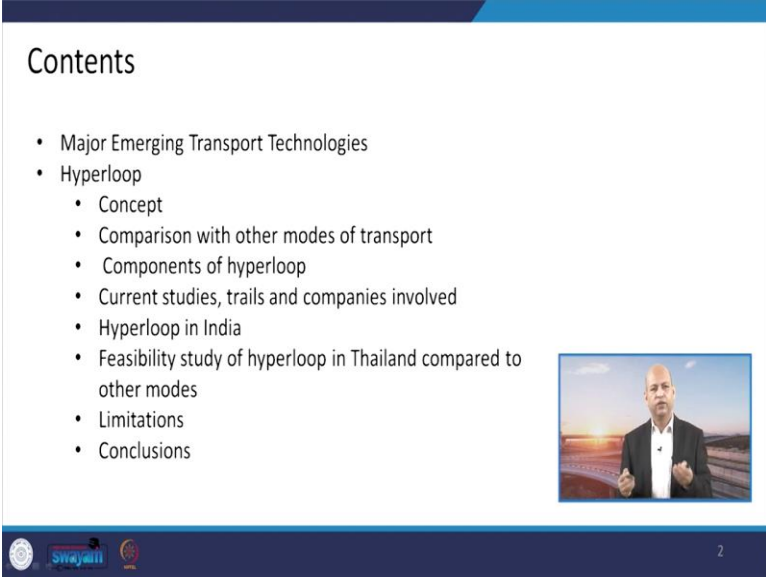


Sustainable Transportation Systems
Professor Bhola Ram Gurjar
Department of Civil Engineering
Indian Institute of Technology, Roorkee
Lecture 49

Emerging Transport Technology - Hyperloop


Hello, friends. So, we have discussed several transportation systems and technologies within the purview of sustainable transportation system. And today we will discuss about some emerging transport technologies, which are like, the growing technologies, which will be the normal technology of the transportation in future. So, today we will discuss about the Hyperloop.


(Refer Slide Time: 00:55)



Contents

- Major Emerging Transport Technologies
- Hyperloop
 - Concept
 - Comparison with other modes of transport
 - Components of hyperloop
 - Current studies, trails and companies involved
 - Hyperloop in India
 - Feasibility study of hyperloop in Thailand compared to other modes
 - Limitations
 - Conclusions

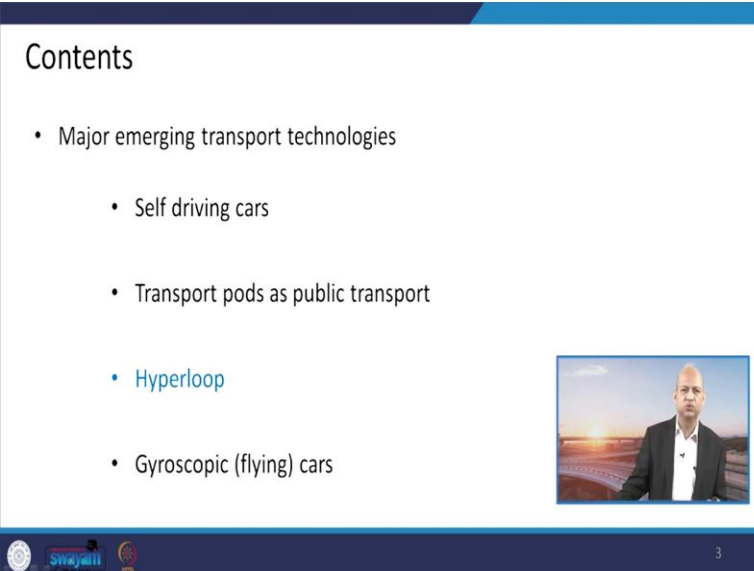


 2

But before that, we can see like what are the major emerging transport technologies these days. And then we will discuss in detail about the Hyperloop, we will focus our lecture on Hyperloop related concepts and then the comparison with other modes of the transport and components of Hyperloop, which are very important for designing purpose, and then the current studies and trails or trends and the companies which are involved in this new technology of the Hyperloop.

And within India what are the projects which are linked with the Hyperloop, and then the feasibility study of Hyperloop in Thailand compared to other modes. So, that is also one data set, we will discuss. Then we will also discuss like limitations of this new technology in, those kinds of limitations, how can we overcome those limitations in future? Otherwise, how can we address those limitations? And then we will conclude.

(Refer Slide Time: 01:50)



The slide is titled "Contents" and features a bulleted list of transport technologies. The items are: "Major emerging transport technologies", "Self driving cars", "Transport pods as public transport", "Hyperloop", and "Gyroscopic (flying) cars". The word "Hyperloop" is highlighted in blue. To the right of the list is a small video inset showing a man in a dark suit and white shirt speaking against a background of a sunset or sunrise over a body of water. At the bottom of the slide, there are logos for "Swayam" and "3".

