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Review Article

Advance in Environmental Waste Management & Recycling

HYPERLOOP – The Sustainable Transportation

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Abstract

Due to rapid urbanization and emergence of mega-cities, urban transportation infrastructures are stressed leading to traffic congestion, high fuel consumption as well as increasing number of accidents and fatalities. Present transport sector globally is largely two-dimensional and may not be able to cope up with the growth of cities which is three-dimensional in nature, the environmental pollution, the traffic congestion, the sustainability, etc. This has led to efforts towards three dimensional transportation systems such as passenger drones, flying cars, cars moving through multi-layer underground tunnels etc. The overall concept of three-dimensional transportation demonstrates that the transportation sector has made a significant progress towards comprehending the necessity of a proper and sustainable transit system, which otherwise has implications on environment, health, infrastructure and sustainability as well. However, some of these futuristic options may be associated with safety and security concerns – both for them, as well as caused by them. Some of these options envisage utilization of artificial intelligence and even augmented reality. Technological challenges, the potential for cost-effectiveness, and their socio-economic impacts are also important considerations. Through deep and critical study, in this journal, the author will try to analyze the concept of hyper loop and its practicality; about its various components, its working, global acceptance of hyper loop and its possible advantages and unaddressed issues. Some critics are of the opinion that hyper loop is more of a hypothetical idea which is totally impractical and impossible, but optimistic experts say that it just needs some hard work, a decade's time and huge amount of money which would then result in revolution of the whole transportation system in a unique, unpredictable and sustainable way. A cross-impact analysis to evaluate possible future scenario for this will also be taken up.

Keywords: Urban, Hyperloop, Tunneling, Boring, Sustainable, Transportation, 3-Dimensional transportation, Elon Musk, Environment

Hyperloop

Looking at the present scenario all around the world, transportation system has tended to become more of vehicle dominated with preponderance of personalized modes of transport, sacrificing sustainability in both developed as well as the developing world. Particularly in developing countries, cities are experiencing a massive urbanization and the economic diversification resulting in growth of transport related challenges including pollution, accidents, congestion, decline in public transport, environmental degradation, climate change, loss of precious man hours, and depletion of energy resources and lack of accessibility for urban poor. It is reducing the efficiency of the prevailing transport system through stasis of mobility and costly travel. Recognizing the fact, there is a growing need felt for a carefully viable and sustainable transportation system to mitigate the existing urban ills and cope up with the aggravating emerging challenges. For purposes of economic considerations and social significance there is dire need to innovate, plan, design and invest in the transport infrastructure to obtain functional and sustainable urban development. Since transport is a key sector, plays a very vital role in the overall development of the nation by providing people access to educational centers, markets, creating employment, recreation, health care, work centers and other key services. In most of the developing cities, the transportation system seems to be way too far away from what is ideally required for proper functioning and stimulating development. To make the cities livable, people around the world are probing, innovating and presenting new ideas, on how to give a right direction to the urban transportation system and explore a way forward for more sustainable and resilient future. One such innovative idea for meeting the future requirements of city transport given in 2012 by Elon Musk is of Hyperloop.

According to Elon Musk, hyperloop is a high speed, underground transportation system which can travel hundreds of miles in less than sixty minutes (Dubai to Abu Dhabi, 86.6 miles in 12 minutes; Mumbai to Pune, 100 miles in 25 minutes). The basic reason for coming up with the idea of hyperloop was to alleviate the traffic of the city which has otherwise been a serious concern for urban administrators and city planners.

Hyperloop is a train 'car-style' pods moving in a vacuum tube with very less air at a speed of 700 mph. The whole system in the tube is almost frictionless and the movement of the pods is propelled with

the help of electric propulsion, which does not necessitate use IC engines. The tubes will be present in the tunnels that will be bored underneath the cities in open or underlying the city infrastructure. Inside a hyperloop, there is a pump system present which time to time reduces the pressure inside the tunnel so that the pods can move at a faster speed without any interruption. Since hyperloop will be an underground transportation system, unlike subways it would not require large stations, but would have almost thousands of small stations, sizing a single car parking which will take the travelers close to their destinations, otherwise a main reason for peak hour jams in most of the cities especially in megacities.

Hyperloop was initially being introduced for the public mass transit, but the Elon Musk announced that he would like to prioritize pedestrians and cyclists (personalized mass transit) over cars at first because one must be fairer with everyone. The introduction of hyperloop is expected to revolutionize not only the transportation system but also the urban and regional commuting and travel patterns. It can also benefit freight transportation causing less damages and pressure on the infrastructure. Introduction of hyperloop transit in any city would also attract high-tech companies to that region stimulating economic growth momentum with cumulative causative effects on other sectors. The design of tunnel for the hyperloop would be such an entry and exits that it will encourage more vehicles than regular subways to depart. The pods are to be designed in such a way that they can easily speed up inside a tube at a maximum speed of 760 mph levitated by compressed air without sacrificing the passenger safety and convenience.

