

Consumer Desirability of the Proposed Hyperloop



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Introduction of the Hyperloop

The Hyperloop, a “fifth mode of passenger and/or freight transportation,” was proposed by Elon Musk back in 2012. With proposed speed over 700 mph, it is aimed to transport both passengers and cargo freights with its plane-like speed and train-like convenience. The original concept is to propel a magnetically levitating pod through a vacuum tube at an approximate speed of 760 mph over long distances with safety and comfort.¹ With more research and development being done in the past few years, various solutions emerged using different design and technology but with the same basic concept - pods travelling in a tube. With feasibility studies also being conducted for test tracks, the Hyperloop currently aims to connect major cities, especially ones facing severe traffic problems (e.g. Washington D.C. to Baltimore and other nearby cities). At its current stage, many engineers are trying to increase the Hyperloop’s speed to hit the 760 mph target while also developing pods that can meet the requirements to transport passengers and cargo. Earlier this year, the Indian government and Virgin Hyperloop One reached an agreement to build a Hyperloop route between Mumbai and Pune²; Elon Musk, founder of The Boring Company, is also working on government approval to build structures for “NY-Phil-Balt-DC Hyperloop”.³ Undoubtedly, there will be many more exciting news and developments in the times to come, and as the Hyperloop matures, we can finally see if it can live up to the hype and ambition of being “the fifth mode of transportation”.

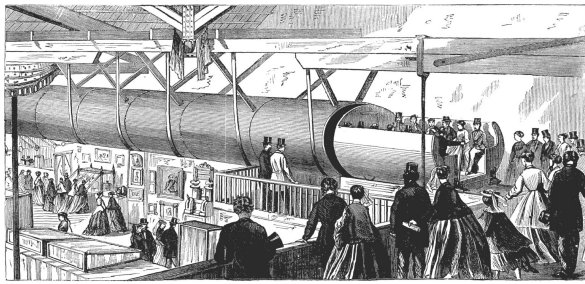
1. Vivek W. 2016. Your future commute: Flying through tubes at 760 mph. The Washington Post.

2. PTI, 2018. Maharashtra Exploring Hyperloop to Reduce Mumbai-Pune trip to 25 mins.

3. Michael L, Brian F., 2017. Elon Musk says he has 'verbal govt approval' for D.C.-to-New York Hyperloop. The Washington Post.

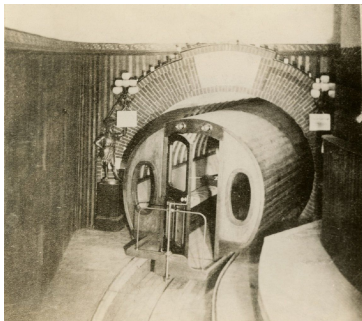
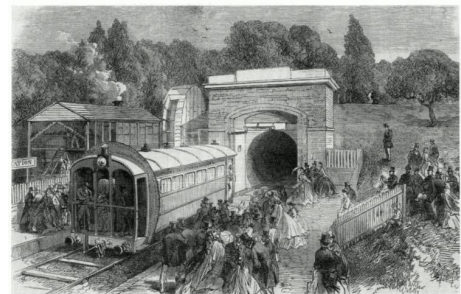
Timeline:

In **1799**, inventor George Medhurst proposed an idea to move goods through cast-iron pipes using air pressure. In **1844**, he built a railway station (for passenger carriages) in London that relied on pneumatics until **1847**.



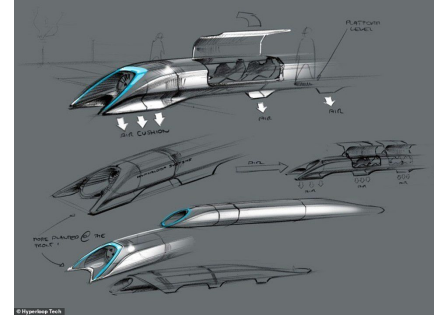
Throughout the **mid-1850s**, several more pneumatic railways were built in Dublin, London, and Paris. The London Pneumatic Despatch system was meant to transport parcels, but it was large enough to carry people, too. To mark its opening, the Duke of Buckingham traveled through it in **1865**.

In the **mid-1860s**, South London constructed the Crystal Palace atmospheric railway, which ran through a park. A fan, which measured 22 feet in diameter, propelled the train. On return journeys, the fan's blades reversed, sucking the carriage backwards.



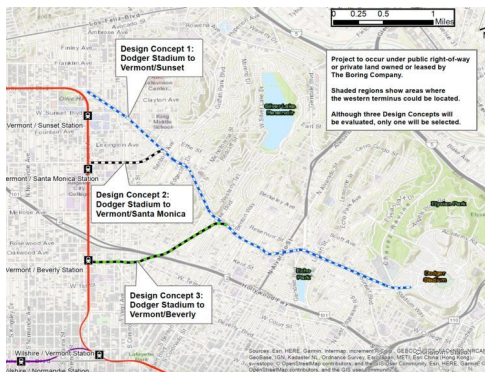
The Beach Pneumatic Transit, which operated in Manhattan from **1870** to **1873**, was New York City's earliest subway predecessor. Designed by Alfred Ely Beach, it had one stop and a one-car shuttle that used compressed air to move riders.

Three years later, Elon Musk published his proposal for the Hyperloop in a 57-page white paper. According to his design, sealed pods containing 28 people each would whisk through tubes. A trip from NYC to DC would take 29 minutes, he tweeted in **2017**.



Hyperloop Transportation Technologies, a startup building off Musk's concept, is creating a 5-mile test track for a Hyperloop system in Quay Valley, California. Construction began in **2016**, and the company is aiming for the train to reach 760 mph.

In **July 2017**, a startup called Hyperloop One successfully tested a full-scale system on its DevLoop test track in Nevada. Using maglevs, the vehicle reached a top speed of 70 mph. The company hopes to reach 250 mph.



Boring Company unveils Hyperloop route for L.A.'s Dodger Stadium in August **2018**

Preface to the Question

Since the reintroduction of the Hyperloop concept is only six years old, there are still many questions and problems to be answered. The two main issues are optimizing the technology and researching the economics and financials. Most private companies and universities have prioritized engineering the linear induction motors to make the pods optimal, as this technology allows the Hyperloop to operate at its standard. Others are looking into the cost and funding of the Hyperloop as the system demands a high initial upfront cost. These two issues demand extensive time, knowledge, and manpower, which still need additional work to this day.