So, when we talk about major, emerging, or new transport technologies then you might have read several articles in the newspapers and also social media or these popular media, like self driving cars. Google related self driving cars, you must be knowing about. So, that they are being trained by some software some sensors as well as GPS system.

Everything is there and it can take you from one place to another place with the given coordinates and it takes care of all that turns and everything. Even it saves you from any kind of possible accidents and those kinds of things are there. So, this is one very important development in the sector. Then transport pods as public transport. So, these are different than the simple high-speed rails or means cars et cetera. These are, in, different in the sense of their carrying capacity, their speed and their size et cetera.

Then one is Hyperloop which we will discuss in detail just now. Then there are like flying cars also. The cars which are able to like fly from one place to another. So, these kinds of experiments are going on. It is said that Israel has already developed this flying car. So, some prototypes are there, some are in very nascent stage of the development, but they may be like normal transportation mode in the future.

And because, every time when we develop a new kind of technology then there is a period of inertia when investment is needed in big quantity, plus infrastructure are needed, like, electric cars we are talking nowadays, but unless infrastructure is in place, its popularity will take time, but it is one thing which is coming very fast. But we will discuss like, Hyperloop.

Otherwise drones also. Like, you might have read I think in Telangana they have tried to transport medicines from one place to another. So, those kind of transportation of goods or services can be through drones. Plus, also there are other like, flying this kind of new technologies are also coming.

But basically, today we will discuss about Hyperloop as a case study so that you can get excited about the new technologies and you can also think in different way, in out of box way and maybe you can devise some new technology which can be part of the future technologies of the transportation.

(Refer Slide Time: 04:35)

What is Hyperloop?

- Hyperloop consists of a sealed tube or system of tubes with very low pressure inside, through which a pod can travel at a very high speed.
- Due to its unique features, it is also termed as 'fifth mode of transportation'

Image source: railwat-technology.com

4


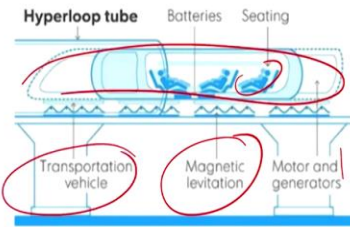
Well, so what is Hyperloop? When we talk about the Hyperloop, so this is basically consists of is sealed tube. One tube means, big pipe, you can imagine. And this is a system of tubes with very low pressure inside, so that friction is bare minimum. And through which, a pod or, like you can say, one wagon or, or that kind of capsule is traveled, or it can travel at a very, very high speed. It is, even you can compare it with the aeroplane.

And due to the unique feature, it is also termed as like fifth mode of transportation. So, you can see, one, this cross section is there. So, this is the outer form of the tube and within this tube, this is the capsule or you can say this is the pod, which is taking passengers from one place to another.

(Refer Slide Time: 05:35)

Principle of hyperloop

- Hyper loop is based on a principle of magnetic levitation.
- The principle of magnetic levitation states that the vehicle can be suspended and propelled on a guidance track made with magnets.
- The capsule on the top of the track is propelled by linear induction motors



The diagram illustrates the components of a hyperloop system. The top part shows a cross-section of a 'Hyperloop tube' containing 'Batteries' and 'Seating' for a 'Transportation vehicle'. The bottom part shows the 'Transportation vehicle' on a track, supported by 'Magnetic levitation' and powered by 'Motor and generators'.

Well, the principle which are kind of fundamental thing to design the Hyperloop or on which it works. So, this is basically based on a principle of magnetic levitation. So, it, it is like in the air it, on a cushion kind of something. It does not touch the surface and it travels in the air, and, on some height, you can say.



The principle of magnetic levitation states that the vehicle can be suspended in the air. You can suspend it, nor the touching. And it can be propelled on a guidance track made by the magnets, made with the magnets. The capsule or the pod, on the top of the track, is propelled by linear induction motion.

So, those kinds of fundamental principles are used. You can see here. These are shown, like batteries are there, then seating arrangements are there, magnetic levitation, you can see here, and then the motor and generators are there, transportation vehicle, which is the, this capsule, you can see. So, all these parts are there.

(Refer Slide Time: 06:45)

Evolution of Hyperloop

- The Hyperloop concept was first introduced in 2013 with the release of Elon Musk's Alpha paper.
- The paper outlined Hyperloop, a new transportation mode that utilized low-pressure tubes to propel capsules at high speeds over significant distances.
- The white paper was designed to be a launching point for innovation of the concept. To promote the Hyperloop concept, SpaceX, a private aerospace company owned by Elon Musk, initiated the Hyperloop Pod Competition in 2015, focused on the development and testing of a subscale prototype of Hyperloop.

