOP TRANSPORTATION SYSTEM

Hyperloop is a proposed transportation system for traveling between Mumbai, Jaipur, and Delhi, Udaipur in 25 minutes. The Hyperloop consists of several distinct components, including:

a) Capsule :-

- Sealed capsules carrying 28 passengers each that travel along the interior of the tube depart on average every 2 minutes from Mumbai or Delhi (up to every 30 seconds during peak usage hours).
- A larger system has also been sized that allows transport of 3 full size automobiles with passengers to travel in the capsule.
- The capsules are supported via air bearings that operate using a compressed air reservoir and aerodynamic lift.
- The capsules are separated within the tube by approximately 23 miles (37 km) on average during operation.

b) Tube :-

- The tube is made of steel. Two tubes will be welded together in a side-by-side configuration to allow the capsules to travel both directions.
- Pylons are placed every 100 ft (30 m) to support the tube.
- Solar arrays will cover the top of the tubes in order to provide power to the system.

II. TUBE COST

The overall cost of the tube, pillars, vacuum pumps and stations is thus expected to be around $4.06 billion USD for the passenger version of the Hyperloop. This does not include the cost of the propulsion linear motors or solar panels. The tube represents approximately 70% of the total budget.

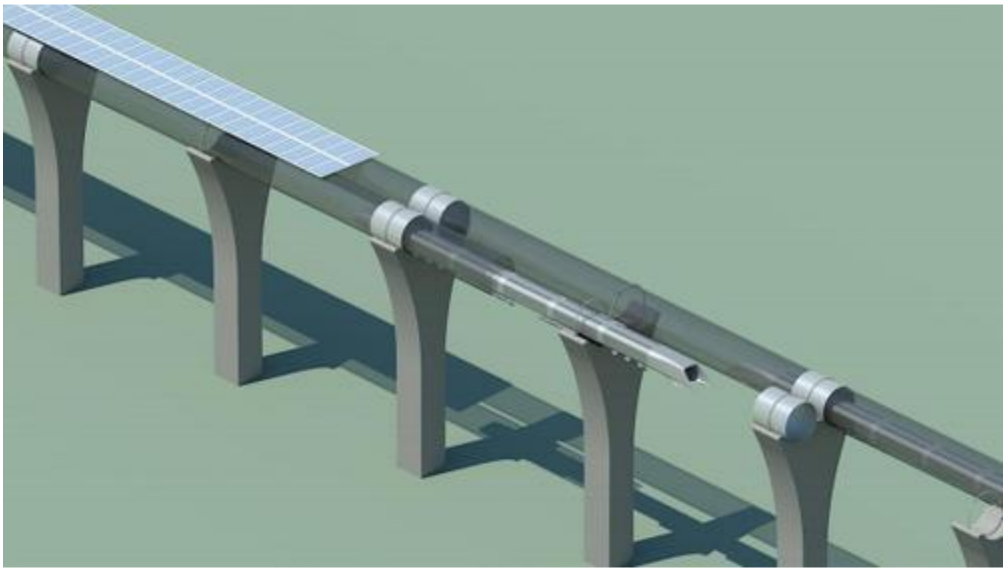
The larger 10 ft 10 in. (3.3 m) tube would allow the cargo and vehicle capsules to fit at a total cost including the tube, pillars, vacuum pumps, and stations around $5.31 billion USD. This minimal cost increase would allow a much more versatile Hyperloop system.

c) Propulsion :-

- Linear accelerators are constructed along the length of the tube at various locations to accelerate the capsules.
- Rotors are located on the capsules to transfer momentum to the capsules via the linear accelerators.

d) Route :-

- There will be a station at Delhi and Mumbai. Several stations along the way will be possible with splits in the tube.
- The majority of the route will follow I-5 and the tube will be constructed in the median.



Hyperloop structure

In addition to these aspects of the Hyperloop, safety and cost will also be addressed in this study.

The Hyperloop is sized to allow expansion as the network becomes increasingly popular. The capacity would be on average 840 passengers per hour which is more than sufficient to transport all of the 6 million passengers traveling between Delhi and Mumbai areas per year. In addition, this accounts for 70% of those travelers to use the Hyperloop during rush hour. The lower cost of traveling on Hyperloop is likely to result in increased demand, in which case the time between capsule departures could be significantly shortened.

III. CAPSULE

Two versions of the Hyperloop capsules are being considered: a passenger only version and a passenger plus vehicle version.

3.1 Hyperloop Passenger Capsule

Assuming an average departure time of 2 minutes between capsules, a minimum of 28 passengers per capsule are required to meet 840 passengers per hour. It is possible to further increase the Hyperloop capacity by reducing the time between departures. The current baseline requires up to 40 capsules in activity during rush hour, 6 of which are at the terminals for loading and unloading of the passengers in approximately 5 minutes.