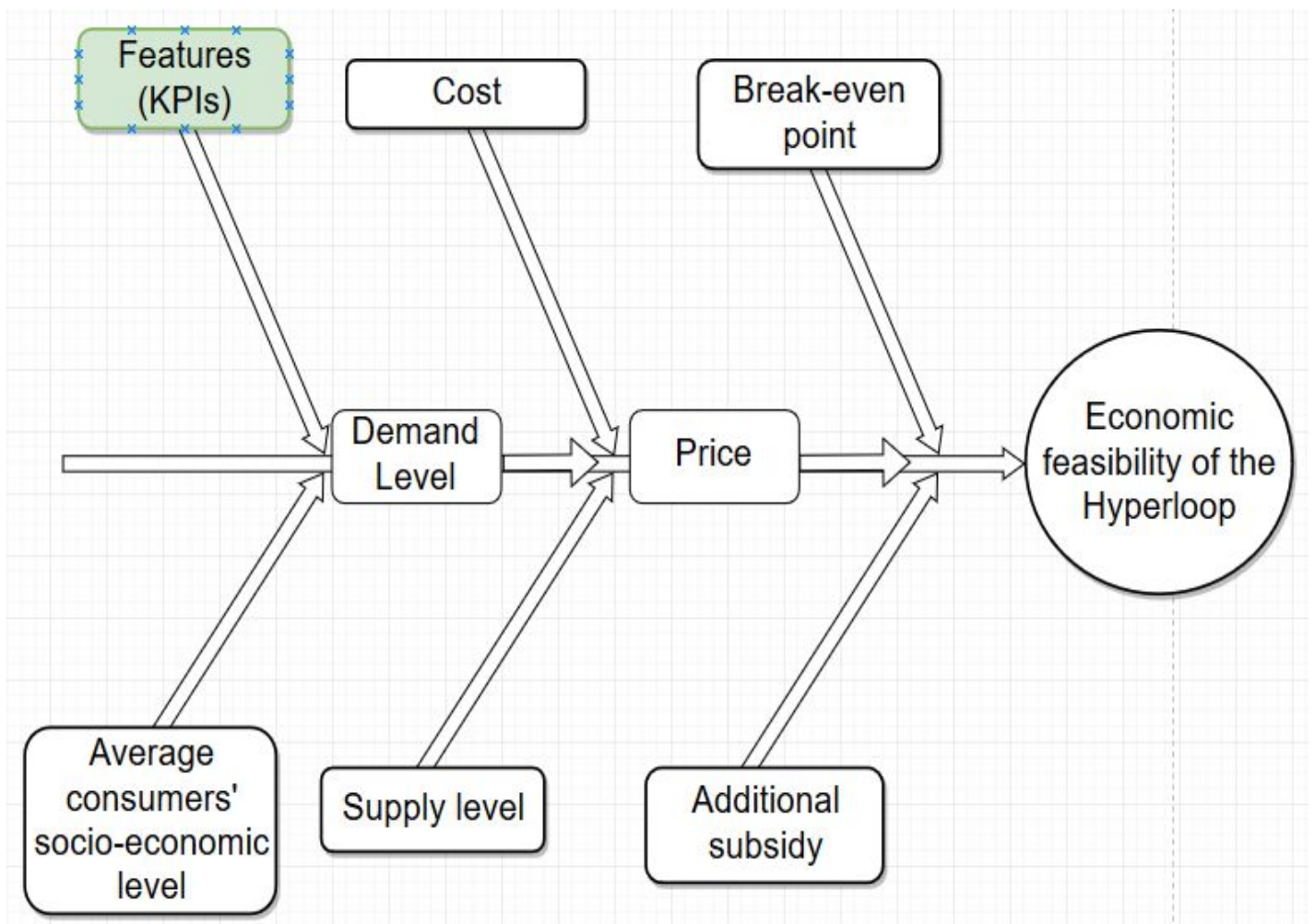
Introducing the Question and the Reasoning Behind Why the Question Should be Tackled

This case report uses the two challenges of technology and financials to look into the question: “**Comparing key performance indicators of past, present, and future forms of transportation, will the Hyperloop cover the main needs of consumers better than other similar modes of transportation?**”

This question is crucial to answer as the Hyperloop’s main intent is to change the way humans travel, work, and live. Even if the technology works and enough funding is allocated to build the system, there needs to be enough consumption to sustain the system.

It is empirical to understand that this case study’s main objective is not to give a **definitive** answer to our question due to the fact that the industry is quite new and certain proposed parameters might change in accordance to characteristics that affect consumers’ decisions. This report rather gives the answer to this question in accordance to the proposed Hyperloop’s **current state** but more importantly creates a simplified standard structure for determining whether or not the Hyperloop covers the main needs of consumers. By doing this, researchers and those involved with the Hyperloop can refer back to this case study and adjust the analysis when specific parameters related to the main needs of consumers are changed. It is important to refer to the question asked in this case study as it is a building block to answering the economic feasibility of the Hyperloop. By determining the economic feasibility on paper rather than on full scale trials, a large sum of money can be saved by Hyperloop companies, the government, and the rest of society.

Flowchart for Determining the Economic Feasibility of the Hyperloop



Methodology

This case report was conducted by analyzing information provided by actual Hyperloop companies and information drawn from online sources. By using information drawn from partners who work hands on with developing the Hyperloop, this report draws conclusions from primary information. Since the actual Hyperloop system has not been built, there are few papers to draw from, so using internet sources is the next best alternative for finding reliable information on the Hyperloop.

Clarifying the Case Study Parameters

Question

Comparing key performance indicators of past, present, and future forms of transportation, will the Hyperloop cover the main needs of consumers better than other similar modes of transportation?

Breakdown of the question

First, this case study tests consumer desirability through a **comparative approach**. The case study compares the Hyperloop to different forms of transportation in order to come to our conclusion.

This case study bases comparisons across **Key Performance Indicators**, or **KPIs** for short. There were many possible factors, but this case study narrowed it down to four: **price, travel time, safety, and comfort**. These factors were decided on factors based on relevance to the consumer.

This case study compares the Hyperloop to **past, present, and future modes of transportation**. This is to ensure a holistic approach. The case study studies the past modes of transport to ensure the Hyperloop doesn't make the same mistakes of the past, and this case study studies the present and future modes of transportation to study the relevant target markets.

This case study wants to see **if the Hyperloop would cover the main needs of the consumer**, and if it would do so **better than other forms of transportation**. This was to check the Hyperloop's competitive advantage in the market, in terms of fulfilling general consumer needs. This was to make sure it would be able to dominate market share in its niche. The "fifth form of transportation" is only as good as its market demand.

Under the category of **consumers**, this case study does not include any specifications based on purpose. In other words, this case study does not classify whether the consumer used the Hyperloop for personal or business purposes. The case study broadly categorized “consumer” as any entity that consumes the services of the Hyperloop.

KPI Clarification

Price

The Hyperloop ticket price is a large factor in determining whether or not people will use the Hyperloop. If the price goes up, quantity demanded will be lowered, leading to potential losses of revenue and long run profits. However, according to economic theory, if tickets are priced too low, quantity demanded will increase, driving prices up to equilibrium. Furthermore, the Hyperloop should be time efficient, because its selling point is that it is faster than its competitors (railroads, cars, etc.). Without achieving adequate pricing, consumer desirability for the Hyperloop is questionable. Consumers are willing to pay a higher price if the money they spend increases their utility of time and consumption. In the past, it was often a tradeoff between the price and the speed. If the Hyperloop can find the utility maximizing combination of the two factors, it would be competitive in the transportation market.

Travel Time

Travel time is an important KPI that many travelers factor into their transportation decisions. Travel time is the amount of time that it takes to get from point A to point B (i.e. how long it takes the Concorde to go from Los Angeles’s LAX airport to London’s Heathrow airport). This case study uses travel time rather than speed since speed doesn’t take into account the the interim time that varies for each mode of transportation. As an example, for a car you can just get in and begin driving to your destination, but with an airplane you have to travel to the airport, go through security, then board the plane one at a time. These factors can add to the total amount of time it takes to travel to your destination. Travel time is such an important factor because time is valuable. However, the value of time, and how much one is willing to pay or sacrifice

comfort for it, varies from person to person. For example, the Concorde's very high price tag attracted mainly business travelers who are generally willing to pay more money for their time compared to someone going on a vacation. Someone with a very ill relative would probably also want less travel time and be willing to sacrifice comfort or paying more.

Safety

Safety affects consumer choices, mainly by altering their opinions of a product. This leads to increased or decreased usage. For example, according to Curiosity.com, the odds of a plane crashing are about 1 in 11 million¹. Yet, there is still the general stigma that planes are unsafe to be on. In comparison, the odds of a car accident are about 1 in 645¹. Planes are almost infinitely more safe to ride than a car, yet people feel safer around cars because of the control humans have over it. One of the main problems with self-driving cars felt by consumers is the lack of accountability. In regards to our current form of cars, consumers feel safe when driven by another person (like themselves) despite the increased chance of an accident. Even though Waymo's self-driving cars have millions of miles in data that prove it is a safer alternative, consumers still have a negative perception of it being safe.

Comfort

While most people think about the most price and time efficient way to travel, comfort is often overlooked when it comes to remembering what's most important to the consumer. Building a mode of transportation, those who are involved in building the hyperloop must recognize the value of comfort during a trip. For people who expect to work or read during the trip, a bumpy ride could induce them to choose alternative modes of transportations. Also, it is foreseeable that the target market of Hyperloop will be in huge need of resting on the trip. Therefore, if the Hyperloop is able to provide consumers the comfortability that they desire, it will be successful in becoming a mode of transportation consumers want to use in the future.

¹Bowman, Ben. "How Do People Survive Plane Crashes?" Curiosity.com, 2 Aug. 2017, [curiosity.com/topics/how-do-people-survive-plane-crashes-o53cN3Xy/](https://www.curiosity.com/topics/how-do-people-survive-plane-crashes-o53cN3Xy/).