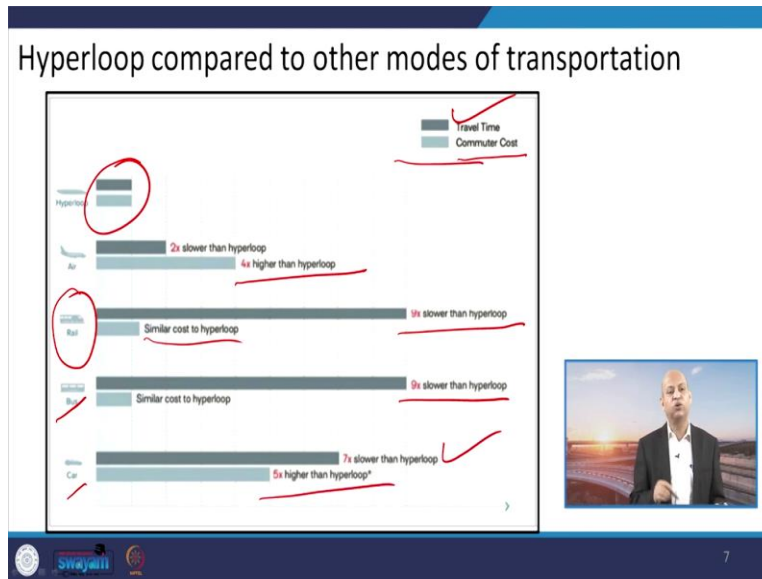


6

And this is another part of like evolution. How this cyber loop really evolved in terms of transportation mode or transportation system. So, basically the concept of the Hyperloop was first introduced in 2013 with the release of Elon Musk's Alpha paper. We have given the reference of this at the end. You can go through in detail. It is more than 50 pages. So, it has given complete design, the principle, very small calculations, concept, everything is there.

And this paper, which outlines the Hyperloop, the new transportation mode which we talked about, and utilize low pressure tubes, as we have already discussed, to prep, to propel the capsules at high speed over significant distances, means larger distances. And this white paper it was designed for launching point of the innovation of this concept, and it was not like patented something, it was an open space so that people can further improve upon those concepts which it has been discussed in the, in this particular paper.

(Refer Slide Time: 07:55)

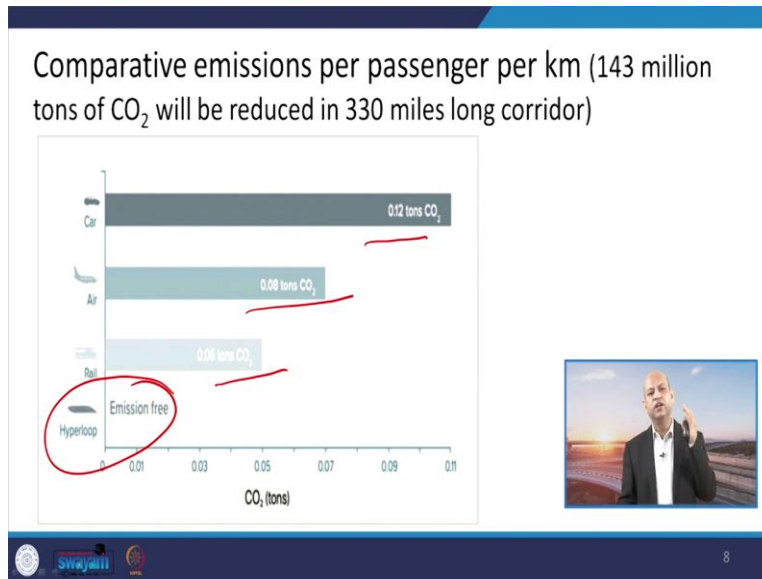


Well, when we talk about like a comparison of the Hyperloop to other modes of transportation, so this pictorial representation gives a clear case, clear cut case that the Hyperloop is very much low in cost and very high in the speed. You can see this is the Hyperloop related travel time in dark color, and in, in this faded color, or this light color, the commuter cost, the passenger cost, you can say.

So, if you compare with the air, air journey, so air journey is twice slower. Like, if you take one hour by air, within half an hour you can reach by the Hyperloop. So, that means twice it is more fast in case of Hyperloop, and four times higher than Hyperloop in terms of cost. So, air is costly, air journey is costly. It is one-fourth, means if you spend like 100 units of cost, then only 25 units are needed for the Hyperloop, you can say.

Similarly, if we compare with the rail, basically the time is much more advantageous in case of Hyperloop because this is like nine times slower railways, railways journey is nine times slower than the Hyperloop. But cost is almost similar, you can say. But at least Time is money as you know. So, if you are saving time, you are saving lot of money in, in that, in that sense. Similar thing happens with the bus, it is nine times slower than the Hyperloop, and cost is around similar. And if you compare with the car, then seven times slower than the Hyperloop car journey and five times costlier than the Hyperloop. So, it is kind of very clear cut case that Hyperloop, once it is there in place properly, then it saves a lot of time, it says, it saves a lot of cost also.

