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An Analysis of The Hyperloop's Feasibility as a Cost Efficient Solution to Public Transportation

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Abstract

With growing concerns regarding the impact of car traffic on the environment and the poor quality of existing public transport infrastructure, especially in America, it is necessary to find a cost-efficient solution to the public transportation problem. This paper examined differences between existing public transport systems and the proposed Hyperloop to determine if the Hyperloop is feasible and effective when compared to existing methods. Projections from multiple Hyperloop companies were compared against existing systems using data from various sources including the Washington Metropolitan Area Transit Authority's public records and studies conducted on cargo throughput for freight trains. A focus was placed on the three main aspects of throughput, speed, and cost per mile - comparing each transportation system with an average freeway lane as a baseline. To determine the efficiency of each system, each aspect was evaluated against the aforementioned baseline in order to provide an overall effectiveness for a transport method. Findings revealed that that if the Hyperloop meets expectations for twenty-foot equivalent unit throughput capacity, it may be a far faster method to transport cargo than freight trains, being able to move 2800 twenty-foot equivalent units per day, compared to the 1786 twenty-foot equivalent units per day moved by freight trains in Felixstowe and 1221 twenty-foot equivalent units per day in Southampton. As for passenger throughput, the proposed Hyperloop system may be less efficient than existing high speed rail systems, namely the California high speed rail system which it was intended to replace.

Keywords: Hyperloop, Public Transport, Vactrain, High Speed Rail

1. Introduction

The Hyperloop is a transportation system centered around the concept of placing magnetically suspended pods in low-pressure tubes, first appearing in 1799 before being popularized by Elon Musk in 2013 as a more efficient mode of transport in a white paper titled "Hyperloop Alpha". The system sends pods propelled by magnetic propulsion through low-pressure tubes at high speeds. Existing systems are riddled with passenger violence problems, crowding, delays, and breakdowns - thus creating the need for an efficient method for public transport which works reliably. Despite the Hyperloop being touted as a system that could entirely revolutionize cargo shipping and transportation, some question the practical feasibility of the Hyperloop. Through the analysis of projections and expectations of current Hyperloop projects and data collected on existing methods of transportation, this paper assesses the feasibility of the Hyperloop as a method for cargo shipping and public transport.

Many doubt the feasibility of the Hyperloop, both from a technical and practical standpoint. Not only do some doubt that certain aspects of the Hyperloop Alpha white paper are possible, but also in regards to whether or not the Hyperloop is a worthy investment that can perform better than technologies already available to us.

Despite the Hyperloop Alpha white paper suggesting that the concept is theoretically possible and despite having working pods already built and tested, there are still some concerns on whether having a fully constructed Hyperloop would be a feasible decision. Richard Muller, a physics professor at UC Berkeley, raised concerns about the solar

Vol. 2023 (2) 304 – 311
ISSN 2688-3651 [online]

panels Musk proposes installing atop the tubes, and whether they would be able to power the entirety of the Hyperloop (Wolverton, 2016). Contrariwise, other estimates suggest that it may be possible to power the Hyperloop on solar panels alone, though it may not be an option outside of the Southwestern US due to lower levels of solar irradiation elsewhere (Rana, 2020), and the costs for constructing the Hyperloop may vary wildly due to other geographical constraints. Should powering the system be possible with solar panels alone, there would be a significant amount of emissions savings generated from diverting travelers from automobiles. However, other factors must be considered when it comes to the environmental impact of the Hyperloop in the entirety of its life cycle from the gathering of construction materials to disposal. No extensive analysis on the other environmental impacts of the Hyperloop (other than emissions) has been conducted as of the writing of this analysis, but Hyperloop projects such as the Great Lakes Hyperloop have begun to undertake Environmental Impact Studies.

Furthermore, safety and security concerns were brought up - if the pods were to get stuck, the entire tube would be rendered useless, and no system exists which allows for pods to convert or divert from one tube to another. Not only this, but such a system may require more airlocks, further dragging down throughput (Johnson, 2013) (Wolverton, 2016). However, these are merely concerns - so far, no such quantifiable metric for the safety of the Hyperloop has been calculated, but it can be presumed that as the system operates in a closed and controlled environment, risks from the weather and collisions may be significantly reduced.

