HYPERLOOP TRANSPORTATION SYSTEM

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Abstract – Hyperloop system works on the principle of electromagnetic attraction forces. In this system, levitation, propulsion and controlling of the pod occur using both electromagnetic and permanent magnets. The Hyperloop system is expected to be established between the two metropolitan cities, Los Angeles and San Francisco. This is an ultrahigh speed transportation system in a vacuum medium with reduced air resistance and pressure.
Keywords – Hyperloop transportation system, Ultrahigh speed vacuum train, synchronous motor, levitation. Electromagnet, permanent magnets, de-pressurization.

1. INTRODUCTION

This is an ultrahigh speed transportation system introduced by Elon Musk on 12th August, 2013. This transportation system means to transport passengers in California (USA) between San Francisco and Los Angeles. In this system, there is going to be a capsule that will travel inside a tube at the speed of 1220 kmph and will cover the distance of approximately 561 kilometers in 30 minutes.

This ultrahigh speed transportation system is called the Hyperloop System and its popularity has resulted in the construction of such systems in many countries.
Although this hyperloop design was initially conceptualized by Elon Musk in 2012, Later it was released to the public as an open source. Many countries are currently involved in the design and production of the pods as well as the vacuum tubes, Virgin Mobile Hyperloop One's design is noticeably superior (Hyperloop One, 2019). Many Competitors, small scale industries and university students are also pursuing to create the hyperloop design successfully. However, the real challenge is creating a test track of significant length that could ensure that the prototype pods will reach the desire maximum speed of 760mph (SpaceX, 2013). Currently Virgin Mobile has achieved the highest pod speed which is nearly 240mph (Hawkins, 2017).

2. DESIGN STRUCTURE

At its core, Hyperloop is all about removing the two things that slow down regular vehicles: friction and air resistance. To do away with the former, you make the pod hover above its track
The Hyperloop consists of several distinct components, including:
Capsule:
Sealed capsules carrying 28 passengers each that travel along the interior of the tube depart on average every 2 minutes from Los Angeles or San Francisco (up to every 30 seconds during peak usage hours).
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.
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

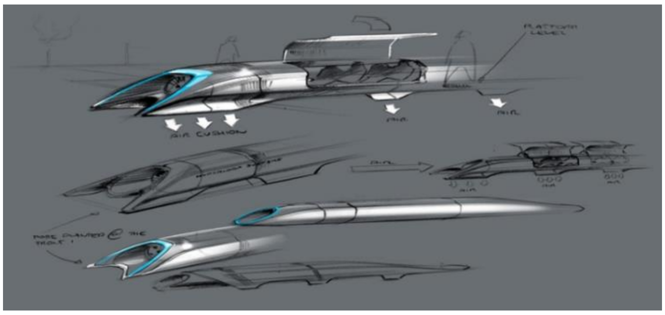
3. CAPSULE

Two versions of the Hyperloop capsules are being considered: a passenger only version and a passenger plus vehicle version. 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.
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
The vehicle is streamlined to reduce drag and features a compressor at the leading face to ingest oncoming air for levitation and to a lesser extent propulsion. Aerodynamic

simulations have demonstrated the validity of this 'compressor within a tube' concept

The interior of the capsule is specifically designed with passenger safety and comfort in mind. The seats conform well to the body to maintain comfort during the high speed accelerations experienced during travel. Beautiful landscape will be displayed in the cabin and each passenger will have access their own personal entertainment system.

The passenger capsule power system includes an estimated 5,500 lb (2,500 kg) of batteries to power the capsule systems in addition to the compressor motor (using 3,400 lb or 1,500 kg of the batteries) and coolant. The battery, motor, and electronic components cost is estimated to be near $150,000 per capsule in addition to the cost of the suspension system. The passenger plus vehicle capsule power system includes an estimated 12,100 lb (5,500 kg) of batteries to power capsule systems in addition to the compressor motor (using 8,900 lb or 4,000 kg of the batteries) and coolant. The battery, motor and electronic components cost is estimated to be near $200,000 per capsule in addition to the cost of the suspension system.