(Refer Slide Time: 10:00)



Well, when we compare about, like, emissions, whenever we talk about sustainability, the emissions of greenhouse gases or air pollutions, they are very important part of discussion. So, when we compare the emissions per passenger per kilometer, this picture gives in comparison to the Hyperloop because Hyperloop is emission free like electric cars. This is, there is no exhaust emissions, basically. So, no emissions are there.


Of course, electricity generation may be responsible for some emissions, but if we go towards like these, these power from renewable sources, then it is a clear winning case. But if you compare with the car like, point, 0.12 tons of the CO₂, in that particular per passenger per car, air is around 0.08, and the rail is 0.06, but Hyperloop is emission free.

And that way this is the, this is taken from a case, and in that case like 330 miles corridor is there. So, if we go for the Hyperloop in that particular corridor 143 million tons of the CO₂ will be reduced by applying this Hyperloop technology.

(Refer Slide Time: 11:11)

Hyperloop: Cost comparisons

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



Well, the cost comparisons are also here. You can see like, very real life experiences, like Shanghai, this Maglev Pudong, airport to Pudong, this is 30.5 kilometer long stretch, and time taken is around seven minutes. The total building cost of this particular transportation system was 1.33 billion dollars, and the cost per kilometer is like 43.6 million. It is very costly, you can say.

But more than that, if you compare Tokyo to Nagoya, this L0 series maglev, so 286-kilometer stretch is there and it takes around 40 minutes. And the total building cost, means the investment was 48.6 billion, estimated cost, and per kilometer it was around 170 million, you can say.


High speed rail, Mumbai to Ahmedabad, which is under construction, this cost, around 510 kilometer, it will take 110 minutes, estimated cost is 15 billion, and 29.4 million per kilometer, this costs. So, it is cheaper than this Shanghai Maglev as well as much cheaper than this L0 series maglev.

Hyperloop, if we compare, one, this estimated cost for Chennai to Bengaluru, so 350-kilometer stretch is there, it will take only 30 minutes. Very, very fast. And 8 billion will be the total estimated cost and 23.1 million per kilometer cost will be opening. So, this is the cheapest option, you can say.

(Refer Slide Time: 12:55)

Hyperloop: Capacity comparisons

Transport Mode	Capacity per unit	Services per day	Frequency	Capacity per day
Air	150 ✓	51 ✓	N/A	7650
High Speed Rail	589	27 ✓	30 min.	15903
Hyperloop-small capsule	28	568	113 Sec.	15904
Hyperloop-Large capsule	40	398	163 Sec.	16520



10

Well, the capacity comparison, if we talk about, then the air capacity per unit, around 150 passengers, average, means you can have larger planes also, and the 51 services per day, and total capacity per day is around 7,650. High speed rail, of course, it is much more total capacity, but the services are less and capacity is more because railways, many more wagons are there.

Hyperloop is small capsule, and large capsule, two options may be there. A smaller one, 28 persons per unit and larger than 40. The total per day capacity because of very high frequency, you can see, very high frequency, and the time only 113 second, 163 second, you can compare like, 30 minutes, in comparison to that it is much more, then 16,520 per day, the capacity of the passengers which can be serviced. So, means from the cost point of view, from the capacity point of view Hyperloop is something which should be welcome.

(Refer Slide Time: 13:58)

Components of Hyperloop

There are five major components of hyper loop:

- Tube
- Capsule
- Compressor
- Suspension
- Propulsion


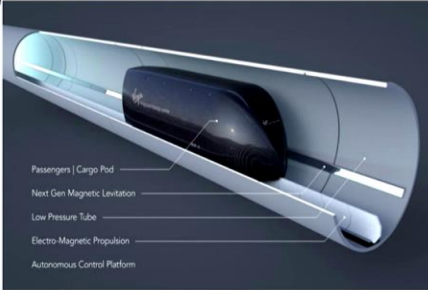


Image source: automotive.arcelormittal.com



11

When we talk about components of the Hyperloop, the major components, so you can see like one is tube, the outer tube, or the pipe, big pipe, and then the capsule, that is, the pod which will carry the passengers, then the compressor is there for air movements, suspension system is there, and the propulsion to force it to move in the linear direction.

(Refer Slide Time: 14:30)

Hyperloop component: Tube 1/2

- Tube is one of the main components of hyperloop system which is made of steel.
- Two tubes are welded together side by side or up and down to allow the capsules travel in both directions.
- These tubes will be supported with the help of pillars. Pillars are placed 30m(100ft) apart from each other.



12


And then you talk about, like tube, then this is the main component of the Hyperloop system, which is made of the steel. So, you can see this is the tube, it is larger cross section. And then that two tubes are placed either side by side or one above one over, so that one tube is dedicated

from one direction, movement of the these capsules, and other for, like one going another coming. So, dedicated tubes may be there. Then these tubes will be supported by pillars, with the help of pillars and those pillars are placed around 30 meters apart from each other.