Critics have raised concerns about how current prototypes and cost projections fall short of the original proposed concept (Adam Something, 2021). Members of the public when viewing publicity material, namely videos of test runs from Hyperloop One, cite the 100mph speeds and 2-person capacity of the XP-2 prototype and liken it to "reinventing the wheel" despite having the possibility of making improvements to the technologies involved in the future. However, the cost of making these improvements may be far more effort than it's worth.

James Moore, director of the transportation engineering program at the University of Southern California, stated that the development costs are the bigger problem, rather than construction costs (Wolverton, 2016). Despite the Hyperloop Alpha white paper's initial estimates showing that the Hyperloop may be a more affordable option with estimates as low as $11.5 million per mile of tubes on a route from Los Angeles to the Bay Area, leaked documents from the company Hyperloop One revealed that a 107 mile loop along the Bay Area alone could cost anywhere from $84 million up to $121 million per mile (Konrad, 2016).

The promise of being superior to both plane and rail transport is one of the most important reasons the Hyperloop has gained traction in the media. However, even this is a subject of intense debate. Proposed as a cheaper alternative to the California High-Speed Rail system, the Hyperloop promises speeds of 760 miles per hour at projected costs of $6 billion, allowing for costs as little as $11.5 million per mile of track. In comparison, the California High-Speed Rail system would have a budget of $68.4 billion and operate at a speed of 164 miles per hour. However, other sources suggest that it would be theoretically possible to build better high-speed rail systems for less - despite the California High-Speed Rail system costing around $123 million per mile, other projects in Europe can range from $33 to $53 million per mile (Konrad, 2016).

Not only this, but the speed of the Hyperloop and how much faster individual trips for passengers will take seem to be the main perks of the system, as shown on the Virgin Hyperloop website and in the Hyperloop Alpha white paper. However, the main concern from many who oppose the Hyperloop is the passenger throughput and freight train capacity (Adam Something, 2021), as the original Hyperloop Alpha white paper proposed pods with a capacity for 28 passengers, but would be spaced out by around 23 miles or from 30 seconds to 2 minutes on average during operation. However, others doubt that 30 seconds between pods would be enough should a safety issue occur - there wouldn't be enough time to decelerate to prevent crashing (Johnson, 2013). Comparisons between the Hyperloop and the existing train system were also made, arguing that it would be more efficient to have slower cars all connected rather than much faster pods all with independent motors being launched at intervals (Adam Something, 2021).

Setting aside speed and cost, throughput is also an important factor to consider. The Hyperport, proposed by Hyperloop TT would have pods capable of carrying 2 TEUs, or Twenty-Foot Equivalent Units, (Drăgan, 2021), as stated on their website, in comparison to a mean capacity of around 55 - 60 TEUs per train in the ports of Felixstowe, Southampton, Tilbury, and Thamesport (Woodburn, 2011). Woodburn also found that rail TEU throughput in the ports of Felixstowe and Southampton were around 1,786 and 1,221 TEUs per day, respectively - in contrast to the

Vol. 2023 (2) 304 – 311
ISSN 2688-3651 [online]

2,800 TEUs per day promised by the Hyperport. It should be noted that the study only measured actual TEU throughput rather than capacity, as throughput is usually lower than theoretical maximum operating capacity. Hyperloop TT stated that their system "can move 2,800 Twenty-foot Equivalent Units, or TEUs, a day in an enclosed operating environment".

Estimates for the efficiency of passenger throughput vary wildly as well. The original white paper established that it would be possible to meet 840 passengers per hour, yet Virgin Hyperloop's proposed system is estimated to have the capacity for 50,000 passengers per hour, per direction. However, considering that a rough estimate for the time taken to decelerate to avoid collisions would probably be around 80 seconds minimum, the maximum number of passengers who would be able to depart in one hour hovers closer to 1,260 (Johnson, 2013). Even if 30-second time between departures were used during peak hours as suggested in Elon Musk's white paper, only 3,360 passengers could depart in one hour.

These estimates are not as exciting when compared to already existing transportation technologies. For instance, the California High-Speed Rail project is estimated to have a capacity of 12,000 passengers an hour, a subway running at 3-minute headways such as the WMATA Red Line can carry 36,000 passengers per hour, and a freeway lane on its own can carry 2,000 cars per hour (Johnson, 2013). Furthermore, to reach or surpass rail throughput, more tubes would be needed. As building costs are a crucial factor, more tracks may not be a viable option (Eichelberger et al., n.d.).