Not Using Environmental Impact

Our research question focuses on how certain KPIs of the Hyperloop are going to affect the consumers' transportation decisions. This case study come to a conclusion that, although nowadays environmental impact has been dominating people's attentions more than ever, for most people, it is still a trivial or even non-existence concern when it comes to the actual decision making process due to the fact of self-interest. For example, consumers put the speed of airplanes as our top priority, and don't consider the fact that it burns more fuel than trains. This is often times due to the mentality that the negative value of their contribution of carbon dioxide is negligible compared with the value of efficient travel that they are obtaining. Thus, this case study has decided that it will only include the most relevant KPIs to consumers which are price, travel time, safety, and comfort.

Setting Up the Theoretical Hyperloop

Price of the Hyperloop

In our study we presume that the the Hyperloop will run for a price of \$20 for 350 miles based off of data from our Hyperloop company partners and credible news sources¹. The major concern with this assumption is that given today's standards, the price of the Hyperloop seemed unusually low. However, we think there are several factors that justify the proposed price. First, once there's enough competition in the market for building and running the Hyperloop, the price will be driven down naturally, and with newer technology also being researched, the initial building and maintenance cost of the Hyperloop will be lowered as well. Secondly, if the Hyperloop revolutionizes the transportation industry and brings many benefits to society, governments will step in and subsidize the Hyperloop industry, further bringing down the price.

Travel Time of the Hyperloop

The Hyperloop's travel time is expected to be shorter than other modes of transportation. The maximum speed of the Hyperloop is predicted to reach 760 mph¹. The Hyperloop plans to reach this speed by travelling through a vacuum tube that will eliminate travel resistance. Elon Musk's original design incorporated pods on air bearings that were powered by compressed air and linear induction motors. However, the maximum speed achieved at this time is only 240 mph and engineers are also exploring other technologies such as large fans. The only faster method of transportation that we analyzed is the Concorde, which was disproportionately more expensive. To travel 350 miles, it would

1. <http://iveybusinessreview.ca/blogs/mzawalskyhba2014/2014/07/16/a-20-dollar-hyperloop-ticket/>

2. Musk, Elon. "Hyperloop Alpha." SpaceX, 2013, www.spacex.com/sites/spacex/files/hyperloop_alpha-20130812.pdf.

take the Hyperloop about 28 minutes while taking a plane 38 minutes and a car 5.5 hours. However, we need to factor in the time that it takes to go through security at an airport and waiting time at a hyperloop station compared to just being able to walk into your garage and start driving your car. According to information provided by Hyperloop companies, boarding and disembarking are projected to take two to three minutes. However, we do not know at this time if there will be security screenings like at an airport. In addition, with the Hyperloop station being similar to an airport, you would have to drive to the nearest station, which adds to travel time. Adding the time it takes to go through security screenings and baggage claiming upon arrival, the flight roughly becomes 2 hours. This is not including the time it takes to drive to the airport from your house, and we will not address this issue due to variability reasons. Assuming the Hyperloop does not have security screenings and there are 4 stops along the way, these four stops would add about 24 minutes to the total travel time ((3 minutes to board + 3 minutes to disembark)*4). This increases the total travel time by Hyperloop to 52 minutes.

Safety of the Hyperloop

Hyperloop is a single system that incorporates the vehicle, propulsion system, energy management, timing, and route. Pods travel in a carefully controlled and maintained tube environment making the system 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. In terms of onboard emergencies, all pods would have direct radio contact with station operators, allowing passengers to report any incident, to request help, and to receive assistance. In addition, all pods would be fitted with first aid equipment. Also, the pods do not require continuous power of travel, so that in the case of power outage, the lithium ion battery packs of the life support systems will bring all pods to a stop at their destinations¹.

Safety is always one of the main concerns for the consumers when it comes to public transportation. In today's world, people have the preconceived notions of transportation being required to be safe, so it is important to make sure that Hyperloop can face and solve all the potential threats that may occur.

¹ Kumar, A. (2017) Hyperloop High Speed of Transportation. International Journal of Innovative Research in Science and Engineering, Vol. No.3, Issue 04. Retrieved from <http://www.ijirse.com/wpcontent/upload/2017/03/IIMT1085ijirse.pdf>

Comfort of the Hyperloop

Comfort is a big component of transportation and often determines which mode of transportation consumers want to use. Within comfort there are a variety of factors such as vibration levels, leg space, and overall environment. While very few modes of transportation excel in all three, they are key components that consumers pay attention to. Taking a closer look at the Hyperloop, we will find lower vibrations due to new technology, making it a comfortable ride for consumers. Furthermore, the pods will provide comfort to the riders by having adequate leg room and cushioned seating. By looking at these factors and combining it with the fact that the Hyperloop is very time efficient, it is evident that the Hyperloop will be a preferable choice for the consumers if these proposed features are to materialize.

Past Technologies Comparison

Why Look at Past Similar Technologies

The reason it's important to analyze the KPIs of the Hyperloop to the KPIs of similar past modes of transportation is to prevent those invested in the Hyperloop from making the same mistakes as before, if any. Those who don't learn from history are doomed to repeat it. We as researchers prioritize studying the past to ensure that the Hyperloop does not repeat the failures of the past.

Hovertrains

General Overview and Comparative Usage of Hovertrains

A hovertrain is a type of high-speed train that replaces conventional steel wheels with hovercraft lift pads, and the conventional railway bed with a paved road-like surface. It first appeared in the 1960s in France and United Kingdom. The concept aimed to eliminate rolling resistance at extremely high speed, while also simplifying the infrastructure needed to lay new lines. At high speeds on conventional rails, trains suffer from a form of instability known as "hunting oscillation" that forces the flanges on the sides of the wheels to hit the sides of the rails, as if they were rounding a tight bend. As a result, at speeds of 140 mph or over, the frequency of these hits increases to the point where they became a major form of drag, dramatically increasing rolling resistance and potentially causing a derailment. This means when travelling above critical speed, a hovercraft could be more efficient than a wheeled vehicle of the same weight because there would be less rolling resistance if the train is lifted. However, while early efforts were made for hovertrains, it was later discovered that it requires the construction of entirely new lines and a large amount of energy to provide lift to the vehicle at high speed. Therefore, in the 1970s, it gradually gave way to maglev trains, which replaced hover pads with electromagnets so that it reduced the weight of the train by 15% and saved energy. We are using hovertrain because, similar to Hyperloop, it aimed to reduce risk and cost, while increasing the speed of intercity transportation.

Examining hovertrains enables us to understand why it failed to become widely used, helping us make sure that it does not happen to Hyperloop. The Hovertrain aimed to reach a speed of 250-300 mph. However, the project ended up unsuccessful. The main reason that it failed, as discussed above, was the competition of maglev trains, its incompatibility with the current tracks, and the high energy costs. Most of the experimental tracks built are only a few miles; and the train reached at most around 200 miles¹. Since it was such a short-living project, there weren't much data concerning comfort and safety issues with hovertrain.

¹ Temperton, J. (2018, June 1). The strange tale of the hovertrain, the British hyperloop of the 1970s. Retrieved from <https://www.wired.co.uk/article/british-hyperloop-hovertrain-maglev-trains>.

Table of KPI Comparisons Between Hovertrains and Hyperloops

| | Hovertrain | Hyperloop |
|--------------------|---|--|
| Price | N/A | \$20/ 350 miles (proposed) |
| Travel time | 20 minutes over 100 miles with speed of 300 mph | 52 minutes over 350 miles with speed of 760 mph |
| Safety | <p><u>Pros</u></p> <ul style="list-style-type: none"> • N/A <p><u>Cons</u></p> <ul style="list-style-type: none"> • No data proving its safety since Hovertrain failed in testing stage | <p><u>Pros</u></p> <ul style="list-style-type: none"> • Engineered with modern technology to ensure extreme safety • Less likely to be affected by other trains <p><u>Cons</u></p> <ul style="list-style-type: none"> • Moves in enclosed space so when accidents happen might be slow to respond |
| Comfort | <p><u>Pros</u></p> <ul style="list-style-type: none"> • N/A <p><u>Cons</u></p> <ul style="list-style-type: none"> • Ride is bumpy • Only 50 - 100 seats with small leg room | <p><u>Pros</u></p> <ul style="list-style-type: none"> • Low vibrations, adequate leg room and cushioned seating <p><u>Cons</u></p> <ul style="list-style-type: none"> • No in-pod service • Can't get up and walk around |

KPI Advantages and Disadvantages the Hyperloop has Relative to Hovertrains

The Hyperloop has advantages in its speed and price. Although the Hovertrain was not commercialized, it was projected to travel from London to Birmingham, which is 100 miles in distance, in 20 minutes¹; while the Hyperloop can run at a speed more than two times of that of Hovertrain. Since the Hovertrain failed in the developmental process and Hyperloop is not yet widely used yet, there is not much data about either transportations in terms of safety and comfort. However, because of the 50 year technology gap between Hovertrain and Hyperloop, Hovertrain is hardly considered safer and more comfortable than Hyperloop. The main factors of the Hovertrain's failure were its high energy cost and the competition from Maglev trains. The energy cost of the Hyperloop should not be a problem if everything works out as Elon Musk proposed. Also, the Hyperloop does not have the same type of competition that Hovertrain faced. In fact, it has advantages, such as speed, against contemporary competitors like trains. So after comparing and analyzing Hyperloop and Hovertrain, Hyperloop does address the problems that caused the downfall of Hovertrain.