(Refer Slide Time: 15:10)

Hyperloop component: Tube 2/2

- Solar arrays are provided on the top of the tubes which provide power to the whole system.
- The geometrical dimensions of the tube are:
 - Inner diameter of the tube is 2.23 m.
 - The tube cross-sectional area is 3.91 m².
- The expected air pressure inside the tube will be maintained around 100 Pa




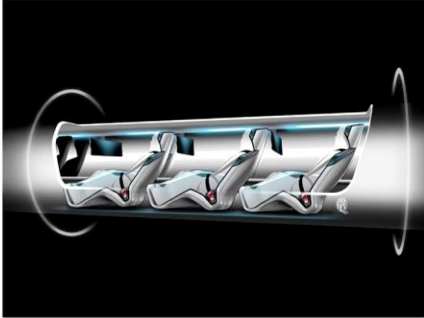
13

When we talk about like other systems or other components of the Hyperloop, then solar arrays are to be provided at the top of the tubes so that continuously it can harness the solar energy. Of course, there will be alternative sources of power also. It is not completely dependent on solar, but a lot of solar energy will be used whenever sunshine is there. Then the geometric dimension, you can see, the inner diameter of the tube, that big pipe is 2.23 meters, it is a larger size. And the tube cross section is around 3.91 square meter. And then the expected air pressure inside the tube will be maintained around 100 Pascal. So, those are the things, or parameters, very simple parameters, which are the part of the design things of the Hyperloop.

(Refer Slide Time: 16:00)

Hyperloop Components: Capsule 1/2

- The proposed capsule has the capacity of carrying 28 passengers at a time and travel at a very high speed throughout the length of the tube.
- Magnetic linear accelerators are used to accelerate the capsules.




14

And when we continue about these Hyperloop components, so this capsule, which has the 28 carrying capacity, 28 passengers, this is the smaller one, the larger one has 40. So, the 28 passengers set a time, and it can travel at very high speed throughout the length of the tube. And then magnetic linear acceleration are used to accelerate the capsules. So, lot of new way of this transportation in terms of magnetic, magnetic forces et cetera.

(Refer Slide Time: 16:28)

Hyperloop Components: Capsule 2/2

- Capsule accelerators are fixed at various stations on the hyperloop tube.
- Each capsule contain rotors fixed at the bottom and the stators on the tube walls.
- The combination of stator and rotor gives momentum to the capsule.
- The capsule are separated within the tube by a approximately 23 miles (37 Km) on average during operation.



15

When we talk about acceleration, so the capsules, accelerators are fixed at various stations on the Hyperloop, so that the uniformity can be maintained. And then each capsule contains rotors fixed

at the bottom and these stators on the tube walls so that it can be used for this combination, this combination of stator and rotor. It gives the momentum to the capsule. So, acceleration and deceleration all these are controlled by this mechanism. And the capsules are separated within the tube by approximate distance of around 37 kilometer, so that safety issues can be operated very comfortably. And then this is during the operation. So, this is the minimum distance which is to be kept within two capsules, you can say.

(Refer Slide Time: 17:20)

Hyperloop component: Compressor 1/2

- The compressor is fitted at the front side of the capsule.
- It sucks the air and transfer to the air bearings which supports the weight of the capsule.



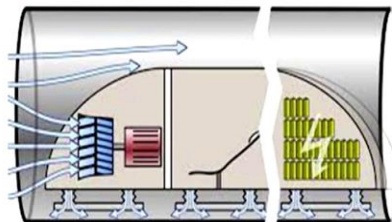


Image source: large.stanford.com, irjet.net


16

When we talk about further, like the compressor, so compressor is fitted at the front side of the capsule so that it can suck the air from the front side and it transfers the air to air bearings which supports the weight of the capsule, like cushion, or you can image in that way.

(Refer Slide Time: 17:42)

Hyperloop component: Compressor 2/2

- The compressor allows the capsule to traverse through low pressure tube without choking the air flow that travels between tube walls and capsule.
- Tube air is compressed with a compression ratio of 20:1 via an axial compressor.
- Up to 60% of this air is bypassed
 - The air travels via narrow tube near bottom of the capsule to the tail.
 - A nozzle at the tail expands the flow generating thrust to mitigate some of the small amount of aerodynamic and bearing drag




17

Well, then this compression allows the capsule to travel through low pressure tube without choking the airflow. So, that is very important. And then it travels between tube and the capsule, that air, so that the choking is not there, otherwise, a problem may arise. Tube air is compressed with a compression of ratio of 20 to 1 via this axial compressor and up to 60 % of this year is bypassed. So, the air which travels via a narrow tube near the bottom of the capsule to the tail and a nozzle at the tail expands the flow generating this thrust and this is used for the mitigating some of the small amount of aerodynamics and bearing drag. So, that, those kind of dragging forces, drag forces can be compensated.