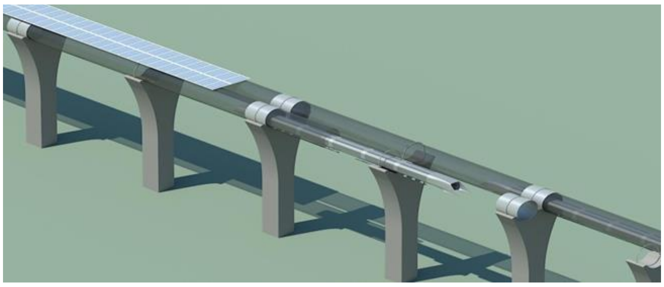
4. TUBE

The main Hyperloop route consists of a partially evacuated cylindrical tube that connects the Los Angeles and San Francisco stations in a closed loop system. The tube is specifically sized for optimal air flow around the capsule improving performance and energy consumption at the expected travel speed. The expected pressure inside the tube will be maintained around 0.015 psi (100 Pa, 0.75 torr), which is about 1/6 the pressure on Mars or 1/1000 the pressure on Earth. This low pressure minimizes the drag force on the capsule while maintaining the relative ease of pumping out the air from the tube. The efficiency of industrial vacuum pumps decreases exponentially as the pressure is reduced, so further benefits from reducing tube pressure would be offset by increased pumping complexity

The Hyperloop travel journey will feel very smooth since the capsule will be guided directly on the inner surface of the tube via the use of air bearings and suspension; this also prevents the need for costly tracks. The capsule will bank off the walls and include a control system for smooth returns to nominal capsule location from banking as well. Some specific sections of the tube will incorporate the stationary motor element (stator) which will locally guide and accelerate (or decelerate) the capsule.

The stations are isolated from the main tube as much as possible in order to limit air leaks into the system. In addition, isolated branches and stations off the main tubes could be built to access some towns along the way between Los Angeles and San Francisco. Vacuum pumps will run continuously at various locations along the length of the tube to maintain the required pressure despite any possible leaks through the joints and stations.

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.



5. PROPULSION

The propulsion system has the following basic requirements:

- Accelerate the capsule from 0 to 300 mph (480 kph) for relatively low speed travel in urban areas.
- Maintain the capsule at 300 mph (480 kph) as necessary, including during ascents over the mountains surrounding Los Angeles and San Francisco.
- To accelerate the capsule from 300 to 760 mph (480 to 1,220 kph) at 1G at the beginning of the long coasting section along the I-5 corridor.
- To decelerate the capsule back to 300 mph (480 kph) at the end of the I- 5 corridor.

6. TECHNOLOGY INVOLVED

Elon Musk made the concept of Hyperloop open to all stating that he himself is too busy to work on this concept till then two companies are working on this design virgin Hyperloop one and HTT(Hyperloop Transformation Technologies) where virgin decided to stick to the basic idea of Hyperloop as envisioned by Musk is that the passenger pods or capsules travel through a tube, either above or below ground. To reduce friction, most -- but not all -- of the air is removed from the tubes by pumps. In musks idea only about one sixth of air pressure will be present this means an operating pressure of 100 pascals, which reduces the drag force of the air by 1,000 times relative to sea level conditions, and would be equivalent to flying above 150,000 feet.

But HTT came up with their own idea which is slight different from the original that in place of using air pressure like air hockey they will use two sets of magnets: one set to repel and push the train up off the track, and another set to move the elevated train ahead same as maglev.

As for air resistance, that's where the tube comes in. (Yes, tubes also just feel like the future, but that's not the point.) The tubes enclose the space through which the pods move, so you can use vacuums to hoover out nearly all the air—leaving so little that the physics are like being at an altitude of 200,000 feet. And so, like a cruising airplane, a hyperloop needs only a little bit of energy to maintain the pods' speed, because there's less stuff to push through.

7. COST

The cost consists of overhead cost, capital cost and operational cost. The operational costs are the cost of maintenance of vehicles and infrastructure, and the cost related to operation of the vehicles and stations. The capital cost are for building the infrastructure that is tracks, stations and for purchasing the vehicles. The overhead cost leads to the capital and maintenance cost of the real estate, and the staff costs.