Hyperloop as a transportation system can help in connecting the economic regions which otherwise have been lacking transportation connectivity and economic development. Thus, it can restore the balance to the economy and take prosperity to the inaccessible areas, less developed resourceful region and in the process harmonize the growth and development in the country.

According to Elon Musk, to solve the everyday traffic mess it is important that the roads must be 3 dimensional i.e. tunnels must be present or the sky buses and flying cars. Since the issue with flying cars and sky buses is that they create noise, depend on weather and sometimes there is increase in anxiety levels while travelling. Therefore, Elon Musk prefers the tunnel. To achieve the proposed goal, Elon Musk established a company, The Boring Company, which would bore the tunnels at low cost and high speed. The main aim of this boring company is 'high tunneling speed and low cost by a factor of 10 or more'. The tunnels dug out in less time and less cost will according to Elon Musk, make hyperloop viably adoptable and would enable rapid travel even in densely populated areas with greater efficiency. The main benefits of tunnels, according to Elon Musk, are:

- There is no practical limit to how many layers of tunnels can be built, so any level of traffic can be addressed.
- Tunnels are weather independent with almost no noise.
- Construction and operation of tunnel are silent and invisible to anyone on the surface. Thus, there is no transportation mess on roads.
- Tunnels don't divide communities with lanes and barriers and avoid urban physical astigmatism/eyesores.

Critical Technologies for Hyperloop

There is a requirement of various latest technologies to meet up the demands and expectations of a Hyperloop. Various technologies have a critical role to play in various aspects of the Hyperloop. Below are given the most important technologies which will make Hyperloop one of the most sustainable, fastest and cheapest means of transit:

1. Cost Reduction of Tunneling

The technique to optimizing the cost of tunneling, according to Elon Musk, is to reduce the tunnel diameter. The standard diameter for a one-lane tunnel is about 28 feet. But by using the vehicles on a stabilized electric skate, the diameter of tunnel can be reduced to less than 14 feet. The reduction in diameter to half will bring down the tunneling costs by 3 to 4 times.

2. Speedy Tunnel Boring

Normally the Tunnel Boring Machines (TBM) are super slow. It is said that a snail is effectively almost 14 times faster than a soft-soil TBM. The goal of Elon Musk's 'The Boring Company' is to defeat the snail in a race.

3. Disaster Resistant Tunnels

It is a known fact that when tunnels are designed properly, they are one of the safest places to be during disasters like earthquake, floods, land subsidence etc. due to the way P and S waves propagate. Looking into the structural safety perspective, tunnels normally are bored out uniformly with the ground, unlike the surface structures making them earthquake resistant. Additionally, a large amount of earthquake damage is caused by falling debris, which will not happen inside tunnels. Some major examples are: In 1994, during Northridge Earthquake, no damage was reported to LA Subway tunnels; In 1989, during Loma Prieta (Northern California) Earthquake, no damage was reported to tunnels which were then used to transport rescue personnel; In 1985, during Mexico City Earthquake, no damage was reported to tunnels, which were then used to transport rescue personnel. Urban flooding is a recurrent phenomenon in the country due climate change, has also to be taken care to avoid damages to the system and its operation.

4. Use of Linear Induction Motor in Hyperloop

Linear induction motor is basically a rotary motor that has been cut and unrolled to generate the linear motion, instead of rotary motion. It consists of two parts, the primary and secondary, which interact with one another only when power is applied. Either the primary or the secondary can be fixed while the other moves. One of the important uses of linear induction motor is said to be hyperloop. Hyperloop incorporates reduced pressure tubes, pressurized pods, linear induction motors, and air compressors. Linear induction motors will be used to propel, accelerate and decelerate the pods through the tubes. These motors are reversible, so the same motor that propels the pod in one direction down the track can propel the pod back to where it started. The main propulsion in the pods will come from a series of linear induction accelerators placed at intervals along the length of tube. Musk chose linear motor over the permanent magnet motor because of the lower material costs, i.e. the rotor in linear motors can be a simple, lightweight, made of aluminum and no magnets are needed. In addition to it, the lateral force exerted by the stator is just 13 N/m which is inherently stabilizing, simplifying the problem of keeping the rotor aligned in the motor's air gap.