(Refer Slide Time: 18:37)

Hyperloop Components: Suspensions

- For the purpose reliability and safety, the air bearing suspension are used which offers stability and extremely low drag at a feasible cost.
- Due to exceptionally high stiffness, air bearing suspension is required to maintain stability at very high speed.
- The skis are pushed away due to the increased pressure which creates considerable discomfort for passengers.
- Hyper loop capsules will float above the tube's surface on an array of 28 air bearing skis. The skis support the weight of the capsule by pressurized cushion of air.



18


And then the suspension system, the suspension system is also very important. So, for that purpose, the reliability and safety is most important issues, and the air bearing suspensions are used which offers stability, and extremely low drag at a feasible cost. So, that is one important design aspect. Due to exceptionally high stiffness, here bearing suspension is required to maintain stability at very high speed.

Then there are some other components like skis, which are pushed away due to the increased pressure, which creates considerable discomfort for passengers. And the Hyperloop or capsules will float above the tube surface on an area of 28 air bearing skis. The skis support the weight of the capsule by pressurized cushion of the air. So, that kind of, very sophisticated design are ensured for suspension purpose.

(Refer Slide Time: 19:33)

Hyperloop Component: Propulsion

- Propulsion system is important component of hyperloop system to accelerate as well as to decelerate the capsule from 0 to 300 mph or 483 km/h.
- To accelerate and decelerate the capsule linear induction motor is used which provides advantage over permanent magnet motor.
- Linear induction motor lowers the material cost, reduces the weight of the capsule and also lowers the dimensions of capsule.



19

Similarly, for propulsion purpose there are mechanism like, this propulsion system is important component and it is required for acceleration and for deceleration of the capsule, from 0 to 300 kilometer, 300 miles per hour or 483 kilometer per hour, that kind of very high speed. And to accelerate and decelerate the capsule linear reduction motor is used, which provides advantage over permanent magnet motor.

Similarly, the linear induction motor lowers the material cost. So, these are the additional advantages and it reduces the weight of the capsule and also lowers the dimension of the capsule. So, in design these are very important features which takes place when we consider the complete design of the Hyperloop system.

(Refer Slide Time: 20:20)



Well, when we talk about means, how many countries are there or where these Hyperloop related companies are operating or some testing facilities exist, and major studies are being conducted, so like in USA there are many, in Europe also. And then you can see in India also there are these companies and studies are there.

(Refer Slide Time: 20:45)

Major companies in hyperloop development

Hyperloop Developer	HQ	Full-time Employees	Testing facilities
VHO ✓	USA ✓	<300	Completed: 500m, USA Developing: 12km, India
HTT ✓	USA	<100	Developing: 320m, France
TransPod	Canada	<50	Developing: 3km*, France
Hardt ✓	Netherlands	<50	Completed: 30m, Netherlands Developing: 3km* Netherlands
Zeleros	Spain	<50	Developing: 2km*, Spain
Hyper Poland	Poland	<50	Completed: 30m*, Poland Developing: 500m*, Poland
KRRI	South Korea	<50	Developing: 7km, South Korea
SwissPod Technologies	Switzerland	<10	Developing: 40m*, Switzerland

* Scaled-down vehicle and tubetrack
 * The table above only listed Hyperloop Developers who participated in the data collection process

21

Well major companies which are kind of leading companies in Hyperloop development, these are like VHO, HTT, TransPod, and their headquarters are given. Like these are in USA, in

Canada TransPod is there, and Netherlands, this Hardt, and Spain Ze, Zeleros, and Poland Hyper Poland, those kind of companies and countries are given.

Full time employees, number of employees are given, and then the testing facilities under these companies, what is the stretch size, all those like 12 kilometer in India, it is being developed by VSO, USA. So, those kind of figures or data are also given.

(Refer Slide Time: 21:28)

The slide is titled "Hyperloop in India" and contains the following text:

- The two planned Virgin Hyperloop projects in India are on the Mumbai-Pune route and possibly between Bengaluru airport and the city.
- The state of Maharashtra has approved the Virgin Hyperloop-DP World Consortium as the original project proponent for the Mumbai-Pune route
- Declared Hyperloop as a public infrastructure exercise.

Image source: qz.com

The slide includes two images: a large Virgin Hyperloop pod with the Indian national flag on its side, and a smaller inset image of a man in a suit speaking.


22

When we talk about Hyperloop in India, so this is basically there are two planned, like one Virgin Hyperloop, project, the company, bridging companies in India and on the, this is on the Mumbai-Pune route. And then the another is possibly between Bangalore airport to the city. So, the state of Maharashtra has approved the Virgin Hyperloop, DP World Consortium, these two companies of different countries, multinational companies, companies, are these. And the original project proponents for the Mumbai-Pune route are these, the conglomeration of these two big companies. And this has been declared as the public infrastructure exercise for kind of a case study if it is very much successful then it can be multiplied in other stretches of India.