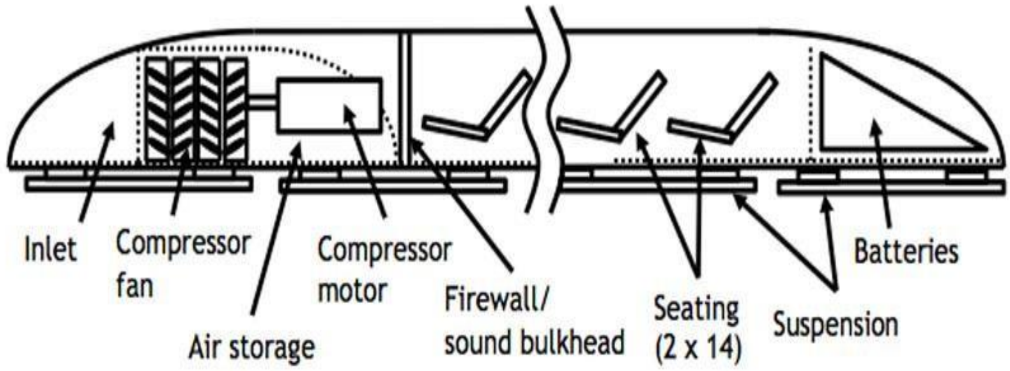
3.2 Hyperloop Passenger Plus Vehicle Capsule

The passenger plus vehicle version of the Hyperloop will depart as often as the passenger only version, but will accommodate 3 vehicles in addition to the passengers. All subsystems discussed in the following sections are featured on both capsules.

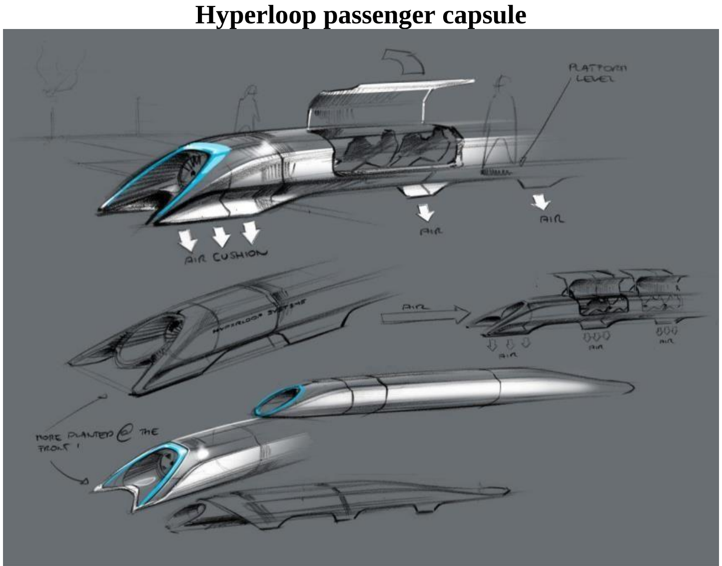
For travel at high speeds, the greatest power requirement is normally to overcome air resistance. Aerodynamic drag increases with the square of speed, and thus the power requirement increases with the cube of speed. For example, to travel twice as fast a vehicle must overcome four times the aerodynamic resistance, and input eight times the power.

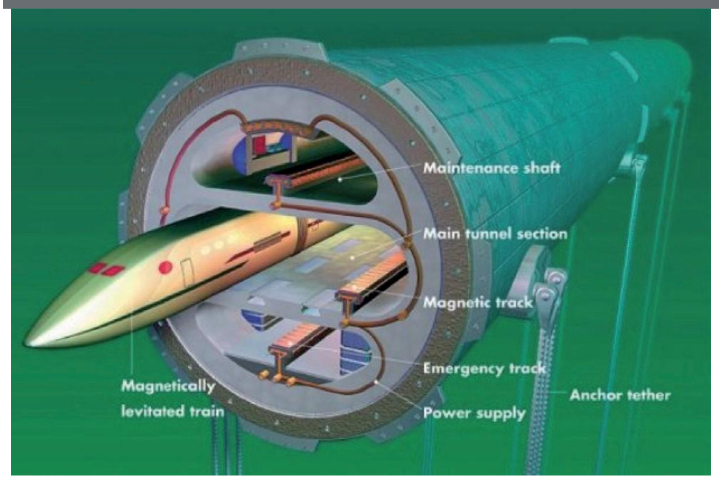
Just as aircraft climb to high altitudes to travel through less dense air, Hyperloop encloses the capsules in a reduced pressure tube. The pressure of air in Hyperloop is about 1/6 the pressure of the atmosphere on Mars.