5. Effectiveness of Hyperloop over Subways

One of the most important differences between the hyperloop and subways is that it moves over the electric skates. Electric skates

are faster than the conventional subway cars which are expected to provide it the speed and efficiency. These are said to be autonomous vehicles. And to add to it, hyperloop is an express public transit system where passengers travel directly to their destination without stopping. Therefore, unlike subways/trains, hyperloop is more advantageous for unidirectional destination-oriented transits.

6. Use of Electric Skate

An electric skate is like a platform on the wheels propelled by multiple electric motors and in case of hyperloop will be propelled by linear induction motors. In hyperloop, electric skate need be used for purposes of reduction in tunnel diameter, to obtain and streamlining system operations benefits like:

- **More safety.** A fully stabilized automatic vehicle has no chance for human error and can swerve off-course i.e. Hyperloop can move off from its original route, possibly to avoid a collision.
- **High speed.** The controlled automatic skate allows for the speed of 125 - 150 miles per hour in urban transits.
- **Multiple payloads.** The electric skate can help in transit of people (mass transit), goods and/or automobiles.
- **Reducing hazardous emissions.** Electric skates are non-emissive vehicles, and therefore do not release hazardous gases like internal combustion engine cars do.

7. Fire Safety Measures

The chance of hyperloop catching fire is very low because in the system, tunnel lining is non-flammable i.e. made up of concrete and in it no flammable materials, like asphalt, are added. Moreover, there is no live electric (third) wire, which minimizes the potential fire sources. According to Elon Musk, even if in the most unlikely case, a fire breaks out, the ventilation system provided will remove the smoke to allow safe passengers evacuation.

8. Process Evacuation

Like every other modes of travel, hyperloop will also have emergency exits along the tunnel route. In an emergency or in a disabled skate scenario:

- The original travel route system will stop, and the skates will automatically transport people away from the place of accident and then out of the tunnel through the nearest emergency exit.
- In the cases where movement of skate will not be possible due to demobilization, passengers will exit the skate and walk to the nearest emergency exit by following the hyperloop's emergency path lighting. The effective emergency walkway is extremely wide.
- Since there are no tunnel hazards in hyperloop, there is nothing a passenger can touch which would hurt them. In any case, if a passenger needs to pass a disabled skate, the forward and rear doors of the skate open to allow passengers to pass through the skate via foot or wheelchair. In the most unlikely case, if the mechanical doors fail, each skate will have a deployable platform to allow both pedestrian and wheelchair access to the side of the skate.

9. Avoidance of Congestion at Entry and Exits

In a hyperloop, there is no upper limit to the number of stations that should be built along the route because the proposed stations are as small as a single parking space. Each station will have a bank of elevators, but the number of elevators depends on the area of land available. The electric skates will descend into a tunnel offshoot before quickly merging into the tunnel network.

Since stations are very small, they can be easily categorized into busy city-centers, residential communities, recreational centers, institutions, hospital or any location along the tunnel route that can accommodate a single parking space. The high density of stations will help reduce congestion by distributing traffic across many access points and by providing more convenient entrance and exit locations.

10. Problems of Urban Tunneling

Before tunneling any urban area, there are some special requirements that are to be met. One such requirement is that while tunneling, the ground surface must remain undisturbed which means that ground subsidence must be avoided at all cost to avoid damages to the standing infrastructure and avoid cost escalations. The conventional urban tunneling in soft ground is done by maintaining the soil pressure during and after the tunnel construction. The only place where it is difficult to do this is some varied strata (e.g., boring through a region where the upper portion of the tunnel face is wet sand and the lower portion is hard rock). Other requirements include getting the government permit for boring, the land acquisition, ensuring people that tunneling is totally safe, etc.

Advantages & Issues

Advantages

Introduction of hyperloop can be a blessing to the urban transportation system because has a large number of advantages. Some of the main advantages are given below:

1. Since this mode of travel is very fast, the transit speed will increase at a very high rate.
2. There will be a great reduction in travel time.
3. It is said that the boring of tunnel for the movement of tube will be done at fast rate with low cost because of the technology being used.
4. There will be reduction in the emission of Green House Gases.
5. Hyperloops will not only develop the transportation sector but it would also help in the diversified development which means it would develop the transportation sector, economy of the region, economy of the rural area nearby, the travel time, easy connectivity, etc.
6. Introduction of hyperloop would not only improve the accessibility but it will also increase the property value.
7. Since hyperloop would shrink the travel time substantially, urban planning would become more like regional planning because hyperloop enables commuting and travel patterns to develop on region basis. Thus, would force planners to plan on regional scale as well.
8. It will help in boosting the rural economy as it could easily connect the far-flung areas to the urban cities.
9. Compared to other modes of travel, it is said to be of faster, safer, low cost, more convenient, and immune to all kind of weathers, sustainably self-powering, earthquake resistant and non-disruptive.
10. Since no IC engines are used, there is no usage of fuel; therefore pollution is not possible.
11. It is said to blend in with the transportation system very easily.
12. It would clear out the urban spaces for people which could then be used for other purposes.
13. This can be one of the best possible solutions towards sustainable transportation.