(Refer Slide Time: 22:15)

Mumbai-Pune Hyperloop

- The company is planning to have its hyperloop system safety-certified by 2025 and make it ready for passenger operations on commercial projects by as early as 2030
- Will save 2.5 hr. in travelling



The map shows a blue line representing the hyperloop route from Mumbai to Pune. Key locations marked include MUMBAI, NAVI MUMBAI INTL, and PUNE. A legend in the top right corner indicates travel times: 25 min (hyperloop), 2.5+ hours (car), and 3+ hours (train).




Image source: virgin hyperloop


23

So, you can see from Mumbai to Pune, this is the kind of path for this Mumbai-Pune Hyperloop, and this company is planning to have this Hyperloop system CERTI, the safety certified by 2025, and it will be ready for passenger operations and like, a commercial project in early 2030. And it will save around 2.5 hours in traveling. So, 2.5 hours in modern era is a significant time span.

(Refer Slide Time: 22:50)

Hyperloop feasibility study in Thailand by Transpod: Comparisons

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



24

When we compare these feasibility of Hyperloop, these feasibility studies in Thailand, then there are comparison with different kinds of aspects, or features like capacity, and you compare it with other modes of transport like air, truck, rail, ship, and then Hyperloop. So, when we talk about

payload capacity, the air is very low in comparison, but Hyperloop is medium. Of course, rail has a lot of capacity and ship also has very high capacity, but truck medium. So, the Hyperloop compared in the truck in that, in that sense.


Greenhouse gas emissions, very high in case of air traffic and the truck mode, and medium in this ship and the rail, but it is very low in case of Hyperloop. That is only related to energy generation or power generation if we are, depending upon these fossil fuel related power plants. Otherwise, this is bare minimum if we go for like renewable resources.

Frequency, high, high and it is high in case of Hyperloop also, but in case of rail and ship, is not so. It is low, rather. Speed, like, it is high in case of air journey and Hyperloop it is also very high. Other modes of transport like trucks, rail and ship, they are like medium or low. Weather resistance, Hyperloop is very high weather resistance because it is under the tube so no flooding, nothing those kind of things are there. Whereas in case of rail and like air traffic also, affected by like bad weather also. Cost per ton, it is very high in case of air journey, but it is low in case of truck and it is medium in case of Hyperloop. But in totality if you go for the total things, you will see other things also.

(Refer Slide Time: 24:50)

Hyperloop feasibility study in Thailand by Transpod:
Comparisons

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




25

So, like if you see the performance, speed performance, frequency of departure, fuel efficiency, energy efficiency, weather resistance, then it is very high in that sense in comparison to other modes of the transport. So, means the totality, in totality the Hyperloop is much more attractive, you can say.

(Refer Slide Time: 25:05)

Hyperloop Route selection

- Limiting the maximum capsule speed to 760 mph (1,220 kph) for aerodynamic considerations
- Limiting accelerations on the passengers to 0.5 g
- Optimizing locations of the linear motor tube sections driving the capsules
- Local geographical constraints, including location of urban areas, mountain ranges, reservoirs, national parks, roads, railroads, airports, etc.
- The route must respect existing structures.



26


And when we talk about the route selection, so there are certain aspects or important features which has to be given good consideration, like limiting the maximum capsule speed. It can be up to only turn 1,220 kilometer per hour. Beyond that it will be difficult because of aerodynamic consideration. So, it should not exceed from that. But this is big, very large speed in fact, if you compare with existing modes of transportation, including air journey.

Then there are limiting accelerations on the passenger to around 0.5 this G, otherwise uncomfortable, this comfort level will be very low. Then optimizing locations of the linear motor, the sections driving the capsule, so that optimization has to be reached. Local geographical constraints are there, like, in urban areas or mountain ranges, reservoirs or national parks or roads, railroads airports et cetera. So, how to integrate with them because it takes the simple straight route then it is good otherwise, it is difficult. And the route must respect existing structure. So, that is one more aspect which to be taken into account.

(Refer Slide Time: 26:30)

Limitations of Hyperloop

- May occur critical situation at turnings w.r.t. safety vs. speed
- Less movable space and comfort for passengers
- May occur dizziness in passengers due to high acceleration and deacceleration