IV. GEOMETRY



Hyperloop passenger capsule





Vacuum tunnel for Elon Musk's Hyperloop

4.1 Hyperloop Passenger Capsule

The maximum width is 4.43 ft (1.35 m) and maximum height is 3.61 ft (1.10 m). With rounded corners, this is equivalent to a 15 ft^2 (1.4 m^2) frontal area, not including any propulsion or suspension components.

The aerodynamic power requirements at 700 mph (1,130 kph) is around only 134 hp (100 kW) with a drag force of only 72 lbf (320 N), or about the same force as the weight of one oversized checked bag at the airport. The doors on each side will open in a gullwing (or possibly sliding) manner to allow easy access during loading and unloading. The luggage compartment will be at the front or rear of the capsule.

The overall structure weight is expected to be near 6,800 lb (3,100 kg) including the luggage compartments and door mechanism. The overall cost of the structure including manufacturing is targeted to be no more than $245,000.

4.2 Hyperloop Passenger Plus Vehicle Capsule

The passenger plus vehicle version of the Hyperloop capsule has an increased frontal area of 43 ft^2 (4.0 m^2), not including any propulsion or suspension components. This accounts for enough width to fit a vehicle as large as the Tesla Model X.

The aerodynamic power requirement at 700 mph (1,130 kph) is around only 382 hp (285 kW) with a drag force of 205 lbf (910 N). The doors on each side will open in a gullwing (or possibly sliding) manner to accommodate loading of vehicles, passengers, or freight.

The overall structure weight is expected to be near 7,700 lb (3,500 kg) including the luggage compartments and door mechanism. The overall cost of the structure including manufacturing is targeted to be no more than $275,000.

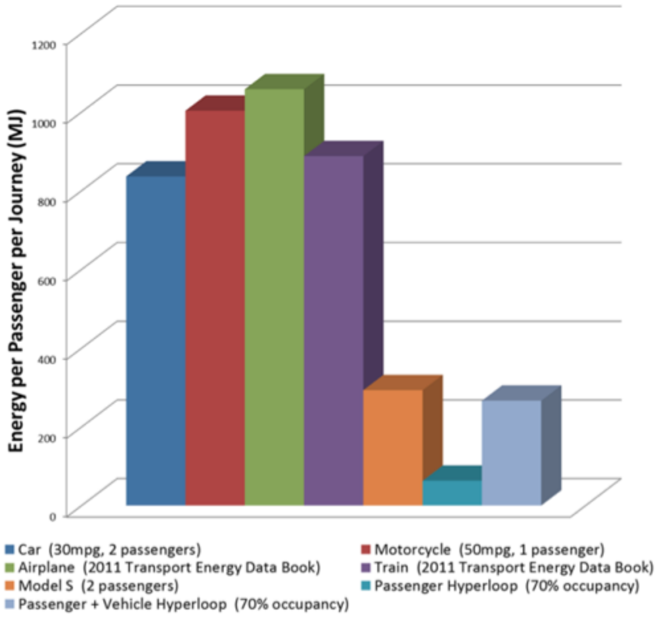


Figure-Comparison of energy expenses on one passenger for a trip to Hyperloop and other means of transport.

V. SAFETY AND RELIABILITY

The design of Hyperloop has been considered from the start with safety in mind. Unlike other modes of transport, Hyperloop is a single system that incorporates the vehicle, propulsion system, energy management, timing, and route. Capsules travel in a carefully controlled and maintained tube environment making the system is immune to wind, ice, fog, and rain. The propulsion system is integrated into the tube and can only accelerate the capsule to speeds that are safe in each section. With human control error and unpredictable weather removed from the system, very few safety concerns remain.

Some of the safety scenarios below are unique to the proposed system, but all should be considered relative to other forms of transportation. In many cases Hyperloop is intrinsically safer than airplanes, trains, or automobiles.

VI. ONBOARD PASSENGER EMERGENCY

All capsules would have direct radio contact with station operators in case of emergencies, allowing passengers to report any incident, to request help and to receive assistance. In addition, all capsules would be fitted with first aid equipment.

The Hyperloop allows people to travel from Delhi to Mumbai in 1 hour. Therefore in case of emergency, it is likely that the best course of action would be for the capsule to communicate the situation to the station operator and for the capsule to finish the journey in a few minutes where emergency services would be waiting to assist.

Typical times between an emergency and access to a physician should be shorter than if an incident happened during airplane takeoff. In the case of the airplane, the route would need to be adjusted, other planes rerouted, runways cleared, airplane landed, taxi to a gate, and doors opened. An emergency in a Hyperloop capsule simply requires the system to complete the planned journey and meet emergency personnel at the destination.