The cost level is defined by the cost value, currency, and the time.

a) Capital cost for building tracks

The capital cost for building 1 km of tube is likely to depend largely on the local conditions. Building in an empty area on flat sandy soil will be cheaper than building in a highly urbanized area, or in mountains. The need to build tunnels or crossing the wide rivers will increase the costs. Elon Musk has estimated the costs of tubes on pylons and tubes in tunnels amounted €10.3 million/km and €34.0 million/km, respectively.

b) Capital cost for building stations

The building costs for a station were estimated to be about 125 million $US. The costs for the two stations of the current Maglev line near Shanghai could be 130 million US$ for two station, The Hyperloop system's stations are more complex than that of the Maglev system because they should give access to vehicles in the evacuated tubes .Therefore, it is assumed that the cost per station of the Hyperloop system of €116 million is a fairly good estimate.

c) Cost of Capsule

The costs for purchase of a capsule were estimated to be about €1.42 million. This is the cost of a capsule without toilets. Adding a toilet is supposed to increase the costs to about €1.52 million.

d) Maintenance cost of infrastructure

The maintenance costs of the Hyperloop tubes , stations, and rolling stock, a fixed ratio to the capital costs is assumed. The World Bank states that the variable component of rail infrastructure cost can vary from just a few percent to about 30% depending on the intensity of use. The Hyperloop system is assumed to be heavily used, leading to relatively high maintenance cost, but the ratio to the capital cost will be smaller than for rail because of the lack of physical contact between the vehicles and the infrastructure. Consequently, the ratio of 10% is assumed for both infrastructure and vehicles setting the annual maintenance costs at 10% of the annual capital costs.

e) Operating Costs

The operating costs consist of the costs for staff in the vehicles and at the stations, and the traffic management costs. The costs for employees in the vehicles and stations depend on the organization, i.e., the number of employees in the vehicles, and manpower needed for ticket sales and control. In the present context, it is assumed that in each capsule one employee is present checking the seat belts, helping in the case of problems, and possibly providing some food and drink. The staff at stations would include two employees per station controlling and possibly selling tickets, and helping and guiding passengers. Assuming that the average operation time of a capsule is 15 h/day, that stations are opened for 18 h/day, and that the average working time of an employee is 7 h/day , Assuming an average annual wage of €35,000, the annual operation cost for one capsule would be €75,000 and for a station €180,000. These costs appear to be relatively small compared to the capital cost. The traffic management costs depend on the intensity of use. It is assumed that these costs are equal to the wage of one employee for each 1000 km of 'double tube'. Assuming an operation time of 18 h per day, 257 full employees are needed per 1000 km of the line/tube. The relating annual costs would be €90/km.

f) Overhead Costs

The overhead costs include the capital and maintenance cost of real estate, and the staff costs. In the present situation, it is assumed that the real estate costs are marginal compared to the capital and maintenance costs of the Hyperloop infrastructure. As such they are neglected. As far as the staff costs, these costs are included by increasing the costs of operational staff for 10%.

Cost element	Unit	Investment cost	Maintenance cost	Operating and overhead cost	Total cost
Track infra					
- Solid soil	Km	917,000	91,700	100	1,010,000
- Weak soil	Km	1,280,000	128,000	100	1,410,000
- Tunnel	Km	2,570,000	257,000	100	2,820,000
Station	Station	4,640,000	464,000	200,000	5,300,000
Capsule	Vehicle	580,000	58,000	82,500	716,000
	Seat[a)]	21,000	2100	3000	26,000
	Seat-km[b)]	0.006	0.0006	0.0009	0.008

[a)]Seat capacity: S = 28 seats/capsule
[b)]Seat capacity: S = 28 seats/capsule; Average speed in operating period: 600 km/h; Operating time: 15 h/day

8. DISADVANTAGES

- The high speed of the container which is nearly equal to the speed of sound may make discombobulating in the travellers that venture out because of vibrations and jarring.
- To set up the venture, initial cost is very high. The production of long vacuum chambers requires progressively stabilized abilities. Keeping this is also a hazard and exorbitant.
- The undertaking organization will have to worry about the land use rights.
- It will be life threatening if some faults occur in the framework.
- There will be restricted space in the train and consequently individuals won't be able to move freely.
- The track of Hyperloop innovation may get ruined because of the steel that is used in the tracks which extends and changes shape when outside temperature is changed. So, this is a factor that should be considered while planning the framework dependent on the area's condition where it is being conveyed.
- The establishment would require the cutting of substantial number of trees which is a great misfortune.

9. SAFETY AND DEPENDABILITY

ON BOARD TRAVELLER CRISIS

There will be direct radio contact in all containers with the station administrator, enabling travellers to report any mishappenings and to get help in case of crisis. What's more is that all the cases would be fitted with emergency treatment hardware.