Prior literature has primarily conducted studies on the economic and technical feasibility of the Hyperloop, with an emphasis placed on the speed that the system is capable of. However, aside from assessing if the system is physically possible to engineer in the first place and if a market exists, little has been done to determine if the rate of passengers moving through the Hyperloop is actually more efficient in terms of throughput than other methods of transportation, rather than looking at how fast the system can move an individual passenger. As such, this paper has aimed to compare the throughput of the Hyperloop for both freight/cargo and passengers with existing methods to examine the overall cost efficiency of the Hyperloop system against existing methods of transport.

2. Materials and Methods

This research focuses on the efficiency of various different public transport methods in terms of passenger throughput, speed, and cost. The analysis is based entirely on secondary research, collected through projections and estimates provided by companies, public records, and other studies conducted on rail network efficiency, placing focus on the three main aspects of throughput, speed, and cost per mile - comparing each transportation system with an average freeway lane as a baseline, expressed as a value of 1.00. To determine the efficiency of each system, each aspect was evaluated against the baseline, with the averages of each value for throughput, speed, and cost per mile in order to provide an overall effectiveness for a transport method. The values for each individual aspect are expressed as the ratio of how much "better" it is - for example, if the passenger throughput of the baseline transportation system is 100 passengers per hour, while another system can move 120 passengers per hour, the values for the "passenger throughput" for each system is 1.00 and 1.20 respectively, (second system divided by baseline) as a higher throughput is better. Contrariwise, if the baseline system were to cost $1 million per mile whilst another cost $1.5 million per mile, the values for each system are 1.00 and 0.67 respectively, (baseline divided by second system) as a higher cost is worse. As such, a higher value indicates higher performance and lower cost. The overall "score" for a transportation system is the average of all three values for passenger throughput, speed, and cost.

It is important to note that due to a lack of previous studies, measurements, data points, and the fact that different studies have a different definition of "commercial operating speeds", the true average speed of certain systems over an entire trip may be slower than what is listed in the tables below. For the purposes of this paper, we will be using the maximum hypothetical operating speed for the Virgin Hyperloop, Hyperloop TT and Hyperloop One estimates, while the Great Lakes study has provided more accurate estimates including acceleration and deceleration between stations/during curves. For the high speed rail speed estimates (save for the California HSR), we will be using the commercial operating speed rather than the maximum operating speed - assumed to be the speed at which most vehicles are observed to travel at in free-flow, favorable conditions. The California HSR estimate was obtained by calculating average speed using the duration of the trip along with the total track distance. For the freeway estimate, a 100 kph speed was adopted, as observed in the speed limits of most urban freeways across most states in the United States. The actual observed speed may differ from this as Americans typically drive considerably faster than the speed limit under favorable weather conditions.

3. Results

3.1 Hyperloop Proposals

It is to be noted that passenger throughput and speed estimates for Hyperloop One and HyperloopTT systems are assumed to be the same as the system outlined in the Hyperloop Alpha white paper, as they intend on using the same design, while Virgin Hyperloop's design utilized a different multi-track system. Cost statistics for the Bay Area hyperloop and HyperloopTT were taken by averaging the minimum and maximum projected cost per mile. Additionally, Virgin Hyperloop and Hyperloop One are the same company (having changed their name), but have provided different estimates for different systems - and as such have been listed separately so as to avoid ambiguity. The Great Lakes study only provided a wide range of costs for the Hyperloop system overall, and as such the cost per kilometer has been averaged. More importantly, their speed estimates were calculated with a 0.1G acceleration time and deceleration needed to navigate curves along a planned route, while the other studies use a more optimistic maximum operating speed.

Table 1. A table outlining rough estimates and projections for the cost per mile, passenger throughput, and speed of several proposed Hyperloop systems.