Issues

Along with the advantages there are certain inherent disadvantages and as such a rational and pragmatic approach needs to be adopted while implementing the technology. Since hyperloop is an idea that involves all the latest technologies, the project till date is at the initial stage only, even after the prototype testing at Nevada Desert, which involved the testing of track, proprietary levitation, propulsion, vacuum control technologies, etc. There are some of the serious cons of the hyperloop. Some of the disadvantages are given below:

1. Even though it is said to be cost effective, the capital investment will be a very huge amount because of the design of tube and pods, the boring of tunnel technology and the other controlling technologies would be costly. This can later, at the time of travelling in Hyperloops increase the travel cost.
2. The cost of land, compliance and construction also adds to the initial investment. The construction of infrastructure for such a project at competitive cost will be no less than any challenge.
3. Because of over optimistic nature of various people working on the idea, there is no accurate understanding of the project.
4. Operation and maintenance cost of hyperloop is very high.
5. It is important to know that if ever 1 pod got stuck in the tube; rest of thousands of pods will also get stuck up causing trouble and inconvenience to everyone.
6. The capacity of hyperloop is not known.
7. No statement, about how comfortable the hyperloop will be, has been issued.
8. Procurement of the land for tunnel boring is also a big issue.
9. Network of intercity hyperloop tubes working with high speed electromagnetic sleds and a separate intra-city transport system will surely be a massively complicated concept.
10. Some experts say that hyperloop is not in any condition going to reduce the average travel time because need for high quality and increased level of infrastructure, it would not in true sense reduce travel time and cost. The concept project of hyperloop has been assumed to be wildly hypothetical because of inflexibility of length change.
11. Electric/Magnetic propulsion + Vacuum tubes/Less air tubes = Insane speed at very low cost. This seems to be a vague concept because the material required for the same, the machines, the pumps etc., would significantly add to the overall cost of the project.
12. This type of transportation system requires a permit/EIA/SWOT studies in any case because:

a. It uses the public right of way.
b. Boring tunnels under private property without permission is also not allowed.
c. If the project is poorly designed and at any point of time there is any casualty, it can then further help in legal procedures.
d. impact of socio-economic life of urban centers is going to be calamitous in nature,

13. The technology of hyperloop has been declared yet unproven/unestablished technology because it was anticipated to have a minimum speed of about 700 mph, but the test system had the speed of only 70 mph and desired targeted speed is yet a milestone to be achieved.
14. The concept of firing the bullet shaped pods of human and freight at 700 mph in a frictionless and nearly vacuum tube seems like an imaginary situation because arises cognitive questions of 'How will the pod stop at the accurate position as it is propelling at a very high speed?'
15. Hyperloops are said to be unfit for humans, be in underground or above the ground because the pressurized, airless/vacuum tubes can cause nausea, breathing problem, vomiting and claustrophobia.
16. If there is some accident inside the tube, whole system will become useless and stagnant. If there is a crack in the tube, exposure to atmosphere or a blast due to any reason inside the tube or hyperloop, the human present in the system will turn to jelly because of the air pressure difference.
17. Even if it won't work for humans; for freight, it would easily work but there seems no advantage in doing that as well because there is no clear solution given on how to carry the shipment to their destination.
18. Experts express reservations that the costs of land acquisition, boring, construction of infrastructure and the machinery will be so high that the total cost for hyperloop for the distance of one mile won't be any less than $ 9 billion, when the tunnel is totally straight and may make implementation of the system a financially costly and investment intensive for urban local bodies.

Hyperloop technology offers opportunities to redress the ailing urban transport sector. It also throws up global challenge due requirement of high level technological inputs. Some are comparing it to interstate highway system; some believe the concept is more hypothetical and seemingly mythical. But the optimists say that it may take some hard work, time and heavy investment to realize and demonstrate that concept is going to be workable and bankable solution to the most daunting and vexing transport problems. Once successfully implemented, it may revolutionize the urban life, transportation planning, urban planning, urban development, and will act as a catalyst for the diffusion of benefits of development and economic prosperity.

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