POWER BLACKOUT

It will be fuelled with two repetitive lithium particle battery packs which would make it unaffected by power blackouts.in case blackout happens after a case has been propelled, every direct quickening agent would be furnished with enough vitality stockpiling to bring all cases at present in the Hyperloop tube securely to a stop at their goal.

CAPSULE DEPRESSURIZATION

Trustworthiness of the capsules will be maintained as they will be subjected to various security benchmarks. In case of a minor release, the installed ecological control framework would keep up container weight utilizing the saved air conveyed locally, available for the brief timeframe that it will take to achieve the goal. The available Hyperloop would be fundamentally the same as air ship and will be able to exploit many years of advancement in comparable framework.

CAPSULE STUCK IN CYLINDER

An exceptionally impossible situation would be a case getting stranded in the Hyperloop tube. In event that the container was stranded in some way, the cases ahead would continue unaffected to the destination ahead. Containers behind would automatically be educated to send their mechanical crisis slowing mechanisms. When all the containers behind the stranded case had been conveyed to rest, cases will drive themselves to well being utilizing little electronic engines installed to control sent engines.

STRUCTURAL TRUSTWORTHINESS

Minor cylinder depressurization probably won't have much effect on the Hyperloop container or the travellers but would certainly be affected by expanded vacuum siphon control. Minor cylinder holes could then be fixed amid standard support.

EARTHQUAKES

Hyperloop framework would stay same with the whole cylinder length working with fundamental adaptability to withstand the quake movements while keeping the tube arrangement in its place.

HUMAN RELATED OCCURENCES

Hyperloop would feature the same abnormal amount of security as that utilized at air terminals. The ordinary take off of the Hyperloop would result in a quicker and steadier traveller stream through security screening. Cylinders at arches would confine access to the basic components of framework. A number of repetitive power sources and vacuum siphons will restrict the effect of a single component.

RELIABILITY

The Hyperloop framework including all mechanical, electrical, foundational, programmed parts will be planned with goal that it is solid, dependable, and blame tolerant over its administration life which is 100 years, while keeping up with the well-being levels that coordinate the security standards of air transportation business.

10. IMPACT OF HYPERLOOP

Since this is a huge project, and requires lots of human force and lands too, it is going to have a great impact on the human lives here. Most importantly, it would help the citizens here only if it was made affordable or reasonable to travel via the Hyperloop. Building the infrastructure is going to be expensive. But once the Hyperloop network is in place it is going to be a different story. Hyperloop uses vacuum and magnetic levitation to get high speeds. So, the energy consumption is very low compared to other faster modes of transport like bullet trains or aircraft. The maintenance cost of Hyperloop pod is low as there is no mechanical contact happening real-time. This means there will be less wear-and-tear due to friction. Also, the pods are weather-proof.

11. THE SCOPE OF HYPERLOOP

India is the seventh largest country and second most populous and it houses almost 1.3 billion people India is currently one of the fastest growing economies in the world. Hyperloop could definitely be a worthy leap to be taken in the Transportation sector in the nation. Currently, the fastest train which runs in India is at around 100mph (160 km\h). This clearly explains how much time the Hyperloop would be saving for the people of this country. Several Hyperloop companies have already been in talks with the Indian Government and some routes have been proposed too for immediate implementation of this in India. Since this would reduce the travel time between two cities drastically at a reasonable price, this would open opportunities for people to reside in one city and work in another. Hyperloop, the 5th mode of transport, would be the solution to bridging the gap between the large population and the lack of existing infrastructure. It is rightly said that India has more scope for urban transport than the UK, given the current challenges it is facing in terms of transportation.

12. CONCLUSION

After seeing all the benefits and features that Hyperloop will have to offer it is easy to stay they Hyperloop is one of the greatest and innovative advancement In science as well as transport sector. It does hold the features to become one of the necessity in the future giving people some extra time is a great deal which Hyperloop does deliver but it still does have some improvements still to be made the passenger is capacity is still very low and the routes are fixed and access only few places. Consequently, the investment costs of HL infrastructure make up a large part of the total costs per seat-kilometer, raising the latter to a higher level than those of its counterparts – HSR and APT. Hence, the break-even fares would also be higher, even if the load factor is relatively high. This finding suggests that HL-application may be limited to the premium passenger In comparing the Hyperloop with the railway and airways system, it has been found that the Hyperloop system has relatively positive social/environmental performances, particularly in terms of the energy consumption, emissions of GHGs, and noise. The Hyperloop system can potentially be a very safe mode

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