Transportation Method	Cost (Cost/Km)	Passenger Throughput (Passengers/Hr)	Speed (Km/Hr)
Virgin Hyperloop	$7,130,000[a]	50000[b]	1080[b]
Hyperloop Alpha	$7,130,000[a]	840[a]	1220[a]
Hyperloop One (Bay Area)	$63,550,000[d]	840[a]	1220[a]
Hyperloop One (Abu Dhabi)	$32,240,000[d]	840[a]	1220[a]
Hyperloop One (Helsinki/Stockholm)	$39,680,000[d]	840[a]	1220[a]
HyperloopTT	$7,750,000[e]	840[a]	1220[a]
Great Lakes (Hypothetical, No Curves)	$38,835,000[c]	840[a]	954[c]
Great Lakes (Chicago/Cleveland)	$38,835,000[c]	840[a]	706[c]
Great Lakes (Hybrid Chicago/Cleveland)	$38,835,000[c]	840[a]	891[c]
Great Lakes (Cleveland/Pittsburgh)	$38,835,000[c]	840[a]	545[c]
Great Lakes (Hybrid Cleveland/Pittsburgh)	$38,835,000[c]	840[a]	719[c]

[a](Hyperloop Alpha, n.d.). [b](Virgin Hyperloop, n.d.). [c](HyperloopTT, 2020). [d](Konrad, 2021). [e](HyperloopTT, n.d.).

Several key points can be identified: the first of which being the vast jump between the original cost per mile estimates in the Hyperloop Alpha white paper and the Great Lakes and Hyperloop One estimates. Furthermore, it can be seen that there is another large gap between the Hyperloop Alpha proposal's initial estimate for passenger throughput and Virgin Hyperloop's proposal - Virgin Hyperloop's concept appears to be able to move nearly 60 times the amount of passengers in an hour.

Table 2. A table outlining the cost per mile, passenger throughput, and speed for several high speed rail systems in Europe, as well as the average statistics for all three individual aspects.

Transportation method	Cost (Cost/Km)	Passenger Throughput (Passengers/Hr)	Speed (Km/Hr)
Rome-Naples HSR	–	416[f]	300[f]
High Speed 1	$35,278,000[a]	–	300[a]
Naples-Salerno HSR	–	416[c]	250[c]
Mannheim-Stuttgart HSR	$12,400,000	–	280
LGV EST	$15,190,000[e]	–	320[d]
LGV Sud-Est	$6,200,000[b]	–	300[b]
Average	$17,267,000	416	292

[a]("High Speed 1", 2022). [b]("LGV Sud-Est", 2022). [c]("Naples–Salerno high-speed railway", 2022). [d](LGV EST, n.d.). [e]("LGV Est", 2023). [f](Brown, 2017).

3.2 High Speed Rail in Europe

As this paper relies entirely on secondary research, it was not possible to retrieve data for certain aspects of certain rail lines. As such, the incomplete data for each rail line has been

Vol. 2023 (2) 304 – 311
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3.3 Overall Statistics

Table 3. A table combining the statistics of the previously mentioned HSR systems and Hyperloop proposals while also incorporating statistics for the WMATA Green Line and the average American freeway lane.

Transportation method	Cost (Cost/Km)	Passenger Throughput (Passengers/Hr)	Speed (Km/Hr)
Freeway Lane	$4,774,000[j]	2000[i]	100[k]
Virgin Hyperloop	$7,130,000[a]	50000[b]	1080[b]
Hyperloop Alpha	$7,130,000[a]	840[a]	1220[a]
WMATA Green Line	$62,000,000[f]	6300[g]	121[h]
California HSR	$81,840,000[d]	12000[i]	270[i]
Hyperloop One (Bay Area)	$63,550,000[d]	840[a]	1220[a]
Hyperloop One (Abu Dhabi)	$32,240,000[d]	840[a]	1220[a]
Hyperloop One (Helsinki/Stockholm)	$39,680,000[d]	840[a]	1220[a]
HyperloopTT	$7,750,000[e]	840[a]	1220[a]
HSR Composite	$17,267,000	416	292
Great Lakes (Hypothetical, No Curves)	$38,835,000[c]	840[a]	954[c]
Great Lakes (Chicago/Cleveland)	$38,835,000[c]	840[a]	706[c]
Great Lakes (Hybrid Chicago/Cleveland)	$38,835,000[c]	840[a]	891[c]
Great Lakes (Cleveland/Pittsburgh)	$38,835,000[c]	840[a]	545[c]
Great Lakes (Hybrid Cleveland/Pittsburgh)	$38,835,000[c]	840[a]	719[c]

[a](Hyperloop Alpha, n.d.). [b](Virgin Hyperloop, n.d.). [c](HyperloopTT, 2020). [d](Konrad, 2021). [e](HyperloopTT, n.d.). [f](McGowan, 2005). [g](WMATA, 2019). [h](WMATA, 2015). [i](Johnson, 2013). [j]("Speed limits in the United States", 2023). [k](Strong Towns, 2020).

condensed by taking the average of all existing statistics, now referred to as the "HSR Composite" from hereon after. It is to be noted that the cost statistic for the Mannheim-Stuttgart HSR line was taken by averaging the minimum and maximum estimated costs, converted from 1973 Deutsche Marks - not accounting for inflation.