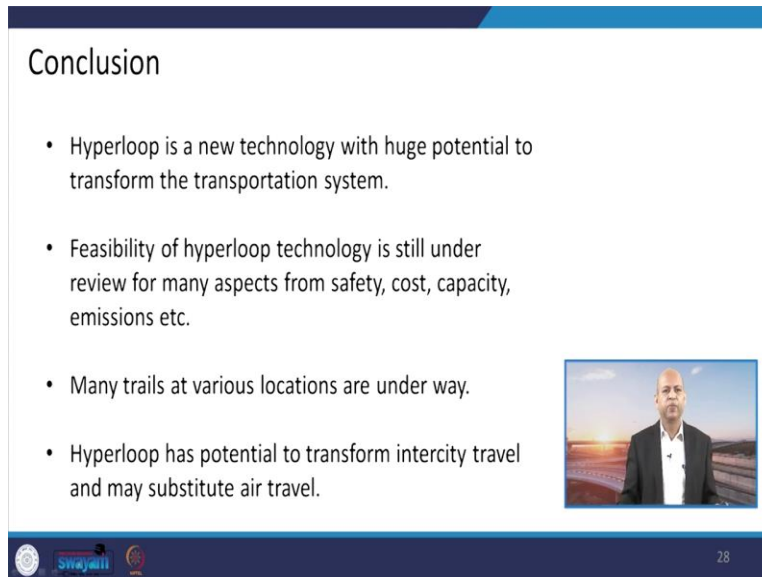


27

But there are some limitations of the Hyperloop. Like, it can occur, like, critical situation at turning with respect to the safety and the speed. So, turning should be very minimum and it should not be very sharp turns. So, the design of the route has to be taken very, in a sensitive way so that turning can be avoided. Only the straight routes can be designed.

Less movable space and comfort of the passengers, the comfort level in comparison to other modes of transport like railway et cetera, it will be less at present, in present context of the design. Then it is, it can result into like some health issues like dizziness in passengers just because of very high acceleration and deceleration. So, it can affect the health issues also. So, those are the limitations. Maybe some technological interventions can be implemented to reduce these limitations.

(Refer Slide Time: 27:30)



The slide is titled "Conclusion" and features a list of four bullet points. To the right of the third bullet point is a small video inset showing a man in a suit speaking. At the bottom of the slide, there are logos for "Swayam" and "28".

Conclusion

- Hyperloop is a new technology with huge potential to transform the transportation system.
- Feasibility of hyperloop technology is still under review for many aspects from safety, cost, capacity, emissions etc.
- Many trails at various locations are under way.
- Hyperloop has potential to transform intercity travel and may substitute air travel.

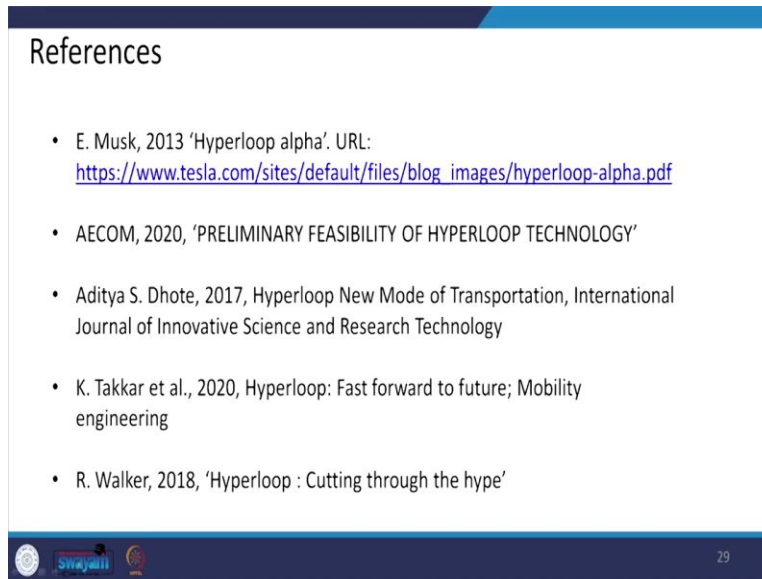
28

So, in conclusion, we can say that this Hyperloop is a new technology, very emerging technology, but it has huge potential to transform the transportation system from the existing to the new system. And the feasibility of Hyperloop technologies is still under review, at many, for many aspects like safety, cost, capacity, emissions or route related things.

And then many trails are, are they are like at various locations, some stretches are being tried. So, data will be available after some time. Then this Hyperloop has potential to transform this intercity travel, and it can also substitute the air travel. It will save a lot of time and cost also. Also, it will be very environment friendly.

So, we can say that this is the very upcoming and very welcoming technology. And maybe after a decade or so it can be very popular mode of transportation. And I hope that many of you can think in that way, in out of box thinking or creativity and you can also come up with some new ideas of the transportation.

(Refer Slide Time: 28:45)



References

- E. Musk, 2013 'Hyperloop alpha'. URL: https://www.tesla.com/sites/default/files/blog_images/hyperloop-alpha.pdf
- AECOM, 2020, 'PRELIMINARY FEASIBILITY OF HYPERLOOP TECHNOLOGY'
- Aditya S. Dhote, 2017, Hyperloop New Mode of Transportation, International Journal of Innovative Science and Research Technology
- K. Takkar et al., 2020, Hyperloop: Fast forward to future; Mobility engineering
- R. Walker, 2018, 'Hyperloop : Cutting through the hype'

These are the references. You can go through to get additional information. And this is all for today. So, thank you for your attention. See you again. Thanks a lot.