¹ Edwards, E. (2014, January 12). Hover Train (Tracked Hovercraft) Experiments, Earith-Sutton Gault. Retrieved from www.ousewashes.info/experiments/hovertrain.htm

Concorde

General Overview and Comparative Usage of the Concorde

Built by Sud Aviation and British Aircraft Corporation, the Concorde was the result of a British and French treaty. It was an incredibly fast plane with a maximum speed of mach 2.04¹, which enabled Concorde to travel from JFK to Heathrow in about 3 hours compared to about 6 hours for a Boeing 777. However, it only operated from 1976-2003² due to multiple factors. To start, the development stage was quite over budget resulting in the companies only being able to build 20 Concorde. At first, the Concorde was flown domestically as well as internationally, but the sonic boom caused by the plane breaking the sound barrier created too many complaints from residents under Concorde routes, which restricted the Concorde from being used for overseas travel. The ticket price to travel on the Concorde was quite high as well, costing about 10 to 20 times more than a regular plane ticket in 1997³, when traveling via Concorde hit its peak. The ticket price was this high because the Concorde did not seat that many people and because maintenance and fuel costs exceeded the widebody jet alternatives. Later, 9/11 led to an overall downturn in air travel, and an accident involving a Concorde killed everyone on board. This ultimately led to the discontinuation of the Concorde.

The Concorde is comparable to the hyperloop because it was revolutionary for its time period. It promised high speed travel getting passengers from point A to B much quicker than any other mode of transportation at the time. In addition, the sentiment around the Concorde was similar to Hyperloop. It was a bit mystical in a way, as many people were amazed at the technology and feat of engineering that allowed the Concorde to be possible.

Just like any mode of transportation, consumers had expectations of speed, cost, safety, and comfort. The Concorde's selling feature was its speed and it delivered. However, as discussed above, the cost was definitely a limiting factor to the average Joe trying to take a trip on this plane. With such a high ticket price, the consumers that were able to spend that amount of money were typically wealthier and used to traveling in luxury. In terms of comfort, the Concorde was far from a luxury experience, since it

was sleeker and more cramped than a regular airplane, and also short of amenities. Compared to the Hyperloop, early studies have shown that the ergonomics will be an improvement over the Concorde with modern design elements giving the cabin a spacious feeling. However, we believe the Hyperloop will lack amenities as well with no standing room and flight attendants. Safety is also a large factor in consumers' traveling decisions. After 9/11, most people were already questioning the safety of air travel in general, and with the crash of a Concorde many people developed a negative perception of its safety.

¹Dimery, Rob. "1996: Fastest Flight Across the Atlantic in a Commercial Aircraft." *Guinness World Records*, Guinness World Records, 18 Aug. 2015,

www.guinnessworldrecords.com/news/60at60/2015/8/1996-fastest-flight-across-the-atlantic-in-a-commercial-aircraft-392882.

²Lawless, Jill. "Final Concorde Flight Lands at Heathrow ." *The Washington Post*, WP Company, 24 Oct. 2003, www.washingtonpost.com/wp-dyn/articles/A11477-2003Oct24.html?noredirect=on.

³Linden, Robert van der. "My Ride on the Concorde." *Air & Space Magazine*, Air & Space Magazine, 1 Mar. 2004, www.airspacemag.com/flight-today/my-ride-on-the-concorde-6783087/.

Table of KPI Comparisons Between Concorde and Hyperloops

| | Concorde | Hyperloop |
|--------------------|---|--|
| Price | \$809/350 miles | \$20/350 miles (proposed) |
| Travel Time | 105 minutes over 350 miles with speed of 1354 mph and 1.5 hrs preflight/postflight at airport | 52 minutes over 350 miles with speed of 760 mph and 24 minutes for stops. |
| Safety | <p><u>Pros</u></p> <ul style="list-style-type: none"> Regulated by FAA <p><u>Cons</u></p> <ul style="list-style-type: none"> 109 fatality accident, seats more so more lives at risk per crash | <p>No data on safety yet but expected to be safer than Concorde</p> <p><u>Pros</u></p> <ul style="list-style-type: none"> Slower speeds modern technology Closed tube design makes Hyperloop less affected by outside hazard <p><u>Cons</u></p> <ul style="list-style-type: none"> No specific regulations yet |
| Comfort | <p><u>Pros</u></p> <ul style="list-style-type: none"> Has a onboard bathroom, serves drinks, inflight magazines <p><u>Cons</u></p> <ul style="list-style-type: none"> Lacking amenities compared to other types of air travel, uncomfortable ride | <p><u>Pros</u></p> <ul style="list-style-type: none"> Modern ergonomic seats, more comfortable ride <p><u>Cons</u></p> <ul style="list-style-type: none"> No in-pod service Can't get up and walk around |

KPI Advantages and Disadvantages the Hyperloop has Relative to the Concorde

When analyzing the KPIs we examined, the Hyperloop beats the Concorde in every category. However, there are external factors that may add up over long distances leading to the Concorde being faster such as how the Hyperloop will have an increasing number of stops as the distance increases but the time the Concorde spends at an airport is fixed. Despite this, we believe the Concorde and Hyperloop serve two different markets. The Concorde was only used for overseas travel after hundreds of noise complaints from residents living under Concorde routes were filed with the FAA. The first few iterations of the Hyperloop will probably be over land in routes such as from Los Angeles to San Francisco. Even over longer distances, the Hyperloop has the edge in every other KPI. It has a much more reasonable price tag, has much less noise pollution, and is not marred by a fatal accident. The downfall of the Concorde has to do with the small customer base that it served due to the limitation to overseas routes and the extreme premium that travelers paid compared to airfare on a normal widebody jet. Mostly business travelers were the only demographic willing to pay the high premium for shortened travel time. The average person was not willing to splurge on the sky high prices to save a couple hours and the wealthy did not like the lack of amenities onboard and overall lack of comfort. The final nail in the coffin was the fatal accident that left many questions regarding the safety of the Concorde. On top of 9/11, this led to hesitations traveling via planes in general. We believe the Hyperloop is much more affordable and has a larger potential customer base. While it has yet to prove its safety record, the common consensus as of currently in the industry is that it is very safe.

Current Technologies Comparison

Why Look at Current Similar Technologies

We examined past modes of transportation similar to the Hyperloop to learn from the mistakes that made them inefficient. Equally as important is looking at current transportation systems and making sure that the Hyperloop will be distinguishable among them. As researchers, we are tasked with making sure that the Hyperloop satisfies consumers' preferences and needs. To do this, we are also comparing the Hyperloop to similar, current modes of transportation to determine if consumers will want to ride the Hyperloop, and that it does not have the same inefficiencies that current types of transportation have. As the transportation of the future, the Hyperloop has a responsibility to provide similar, if not better, levels of KPIs for consumers. This means ensuring that the level of safety, time efficiency, moderate pricing, and comfort to not only be met, but also exceeding those of current modes of transportation.

Toyota Corolla

General Overview and Comparative Usage of the Toyota Corolla

As the most purchased car currently in the automotive industry, the Toyota Corolla gives us a good estimate of the average KPIs consumers experience when traveling in cars. Carrying up to 5 passengers and with very good fuel economy stats of roughly 30 combined mpg¹, Corolla is among one of the most environmentally friendly gas powered cars. It certainly doesn't give the most comfortable rides due to its small size and moderate interior design, but with few exceptions, cars in general won't differ much in this aspect.