Despite slightly lower costs, passenger throughput and speed for high speed rail cannot compete with the Hyperloop - with the proposed system estimated to be able to reach 1220 kph compared to existing operating speeds of 250 to 320kph, and with the Hyperloop's projected 840 to 50000 passengers per hour compared to existing high speed rail systems' throughput of 416 passengers per hour.

3.4 Comparison with Baseline

Virgin Hyperloop's proposal appears to be an outlier, promising to be 12.16 times more efficient than a freeway lane, far surpassing any other proposal or existing transport method. Again, the statistics gathered from their website are most likely optimistic projections due to the lack of any existing Hyperloop system. The original Hyperloop Alpha proposal can be estimated to be 4.43 times as efficient as a freeway lane, and the California HSR project which the Hyperloop was intended to derail was found to be around 2.92 times more efficient, putting the original Hyperloop Alpha concept on top. However, it is important to note is that the Hyperloop's success hinges on its ability to maintain its speed for long periods of time - the more detailed Great Lakes speed estimates which accounted for deceleration inside of curves rarely ever had capsules reaching their maximum speed. Not only this, but a perfectly straight tube accounting for acceleration and deceleration at the beginning and ends of the trip, respectively, was estimated to only be 3.15 times as efficient as a freeway lane, only slightly more efficient overall than the California HSR project. The value of 2.92 in the California HSR also fails to account for curves, acceleration, and deceleration, though, and as such may fall even lower when measured after its completion. Furthermore, the European HSR composite showed to be only

Table 4. A table comparing the statistics of every transportation method previously mentioned against the average freeway lane, expressed as a ratio of how much "better" a transportation method is. A larger value means higher performance.

Transportation Method	Passenger Throughput	Speed	Cost per Mile	Overall
Freeway Lane	1.00	1.00	1.00	1.00
Virgin Hyperloop	25.00	10.80	0.67	12.16
Hyperloop Alpha	0.41	12.20	0.67	4.43
WMATA Green Line	3.15	1.21	0.08	1.48
California HSR	6.00	2.70	0.06	2.92
Hyperloop One (Bay Area)	0.42	12.20	0.08	4.23
Hyperloop One (Abu Dhabi)	0.42	12.20	0.15	4.26
Hyperloop One (Helsinki/Stockholm)	0.42	12.20	0.12	4.25
Hyperloop One (Abu Dhabi)	0.42	12.20	0.15	4.26
Hyperloop One (Helsinki/Stockholm)	0.42	12.20	0.12	4.25

Vol. 2023 (2) 304 – 311
ISSN 2688-3651 [online]

Table 4_Continued

Transportation Method	Passenger Throughput	Speed	Cost per Mile	Overall
HyperloopTT	0.42	12.20	0.62	2.88
HSR Composite	0.20	2.92	0.28	1.13
Great Lakes (Hypothetical, No Curves)	0.42	9.54	0.12	3.36
Great Lakes (Chicago/Cleveland)	0.42	7.06	0.12	2.53
Great Lakes (Hybrid Chicago/Cleveland)	0.42	8.91	0.12	3.15
Great Lakes (Cleveland/ Pittsburgh)	0.42	5.45	0.12	2.00
Great Lakes (Hybrid Cleveland/Pittsburgh)	0.42	7.19	0.12	2.57

1.13 times as efficient when compared to a freeway lane - though the lack of complete statistics on specific lines makes it hard to provide an accurate average.

3.5 TEU Throughput

HyperloopTT's HyperPort aims to utilize the Hyperloop as a high-speed cargo transport and freight solution, using individual pods rather than trains to move TEUs. As the studies conducted within this paper rely entirely on secondary research, it was difficult to gather TEU throughput statistics for freight trains from a wider variety of examples. Even with limited data, the Hyperport appears to have a larger TEU throughput capacity than that of the ports of Felixstowe and Southampton. It is also important to note that the 2800 TEUs per day outlined by HyperloopTT's estimates is an operating capacity rather than actual recorded throughput.