VII. POWER OUTAGE

The vast majority of the Hyperloop travel distance is spent coasting and so the capsule does not require continuous power to travel. The capsule life support systems will be powered by two or more redundant lithium ion battery packs making it unaffected by a power outage. In the event of a power outage occurring after a capsule had been launched, all linear accelerators would be equipped with enough energy storage to bring all capsules currently in the Hyperloop tube safely to a stop at their destination. In addition, linear accelerators using the same storage would complete the acceleration of all capsules currently in the tube. For additional redundancy, all Hyperloop capsules would be fitted with a mechanical braking system to bring capsules safely to a stop.

In summary, all journeys would be completed as expected from the passenger’s perspective. Normal travel schedules would be resumed after power was restored.

VIII. CAPSULE DEPRESSURIZATION

Hyperloop capsules will be designed to the highest safety standards and manufactured with extensive quality checks to ensure their integrity. In the event of a minor leak, the onboard environmental control system would maintain capsule pressure using the reserve air carried onboard for the short period of time it will take to reach the destination. In the case of a more significant depressurization, oxygen masks would be deployed as in airplanes. Once the capsule reached the destination safely it would be removed from service. Safety of the onboard air supply in Hyperloop would be very similar to aircraft, and can take advantage of decades of development in similar systems.

In the unlikely event of a large scale capsule depressurization, other capsules in the tube would automatically begin emergency braking whilst the Hyperloop tube would undergo rapid re- pressurization along its entire length.

IX. EARTHQUAKES

India is no stranger to earthquakes and transport systems are all built with earthquakes in mind. Hyperloop would be no different with the entire tube length built with the necessary flexibility to withstand the earthquake motions while maintaining the Hyperloop tube alignment.

It is also likely that in the event of a severe earthquake, Hyperloop capsules would be remotely commanded to actuate their mechanical emergency braking systems.

X. HUMAN RELATED INCIDENTS

Hyperloop would feature the same high level of security used at airports. However, the regular departure of Hyperloop capsules would result in a steadier and faster flow of passengers through security screening compared to airports. Tubes located on pylons would limit access to the critical elements of the system. Multiple redundant power sources and vacuum pumps would limit the impact of any single element.

XI. RELIABILITY

The Hyperloop system comprising all infrastructure, mechanical, electrical, and software components will be designed so that it is reliable, durable, and fault tolerant over its service life (100 years), while maintaining safety levels that match or exceed the safety standard of commercial air transportation.

XII. COST

Total cost of the Hyperloop passenger transportation system. Cost Component (million USD)

Capsule	54 (40 capsules)
Capsule Structure & Doors	9.8
Interior & Seats	10.2
Compressor & Plumbing	11
Batteries & Electronics	6
Propulsion	5
Suspension & Air Bearings	8
Components Assembly	4
Tube	5,410
Tube Construction	650
Pylon Construction	2,550
Tunnel Construction	600
Propulsion	140
Solar Panels & Batteries	210
Station & Vacuum Pumps	260
Permits & Land	1,000
Cost Margin	536
Total	6,000

Table 9. Total cost of the Hyperloop passenger plus vehicle transportation system.
Cost Component (million USD)

Cargo Capsule	30.5 (20 capsules)
Capsule Structure & Doors	5.5
Interior & Seats	3.7
Compressor & Plumbing	6
Batteries, Motor & Electronics	4
Propulsion	3

Suspension & Air Bearings	5.3
Components Assembly	3
Passenger Only Capsule	40.5 (30 capsules)
Capsule Structure & Doors	7.4
Interior & Seats	7.6
Compressor & Plumbing	8.2
Batteries, Motor & Electronics	4.5
Propulsion	3.8
Suspension & Air Bearings	6
Components Assembly	3
Tube	7,000
Tube Construction	1,200
Pylon Construction	3,150
Tunnel Construction	700
Propulsion	200
Solar Panels & Batteries	490
Station & Vacuum Pumps	260
Permits & Land	1,000
Cost Margin	429
Total	7,500

XIII. CONCLUSION

A high speed transportation system known as Hyperloop has been developed in this document. The work has detailed two versions of the Hyperloop: a passenger only version and a passenger plus vehicle version. Hyperloop could transport people, vehicles, and freight between Delhi and Mumbai in 1 hour. Transporting 7.4 million people each way every year and amortizing the cost of $6 billion over 20 years gives a ticket price of $20 for a one-way trip for the passenger version of Hyperloop. The passenger only version of the Hyperloop is less

Than 12% of the cost of the proposed passenger only flight system between Delhi to mumbai.

An additional passenger plus transport version of the Hyperloop has been created that is only 25% higher in cost than the passenger only version. This version would be capable of transporting passengers, vehicles, freight, etc. The passenger plus vehicle version of the Hyperloop is less than of the cost of the proposed passenger only air travel system between Delhi to Mumbai. Additional technological developments and further optimization could likely reduce this price.

The intent of this document has been to create a new open source form of transportation that could revolutionize travel. The authors welcome feedback and will incorporate it into future revisions of the Hyperloop project, following other open source models such as Linux.

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