Cars are a major part of current day transportation and the demand for cars is only going up. By being the most dominant mode of transportation in the present age, cars inadvertently set the standards of what consumers expect in terms of transportation. The reason why we're using the Toyota Corolla for this case study is due to the fact that the Toyota Corolla is the top selling car in the world, according to Forbes.² Since it's the top selling car in the world, using the Corolla's KPIs in regards to general consumers is a safe estimate, as not only are the KPIs a good representation of average performance in regards to other models and brands but also because many people are familiar with this model and brand over other models and brands.

1. Forbes. 2011. The world's best selling cars.

2. U.S.News. 2018. 2018 Toyota Corolla Review.

Table of KPI Comparisons Between Toyota Corolla and Hyperloops

| | Toyota Corolla | Hyperloop |
|--------------------|---|---|
| Price | \$30/350 miles (in California) | \$20/350 miles (proposed) |
| Travel Time | 5 hours 23 minutes over 350 miles with speed of 65 mph | 52 minutes over 350 miles with speed of 760 mph |
| Safety | <p>Fatalities in 100,000 population: 11.59</p> <p><u>Pros</u></p> <ul style="list-style-type: none"> • Having control over the vehicle enables driver to avoid accidents <p><u>Cons</u></p> <ul style="list-style-type: none"> • Accidents caused by other drivers sharing the road¹ | <p>Expected to be safer than driving, but no available data</p> <p><u>Pros</u></p> <ul style="list-style-type: none"> • Less likely to be affected by other trains <p><u>Cons</u></p> <ul style="list-style-type: none"> • Seats more people so more lives at stake in times of accidents |
| Comfort | <p><u>Pros</u></p> <ul style="list-style-type: none"> • Flexible resting period • Open windows <p><u>Cons</u></p> <ul style="list-style-type: none"> • Limited space • Fixed seating position • Stiff seats | <p><u>Pros</u></p> <ul style="list-style-type: none"> • More room in the cabin • More comfortable seats • Smoother ride • Shorter travel time <p><u>Cons</u></p> <ul style="list-style-type: none"> • Enclosed space |

1. MOTOR VEHICLE TRAFFIC FATALITIES & FATALITY RATE: 1899 - 2003.

KPI Advantages and Disadvantages the Hyperloop has Relative to the Toyota Corolla

In the major KPIs we look at in this study, the Hyperloop comes (or is expected to come) on top in every aspect. Based on a 42 highway mpg¹ for the Corolla, it takes \$30 to travel over 350 miles, whereas the Hyperloop, according to Elon Musk's proposal, takes \$20. We do have questions about the feasibility of such a price, but with the lack of data, it's rather difficult to draw a final conclusion. The same issue lies in terms of safety, as there's not enough data to determine precisely how safe would Hyperloop be once it enters its commercialized stage. We expect that it'll be at a close level to traditional trains, since these two share the most resemblance. Based on this expectation, the Hyperloop will be safer than cars in general. To the aspects that we have more solid information on, the Hyperloop is much faster, 760 mph vs. 65 mph, and gives smoother rides than Toyota Corolla.

1. 2018 Toyota Corolla Review. Retrieved from <https://cars.usnews.com/cars-trucks/toyota/corolla>

Amtrak

General Overview and Comparative Usage of the Amtrak

The Amtrak was originally established on May 1st, 1971, in an effort to help connect people and make transportation easier. While it started out running on just one route, Amtrak has spread to over 33 routes all over the United States¹. Through time, Amtrak has also developed high speed trains which run from Washington DC to Boston. It is evident that the Amtrak has been impactful to communities and made transportation that much more accessible for the middle class. Furthermore, the Amtrak has done a wonderful job consistently making their customers feel safe while riding and ensuring that safety comes before speed or even convenience at times. While there are other train options rather than Amtrak, Amtrak has done a great job providing comfort, safety, and good time efficiency along with providing route options that attract consumers.

If one is looking to avoid traffic or maybe don't have a car and is traveling a mid-range distance, their best mode of transportation is the Amtrak as of currently. While it may not move at a fast speed, the Amtrak will usually get a consumer to their destination safely. However, while the Amtrak is still around, it doesn't seem to be used that often, as cars still seem to be the main mode of transportation for people. Hence, by examining the Amtrak, we as researchers can see what weaknesses it has to ensure that the Hyperloop does not have those same issues. By looking closely at their KPIs we are able to see the areas in which the Hyperloop must be strong to have the consumer desirability it needs to be profitable.

¹ The Beginning of Amtrak History: How We Started | Amtrak Blog. (2014, January 02). Retrieved from <http://blog.amtrak.com/2014/01/amtrak-history>

Table of KPI Comparisons Between Amtrak and Hyperloops

| | Amtrak | Hyperloop |
|--------------------|--|--|
| Price | \$30/100 miles | \$20/350 miles (proposed) |
| Time Travel | 9 hours 30 min over 350 miles with speed of 40 mph | 52 minutes over 350 miles with speed of 760 mph |
| Safety | <p><u>Pros</u></p> <ul style="list-style-type: none"> • Trains are sturdy <p><u>Cons</u></p> <ul style="list-style-type: none"> • 4 fatal accidents in the past 2 months | <p><u>Pros</u></p> <ul style="list-style-type: none"> • 90% less accidents than Amtrak <p><u>Cons</u></p> <ul style="list-style-type: none"> • N/A because hasnt been used yet |
| Comfort | <p><u>Pros</u></p> <ul style="list-style-type: none"> • Convenient • Not too busy <p><u>Cons</u></p> <ul style="list-style-type: none"> • Lack of leg-room • medium level of vibrations • Often delayed • Poor service | <p><u>Pros</u></p> <ul style="list-style-type: none"> • Expected Low vibrations and high comfort considering time efficiency <p><u>Cons</u></p> <ul style="list-style-type: none"> • Getting to the Hyperloop could be difficult |

KPI Advantages and Disadvantages the Hyperloop has Relative to Amtrak

When riding on an Amtrak one shouldn't expect to be receiving the best service. While the Amtrak does get the consumer from one location to another, it doesn't always have the best riding experience. With lots of delays, bad in train service, and weak wifi, riders don't have the best experience on the Amtrak, especially in relation to the lack of time efficiency. Hence, when riding on Amtrak, there will likely be vibrations of the train, a lack of leg space and room, and long train trips. However, that is the price to pay when it comes to taking the Amtrak. Speaking of price, the Hyperloop is proposed to be priced cheaper than the Amtrak, allowing it to reach even more consumers. Along with price efficiency, the Hyperloop is also far more time efficient, allowing riders to get to their destination more quickly². Lastly, when it comes to safety, the Hyperloop is projected to have 90% less accidents than the Amtrak. Sadly, due to its old technology and railways, the number of accidents on Amtraks have been increasing recently. In a two month span there were 4 fatal accidents during their services³. With all of this in mind, the Hyperloop brings hope for future transportation and a safer, more time/price efficient way of traveling.

² Amtrak Tickets, Schedules and Train Routes." *Tickets & Reservations* | Amtrak, www.amtrak.com/home.html.

³ Is it Safe to Travel on Amtrak? (n.d.). Retrieved from <https://traveltips.usatoday.com/safe-travel-amtrak-108216.html>

Boeing 787

General Overview and Comparative Usage of the Boeing 787

The Boeing 787 Dreamliner is a dramatic improvement on previous plane models. Not only is it 20 percent more fuel efficient than the Boeing 767, but also dramatically better in the comfort category.¹ The cabin is relatively more pressurized and humidified, alleviating symptoms such as fatigue, dry eyes, and headaches.² There is also more space for luggage. The Boeing 787 was designed as a replacement for the Boeing 767.³

The route lengths that the Hyperloop industry are targeting are similar to routes the target routes of commercial airlines. We can assume that the Hyperloop industry and the commercial airplane industry will be competing for market space because they are targeting similar consumer needs and destinations. Each mode of transportation has its own competitive advantage. For example, the airplane clearly dominates in international travel, because the Hyperloop cannot be built across bodies of water. However, further studies of the KPIs of both structures are warranted in order to decisively tell which mode of transportation better serves consumer needs.