Table 5. A table comparing TEU throughput per day between rough estimates for the HyperPort's TEU throughput capacity and actual measured TEU throughput for rail freight in the ports of Felixstowe and Southampton.

Port	TEU Throughput (TEUs/Day)
HyperPort	2800[a]
Felixstowe	1786[b]
Southampton	1221[b]

[a](Drăgan, 2021). [b](Woodburn, 2011)

4. Discussion

This paper has analyzed the efficiency of various transportation methods in contrast to the proposed Hyperloop. With limited published information, many holes in existing data, and very few existing prototypes, this paper has relied heavily on optimistic estimates - most prior research was conducted on whether the Hyperloop is feasible from a technical standpoint, rather than if investing into Hyperloop technologies is worth it in the first place. The preceding analysis identified that if the Hyperloop meets expectations for TEU throughput capacity, it may be a far faster method to transport cargo than freight trains, being able to move 2800 TEUs per day, compared to the 1786 TEUs per day moved by freight trains in Felixstowe and 1221 TEUs per day in Southampton. However, the 2800 TEUs per day is an operational capacity rather than an accurate estimate of the actual amount of cargo that will move through the system, compared to the actual measured results at Southampton and Felixstowe.

Furthermore, Virgin Hyperloop's proposal stood out as an outlier, promising to be almost 12 times as efficient than a traditional freeway - though it should be noted that the statistics gathered were only projections, and that actual data may vary heavily if the Hyperloop is to be established. Additionally, current prototypes such as the XP-2 are not even close to reaching the promised capabilities of the Hyperloop, which makes it even more difficult to accurately determine if the Hyperloop can outcompete other methods of transport. Setting the Virgin Hyperloop proposal aside, the analysis determined that the proposed Hyperloop system may be less efficient in terms of passenger throughput than existing high speed rail systems, namely the California HSR system which it was intended to replace. When factoring in speed, cost, and efficiency as a whole, the Hyperloop may only be more efficient than high speed rail when it is capable of sustaining its maximum speed for long periods of time without needing to decelerate at curves - and when deceleration in non-linear routes is factored in, the Hyperloop system may even be less efficient than high speed rail overall. Again, the ability of the Hyperloop to meet its original expectations for speed is still not completely certain.

Further investigation placing a heavier emphasis on primary research, analyzing a wider range of aspects such as safety and environmental impacts, calculating the time required for a system to pay itself off, and using data from functional prototypes would be desirable in order to make a more conclusive decision on the viability of the Hyperloop

Vol. 2023 (2) 304 – 311
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as a cost-efficient transportation method as speed, throughput, and cost are not the only factors that should be considered. Quantifiable measures for safety should be obtained such as deaths per 100,000 passengers, and an extensive analysis on the environmental impacts of the Hyperloop's full life cycle should be conducted rather than simply considering its emissions while operational.

References

Adam Something. (2021, July 25). The HyperPort Is Dumb And Will Most Likely Explode [Video file]. YouTube. https://www.youtube.com/watch?v=dNzjk-kiUmQ

Adam Something. (2021, May 7). The HYPERLOOP Will Never Work, And Here's Why [Video file]. YouTube. https://www.youtube.com/watch?v=CQJgFh_e01g

Atkins. (n.d.). First Interim Evaluation of the Impacts of High Speed 1.

Decker, K., et al. (n.d.). Conceptual Feasibility Study of the Hyperloop Vehicle for Next-Generation Transport. Cleveland, Ohio; NASA Glenn Research Center.

Drăgan, O. (2021, July 7). Forget standard cargo shipping, this sustainable capsule moves at airplane speed. autoevolution. Retrieved July 23, 2022, from https://www.autoevolution.com/news/forget-standard-cargo-shipping-this-sustainable-capsule-moves-at-airplane-speed-164816.html

Eichelberger, M., et al. (n.d.). High-Throughput and Low-Latency Hyperloop. Z ̈urich, Switzerland; ETH Z ̈urich.