Table of KPI Comparisons Between Boeing 787 and Hyperloops

| | Boeing 787 | Hyperloop |
|--------------------|--|---|
| Price | \$180 dollars one way from LA to SF | \$20 for 350 miles |
| Travel Time | 91 minutes for 350 miles | 52 minutes over 350 miles with speed of 760 mph |
| Safety | <p><u>Pros</u></p> <ul style="list-style-type: none"> • Odds of dying are one in eleven million, odds of a plane crash are 1 in every 1.2 million flights <p><u>Cons</u></p> <ul style="list-style-type: none"> • Potential to be hijacked by terrorists | <p><u>Pros</u></p> <ul style="list-style-type: none"> • Tube is insulated, leading for lower chances of for fatal accidents. <p><u>Cons</u></p> <ul style="list-style-type: none"> • High potential for terrorist attacks |
| Comfort | <p><u>Pros</u></p> <ul style="list-style-type: none"> • Better than all prior planes in terms of comfort Greater cabin pressure, humidity, and space <p><u>Cons</u></p> <ul style="list-style-type: none"> • Still a little cramped for each person | <p><u>Pros</u></p> <ul style="list-style-type: none"> • Expected low vibrations <p><u>Cons</u></p> <ul style="list-style-type: none"> • No in-pod service • Can't get up and walk around |

KPI Advantages and Disadvantages the Hyperloop has Relative to the Boeing 787

The Boeing 787 Dreamliner dramatically improves on the previous model, the Boeing 767. Not only is it 20% more fuel efficient than the Boeing 767, but also better in the comfort category.¹ The cabin is more pressurized and humidified, alleviating symptoms such as fatigue, dry eyes, and headaches.² There is also the added bonus of having more space for luggage.

The proposed Hyperloop sweeps the airplane in travel time and price. While no data is out for safety and comfort yet, the Hyperloop is projected to perform very strongly in those KPIs. It is not clear whether or not it tops the statistics of the Boeing 787 and the rest of the airline industry.

To obtain data for price and travel time for price and speed, we looked for the most available Hyperloop data, cross checking it with other sources.

Initially, Elon Musk said a ticket from SF to LA would be 20 dollars. This was confirmed by our partners. A current United ticket from SF to LA is \$135, so the price range is a higher on a Boeing 787 than on a Hyperloop.

To compare the travel time of the Hyperloop to the plane, we looked up the expected travel time of the Hyperloop from LA to SF. We then looked up the flight time of a current airplane from LA to SF. It currently takes 1 hour and 31 minutes to get from LA to SF. The Hyperloop promises to travel 52 minutes on the same route, which is almost twice as quick. What the Hyperloop industry hasn't factored, yet, is the potential long check in and security process.

The Hyperloop has not yet released a safety procedure or security process, and there is not enough data to figure out the mortality rate. Planes have a mortality rate of 1 in 11 million.³

While the Boeing 787 Dreamliner has made dramatic improvements on comfort on its previous models, it has a major disadvantage because of its elevation. While it is better relative to other planes, there are issues regarding space and altitude. There is no customer comfort data for the Hyperloop yet.

In conclusion, the Hyperloop dominates the Boeing 787 when it comes to speed and cost over distance. The Hyperloop does not have any current data for safety and comfort. For mortality rates, the airplane does a decent job, with 1 in 11 million dying. Subjectively, there is quite a bit of room for comfort improvement for the Boeing 787, where discomfort is mostly due to the air pressure at flight elevation. With more data, we will be better able to compare the latter two factors.

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1. <https://www.telegraph.co.uk/travel/hubs/greentravel/7025139/Boeing-Dreamliner-the-promise-of-greener-flying.html>
 2. <https://apex.aero/2015/12/10/turning-down-the-cabin-pressure>
 3. <https://curiosity.com/topics/how-do-people-survive-plane-crashes-o53cN3Xy/>

Shanghai Maglev Train

General Overview and Comparative Usage of Shanghai Maglev

The Shanghai Maglev train, co-developed by Germany and China, connects Shanghai Pudong International Airport to Longyang Road Station. The train reaches a maximum operating speed of 431 km/h (268 mph) in the span of 29.863 km (18.6 mile)¹, which makes it the fastest Maglev train currently operating in the world. Starting in 1999 and after much debate, the Maglev began its construction in Shanghai as a testing ground for a larger scale project which would connect the city to Beijing. Because of this, the Maglev train was not a commercial success. The project cost \$1.2 billion and due to low passenger flow, Shanghai Maglev Transportation Development Co. Ltd suffered more than one billion losses from 2004 to 2006². With estimated passenger load under 50%, the Maglev train in Shanghai nowadays has gradually become more of a tourist attraction rather than a practical transportation mode, and the plan to extend the current line was also long abandoned. Shanghai citizens also expressed that they would rarely consider riding the Maglev since both its stations are located at city outskirts and the subway system provided much more convenience. Because of the high cost to run, China had shifted to the more budget friendly high speed rail system. Although related technology is still being researched, there hasn't been any plan to build more Maglev lines and the current line has remained in experiment product status.

This case study compares the Hyperloop project with the Shanghai Maglev Train as the Hyperloop is aiming more for a train-like riding experience. Therefore it is reasonable to assume similar station layout and loading process etc., which means once built and operating, the Hyperloop will provide many benefits that people look for on normal trains, and will also have to handle many issues that traditional trains encountered before. Compared to driving, trains provide people fast and effortless transportation over longer distances (e.g. between major cities, which are located fairly close by in most cases) and compared to flying which is faster, it's much easier and faster to load without the complication of an airport. We expect people who consider riding the Hyperloop to look for similar attractions when choosing their means of transportation. When the Shanghai Maglev had its first test run in 2002, the concept was still new to the Chinese public, as it was invented and mostly tested by the Germans. After the maglev

plan was abandoned in Germany due to excessive cost, the companies struck a deal with the Chinese government. Even in China, there was protests in adjacent areas expressing concerns about electromagnetic pollution³, which causes small trouble for the construction process. There was also concerns about the train's reliance on energy to be able to run, as emergency power outages would be more likely to cause indents. We see similar concerns about cost of building and maintenance regarding the Hyperloop and worry that, compared to traditional railway, the Hyperloop might also be prone to the potential harms caused by energy outages. We think there'll be similar issues Hyperloop companies will have to face when the construction plan carries out. It's beneficial to learn from the Shanghai Maglev Train to avoid similar problems and improve the feasibility of the Hyperloop.

1. TravelChinaGuide. 2018. Shanghai Maglev Train.

2. Daniel R. 2012. Shanghai's maglev passenger traffic lower than expected.

3. Xiaoci D., 2016. Public concerns over environmental impact of maglev dismissed.

Table of KPI Comparisons Between Shanghai Maglev and Hyperloops

| | Shanghai Maglev | Hyperloop |
|-------------|--|---|
| Price | \$7.53(50 Yuan) for 18.6 mile (29.863 km) | \$20/350 miles (proposed) |
| Travel time | 1 hour 35 minutes over 350 miles with speed of 268 mph (431 kph) (including 15 to 20 minutes loading time) | 52 minutes over 350 miles with speed of 760 mph |
| Safety | <p><u>Pros</u></p> <ul style="list-style-type: none"> • Safer in terms of derailment with T-shaped track design <p><u>Cons</u></p> <ul style="list-style-type: none"> • Power outages might endanger the train's normal operation since electricity is needed for levitating the train¹ | <p><u>Pros</u></p> <ul style="list-style-type: none"> • Closed tube design makes Hyperloop less affected by outside hazard <p><u>Cons</u></p> <ul style="list-style-type: none"> • Higher speed makes potential accidents more dangerous for passengers |
| Comfort | <p><u>Pros</u></p> <ul style="list-style-type: none"> • Open windows provide more natural lighting <p><u>Cons</u></p> <ul style="list-style-type: none"> • No notable disadvantages when compared to Hyperloop | <p><u>Pros</u></p> <ul style="list-style-type: none"> • Smoother ride • Shorter travel time because of higher speed <p><u>Cons</u></p> <ul style="list-style-type: none"> • May have less room than traditional outdoor trains |

KPI Advantages and Disadvantages the Hyperloop has Relative to the Shanghai Maglev Train

The Hyperloop and Shanghai Maglev train have quite a bit of similarities when it comes to customer experience. They are both very fast, with a proposed speed of 760 mph for Hyperloop and a 268 mph commercialized speed for the Shanghai Maglev. They both offer exceptional riding experience, thanks to their wheelless track design and they are both very safe to operate, as when compared to traditional trains, the chance of derailing is significantly lower. However, for the Hyperloop, there hasn't been safe testings as extensive as the Maglev trains, which has been commercially running over 15 years. The Shanghai Maglev falls behind in terms of ticket price, with \$8 for a 20 miles run. This was proven to be rather expensive for the consumers, as the company has been running at a loss for every single year of the Maglev's operation¹. The Hyperloop on the other hand, as proposed by Elon Musk and adopted by other Hyperloop companies, has a very cheap ticket price of \$20 for a much longer ride of 350 miles. However, as no Hyperloop tracks that long has been built yet, this proposed price remains largely hypothetical.

To sum up, Hyperloop beats the Shanghai Maglev trains in virtually every major KPI that we analyze, with the lack of data in some of those aspects. As of right now, we can say pretty confidently that Hyperloop will be a superior mode of transportation for consumers in terms of meeting their needs, given that further testing is still needed.

1. SOCIAL AND ENVIRONMENTAL BENEFITS. Retrieved from <https://maglevinnovation.weebly.com/social-and-environmental-benefits.html>

Future Technologies Comparison

Why Look at Future Similar Technologies

With the increase in technology and development, it's safe to say that the future of transportation is bright. Whatever that future may be, the Hyperloop must provide consumers with a similar or greater level of satisfaction as other modes of future transportation. Hence, it is important to closely examine the various KPIs to ensure that when developing the Hyperloop, we are taking into consideration the current needs of consumers. Also, it's critical to compare the Hyperloop with future modes of transportation to ensure that the Hyperloop provides services and experiences that will be on the same level of future modes of transportation.

Waymo

General Overview and Comparative Usage of Waymo

A self-driving car is a vehicle that is capable of sensing and navigating through its environment without human input. The potential benefits of self-driving cars include increased speed, safety, and customer experience, as well as reduced costs. We're using self-driving cars as a point of comparison because it is one of the most probable future modes of transportation. For this report we will be referring to Waymo - a subsidiary company of Google's parent company, Alphabet Inc. We are using Waymo because of the raw data the company has tracked through LIDAR, which is unrivaled by other companies such as Tesla. As of March 2018, Waymo's self-driving technology had driven more than 5 million miles on public roads.

Waymo's self-driving features are driven by LIDAR sensors which send out millions of laser light signals per second and measure how long it takes for them to bounce back. This projection imaging creates very high-resolution pictures of a car's surroundings. However, LIDAR can be expensive and bulky because it utilizes moving mechanical parts on top of the cars.

In order to test the self-driving equipment for safety, Waymo used a test group of vehicles, with each accompanied in the driver's seat by one of a dozen drivers with unblemished driving records and one of Google's engineers in the passenger seat. In June 2015, the team announced that their vehicles have now driven over 1,000,000 miles. Google founder Sergey Brin confirmed that there had been twelve collisions as of that date¹. Google maintains that in all the incidents up until 2015, the vehicle itself was not at fault because the cars were either being manually driven or the driver of another vehicle was at fault. Because the cars rely on pre-programmed route data, they do not obey certain situations such as potholes, harmless trash, light debris, and temporary traffic lights. Google projects plan on having these issues fixed by 2020.

Assuming that self-driving cars will become a normal form of transportation, Waymo's self-driving cars will improve the traffic flow immensely. The cars are programmed to follow the speed limit of each zone it drives through exactly, while also using sensors to keep a certain distance between vehicles for any potential disruptions. Because all the

cars are following the same speed-limit and the significant decrease in potential accidents, there will be less traffic congestion.

With the needless task of driving and the inherent risk that comes along with driving a car, customer experience will increase. The increased utility of having extra personal time (replaced by the self-driving technology) also increases customer experience. Cars are projected to have a different seating layout, where the seats will face each other instead. The different ways that cars will be formatted allows consumers to enjoy time with company during car rides. Self-driving cars may follow after the Uber model, where consumers send out their location via an app to be picked up by a car. Rather than buying cars individually, it would be a cheaper and more convenient carpool service.

1. <https://en.wikipedia.org/wiki/Waymo>

Table of KPI Comparisons Between Shanghai Maglev and Waymo

| | Waymo | Hyperloop |
|--------------------|--|--|
| Price | \$1/mile | \$20/350 miles (proposed) |
| Travel Time | 5 hours 23 minutes over 350 miles with speed of 65 mph | 52 minutes over 350 miles with speed of 760 mph |
| Safety | <p>Over 1,000,000 miles driven by June 2015 and only 12 collisions.</p> <p><u>Pros</u></p> <ul style="list-style-type: none"> Exponentially safer than present form of driving <p><u>Cons</u></p> <ul style="list-style-type: none"> Issue of liability in case of an accident | <p>Expected to be safer than driving, but no available data</p> <p><u>Pros</u></p> <ul style="list-style-type: none"> Won't be affected by outside traffic due to closed tube design <p><u>Cons</u></p> <ul style="list-style-type: none"> Damaged infrastructure/tunnels can take longer to fix and create a safety problem since maglev technology operates on a small margin of error |
| Comfort | <p><u>Pros</u></p> <ul style="list-style-type: none"> More communal seating More freedom to do work Easier to access at any time <p><u>Cons</u></p> <ul style="list-style-type: none"> People may not own their own car | <p><u>Pros</u></p> <ul style="list-style-type: none"> More comfortable seats Smoother ride <p><u>Cons</u></p> <ul style="list-style-type: none"> Not able to move as freely |

KPI Advantages and Disadvantages Waymo has relative to the Hyperloop

The Hyperloop has advantages in both travel time and price due to the nature of the transportation. Because the Hyperloop requires a lot of space to accelerate and decelerate to and from its top speed, its main purpose will be to transport consumers between cities and further distances. The Hyperloop Pods will be running inside the man-made magnetic tunnels, which is what allows the Hyperloop to have much higher speeds. After the fixed costs of building the tunnels and pods, there are only very small operating expenses left (electricity). This is what allows the consumers to ride the Hyperloop to spend so much less money per mile in comparison to self-driving cars.

The main advantage of Waymo is that it is a feasible mode of transportation for shorter or longer distances. The amount of raw data that Waymo has collected in test driving their cars is very affirming, as only one fatality has happened in over 1,000,000 miles of driving (equivalent to 75 years of driving). This level of safety is an exponential improvement compared to our current crash statistics (1.18 fatalities in 100,000,000 miles). Also, self-driving cars have a more open space during drives due to the layout of the car seats. Instead of being side by side with all the seats facing forward, seats will face each other as all the driving is controlled by A.I². There will be more time to rest, spend time with family, or just do work during these car rides.

The main negatives of Waymo is the consumer concerns and assumptions about safety. Although the data from millions of miles driven shows how safe the self-driving technology is, with only crashing 12 times in 3 years of testing, consumers are still skeptical about not having control. Liability is a huge issue with the self-driving cars and with every accident being heavily publicized, despite the heavily decreased frequency of accidents compared to the normal average of 350 daily crashes), consumers continue to doubt the safety of the self-driving cars³. Also, consumer comfort will heavily rely on Waymo and how they decide to structure the service - whether they want to let consumers buy their own self-driving cars or to utilize a ride-sharing system similar to Uber.

Overall, we believe that self-driving cars, with their versatility and other positive features, have a competitive space in the market with the Hyperloop. All of the data from millions of miles driven helps to affirm that Waymo's product is a huge innovation that will decrease the amount of fatalities from car accidents. Also, because of the nature and

size of cars, it fulfills the need to transport consumers between short distances (intra-city) and also further distances when travelling between cities or counties. It doesn't fulfill consumer needs to travel over long distances in comparison to the Hyperloop due to its inferior speed and pricing. In conclusion, we believe that Waymo will have a dominating presence in the transportation market and will fulfill a need for the consumers. However, the Hyperloop will be joining Waymo as a dominant presence in the market, as it also fulfills the same transportation needs for the consumers - but for larger distances and for a different target crowd of customers.