HyperloopTT. (2022, May 18). Feasibility study. HyperloopTT. Retrieved September 27, 2022, from https://www.hyperlooptt.com/projects/feasibility-study/

Johnson, M. (2013, August 14). Musk's hyperloop math doesn't add up. Greater Greater Washington. Retrieved July 23, 2022, from https://ggwash.org/view/32078/musks-hyperloop-math-doesnt-add-up

Konrad, A. (2016, November 18). Leaked hyperloop one docs reveal the startup thirsty for cash as costs will stretch into billions. Forbes. Retrieved July 23, 2022, from https://www.forbes.com/sites/alexkonrad/2016/10/25/hyperloop-one-seeks-new-cash-amid-high-costs/?sh=154c4ba8125c

McGowan, P. (2019, August 18). Fort Meade proposes metro extension. Baltimore Sun. Retrieved September 27, 2022, from https://www.baltimoresun.com/bal-md.ar.bases09jun09-story.html

Milne, A. (2017). Napoli Afragola – Italy's remarkable new station. RailEngineer. Retrieved October 1, 2022, from https://www.railengineer.co.uk/2017/06/28/napoli-afragola-italys-remarkable-new-station/

Rana, Y. (2020). On the feasibility of the Hyperloop Concept. Retrieved July 23, 2022, from https://dspace.mit.edu/handle/1721.1/127876.

Shrikant, A. (2018, September 26). Why US public transportation is so bad - and why Americans don't care. Vox. Retrieved July 23, 2022, from https://www.vox.com/the-goods/2018/9/26/17903146/mass-transit-public-transit-rail-subway-bus-car

Strong Towns. (2020, January 27). How much does a mile of road actually cost? Strong Towns. Retrieved September 27, 2022, from https://www.strongtowns.org/journal/2020/1/27/how-much-does-a-mile-of-road-actually-cost

The Antiplanner. (2020, November 8). 10 reasons not to build high-speed rail. The Antiplanner. Retrieved October 2, 2022, from https://ti.org/antiplanner/?p=17764

Thompson, D. (2020, February 12). California bullet train adds another $1.3 billion to projected price tag. Los Angeles Times. Retrieved October 2, 2022, from https://www.latimes.com/california/story/2020-02-12/california-bullet-train-adds-another-1-billion-to-projected-costs-for-project

Vol. 2023 (2) 304 – 311
ISSN 2688-3651 [online]

Un nouvel espace temps avec des TGV circulant à 320 km/h. LGV EST. (n.d.). Retrieved October 1, 2022, from http://www.lgv-est.com/rff-construit-la-lgv.php?pg=289. Archived at https://web.archive.org/web/20040506050638/http://www.lgv-est.com/rff-construit-la-lgv.php?pg=289

Virgin Hyperloop. (n.d.). Retrieved October 23, 2022, from https://virginhyperloop.com/
Wikimedia Foundation. (2022, August 22). Speed limits in the United States. Wikipedia. Retrieved September 27, 2022, from https://en.wikipedia.org/wiki/Speed_limits_in_the_United_States

Wikimedia Foundation. (2022, February 10). Naples–salerno high-speed railway. Wikipedia. Retrieved October 1, 2022, from https://en.wikipedia.org/wiki/Naples%E2%80%93Salerno_high-speed_railway#cite_note-tr32008-1

Wikimedia Foundation. (2022, September 28). High speed 1. Wikipedia. Retrieved October 1, 2022, from https://en.wikipedia.org/wiki/High_Speed_1

Wikimedia Foundation. (2022, September 5). LGV Sud-Est. Wikipedia. Retrieved October 2, 2022, from https://en.wikipedia.org/wiki/LGV_Sud-Est

Wikimedia Foundation. (2023, May 29). LGV Est. Wikipedia. Retrieved August 20, 2023, from https://en.wikipedia.org/wiki/LGV_Est

Wikimedia Foundation. (2023, August 19). Speed limits in the United States. Wikipedia. Retrieved August 20, 2023, fromhttps://en.wikipedia.org/wiki/Speed_limits_in_the_United_States

WMATA. (2015). 2015 METRO FACTS.

WMATA. (2019). Metrorail Average Weekday Passenger Boardings.

Wolverton, T. (2016, August 12). Wolverton: Elon Musk's Hyperloop hype ignores practical problems. The Mercury News. Retrieved July 23, 2022, from https://www.mercurynews.com/2013/08/13/wolverton-elon-musks-hyperloop-hype-ignores-practical-problems/

Woodburn, A. (2011, April). An Investigation of Container Train Service Provision and Load Factors in Great Britain. Retrieved July 23, 2022, from https://www.researchgate.net/publication/237397871_An_Investigation_of_Container_Train_Service_Provision_and_Load_Factors_in_Great_Britain.