2. <https://www.investors.com/research/ibd-industry-themes/self-driving-cars-tesla-general-motors-google-waymo-eye-2018-milestones/>

3. <http://www.thedrive.com/news/19756/liability-concerns-make-consumers-wary-of-self-driving-cars-survey-says>

Aggregate Conclusion

Looking back at the original question “**Comparing key performance indicators of past, present, and future forms of transportation, will the Hyperloop cover the main needs of consumers better than other similar modes of transportation?**”, we can definitively state that in terms of fulfilling the main consumer needs (price, travel time, safety, and comfort) based off of currently proposed parameters, the theoretical Hyperloop does just as well or sometimes better for all four major categories when compared with the most similar modes of transportation derived from the past, present, and future.

One thing to keep in mind is that this conclusion is for a **proposed theoretical Hyperloop**. With further development of the Hyperloop, there is the possibility that these set parameters for the Hyperloop will change. If they do change, then this report will need to be adjusted and reanalyzed to determine if the Hyperloop cover the main needs of consumers better than other similar modes of transportation. Until full commercial prototyping, there will be a very high possibility that certain parameters that pertain covering the main needs of consumers (price, travel time, safety, and comfort) will change.

As we have stated in the “Introducing the question and the reasoning behind why the question should be tackled” section, it is empirical to understand that this case study’s main objective is not to give a **definitive** answer to the question presented in this report due to the fact that the industry is quite new and certain proposed parameters might change in accordance to characteristics that affect consumers’ decisions. This report rather gives the answer to this question in accordance to the proposed Hyperloop’s **current state** but more importantly creates a simplified standard structure for determining whether or not the Hyperloop covers the main needs of consumers. By doing this, researchers and those involved with the Hyperloop can refer back to this case study and adjust the analysis when specific parameters related to the main needs of consumers are changed. It is important to refer to the question asked in this case study as it is a building block to answering the economic feasibility of the Hyperloop. By determining the economic feasibility on paper rather than on full scale trials, a large sum of money can be saved by Hyperloop companies, the government, and the rest of society.

As of August 2018, this report provides the most recent analysis regarding “Will the Hyperloop cover the main needs of consumers better than other similar modes of transportation”.

Now that the question of **“Comparing key performance indicators of past, present, and future forms of transportation, will the Hyperloop cover the main needs of consumers better than other similar modes of transportation?”** has been answered and has confirmed to be in favor of the Hyperloop with the current proposed parameters, a piece of the economic feasibility question of the Hyperloop has been answered. The next step is to figure out what the average consumers’ socio-economic level will be as figuring this out will help determine how many people will be using the Hyperloop over a certain time span. We implore those who are interested in answering the overarching economic feasibility question to build on top of our findings as economic feasibility plays a huge component in allowing the Hyperloop to exist for the public in the near future.

Disclaimers

While creating this report, our team ran into issues that we couldn't realistically fix given time and resource constraints. Because of this, we have included a list of disclaimers.

1. This is by no means an exhaustive list of KPIs. We could have looked into more, but given our time constraints and need to have our report standardized, we limited it to the top four most important ones.
2. This case study made assumptions for the price of various modes of current transportation based off of samples or recurring trends of current prices. This may not have been the best representation of the actual market prices, but it was the most readily available, accurate data available to us. We conducted it like this because some of the data wasn't available yet.
3. This case study based Hyperloop prices off the news and theoretical projections, so we had no actual price data, given the system was not built yet. We applied this methodology to safety and comfort, as well.
4. This case study did not take into account insurance when working with Hyperloop prices. This is because we did not have any quantitative data for how the Hyperloop would handle insurance.
5. This case study didn't take into account the "target consumer groups" of this mode of transportation. This was also because our limited time and resources.
6. This case study didn't take into account the possibility of potential government subsidies and positive externalities provided by the Hyperloop. Like earlier, we do not have any quantitative data for how it would handle that.
7. For "travel time" this case study did not include the time it takes to get into a seat and have luggage situated due to no information being provided on this subject matter. We as researchers wanted to keep the information parallel to each other in terms of what is included in our calculations, so we did not include that information in all of our transportation.

Additional Topics that Need to be Looked Into by the Hyperloop Industry that we the Researchers Found that could be a Challenge to the Feasibility of the Hyperloop that are yet to be Answered Comprehensively

Upgradability

One major challenge that needs to be looked into that we as researchers found to be a possible roadblock later down the road of the Hyperloop is how difficult it is to upgrade the technology in the later future. As of right now, the Hyperloop is seen as a potential “vehicle of the future”. But once the future does arrive and the Hyperloop is built, the Hyperloop isn’t a “vehicle of the future anymore as it becomes the “vehicle of the present”. With technology improving at an exponential rate, there will be new modes of transportations that will start to emerge. To not become a “one-and-done” deal, the Hyperloop will have to improve itself through upgradability in order to keep up with its future potential competitors. The problem of upgradability can be seen already with modern day trains. Trains cannot go faster due to the limitations of the angle that they can turn through the hunting oscillation effect. This hunting oscillation range has been limited due to the structuring of the tracks. So for trains, the reason why upgradability is so hard to achieve is due to the fact that it is very costly to take out the old rails and add in improved ones. In fact, the tracks have stayed the same ever since the 19th century.

The Hyperloop seems to repeat the problems of trains with even greater limitation as the Hyperloop is not only restricted to a specific type of track but also the dimensions of the tube as they are fixed. Therefore, unlike trains that have a 2D base restriction for upgradability, Hyperloops have a 3D base restriction as the tube encases the pods. If it's hard enough already to upgrade trains tracks which are just two long parallel metal rails with wood boards in between, then the challenge of upgrading the tracks of the Hyperloop will be even harder. This is due to the fact that the Hyperloop's tracks are more complex than train tracks which will be more costly to upgrade, with the added fact that the tubes are fixed in diameter. We would like other researchers who are interested in this problem to take a closer look at the situation.

Just-in-time Availability Cost

Just-in-time availability is the concept that the product or service is ready for the consumer no matter what contingent problems arise. This concept usually applies to products or services that harbor a promise to their customers that speed is a priority. This can be seen in the Concorde as Air France and British Airways had to position a spare Concorde in New York in case the flight had any problems. For the company, there were airplanes sitting on the ground or in a hanger, not making any money and depreciating, just to serve as a "just in case". The Concorde had to do this because passengers expected to leave right away. The Hyperloop displays the same type of features that will make passengers expect the Hyperloop to be readily available or at least a spare one to be ready to go, as one of its key selling points is that it reduces travel time. If consumers are expected to be on hold and wait due to not having a spare pod like at an airport when something goes wrong with a person's flight, then it will lower the demand level due to negative experiences and expectations with the Hyperloop. Therefore, when looking at if the Hyperloop can become a mode of transportation of the future, it is important for those working on the Hyperloop to also calculate how many additional spare pods will be needed for each route and how much it will increase the cost of the overall Hyperloop system.

Security Process of the Hyperloop

Since the Hyperloop plans to target medium to long distance travel, while boasting reduced travel time compared to air, it is crucial for its security process to be much more simplistic than airport security check. This needs to be done so in order for the Hyperloop to have a more compelling overall travel time compared to the airplanes as the travel time will be almost be identical if security for the Hyperloop takes just as long as airplanes. Due to much higher travel speed than traditional trains, Hyperloop passengers will face more danger in times of an incident. Coupled with the fact that this is a high fixed cost system, it will attract some attention for terrorist activity. We think it is important to maintain the security check at a basic level, at the very least. It's also worth considering that initially the Hyperloop will carry considerably less passengers, which will significantly reduce the waiting time during the process. More information regarding how the security process will be conducted for the Hyperloop needs to be looked into by the Hyperloop industry.

Target Consumer Base After Initial Hype

This is an issue that does not get much mention in articles surrounding the Hyperloop. After the initially daunting expenses of developing the Hyperloop structure (tunnels and pods) and the initial excitement, the Hyperloop will be here to stay until the next big innovation. There will be the initial hype of the Hyperloop that brings in consumers due to the marketing and the public's curiosity of the technical innovation surrounding this new mode of transportation. However, companies will need to start looking at what their consumer base is, whether it's only consumers, tourists, or others, so that they can measure if the Hyperloop is a sustainable financial model to avoid operating at a loss.

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