

Effects of the Introduction of the Hyperloop on Existing Supply Chains

Malick Ndiaye

Department of Industrial Engineering
American University of Sharjah
Sharjah, United Arab Emirates (UAE)
mndiaye@aus.edu

Philip Jarouj, Hassan Sobh, Ali Eisa Almheiri, Anas Azzouz

Industrial Engineering Graduates
College of Engineering, Department of Industrial Engineering
American University of Sharjah
Sharjah, United Arab Emirates (UAE)
pjsy801@outlook.com
hesobh@gmail.com
alialmheiri99@gmail.com
anas.azzuouz@gmail.com

Abstract

The hyperloop is an upcoming transportation technology promising to revolutionize the way people and cargo are transported, given the sheer speed advantage that a hyperloop pod can travel in as compared to that of any other current land-based transportation mode. Using secondary sources to theoretically examine the effects of the hyperloop on existing supply chains, further point estimates are obtained surrounding different variables of the hyperloop such as its speed, carry capacity, and launch rate. A preliminary investigation is then conducted in the context of northern Germany, where 19,360,000 tons of cargo were transported in 2013 using trucks. As such, a mirrored hyperloop-based supply chain is modelled, simulated, and compared to that of the control, using Arena. It is estimated that the hyperloop could have transported 8% more cargo within the same time period, where it is seen that 26% more hyperloop pods are dispatched when compared to trucks, as per the simulation output.

Keywords

Hyperloop Transportation Technology, Supply Chain Capability, Arena Simulation, Transportation Modes

1. Introduction

The hyperloop is a new transportation concept currently in development, promising the ability of transporting cargo and passengers in a point-to-point like system fashion, where individual hyperloop pods can achieve speeds of up to 1200 kilometers per hour when travelling between any two points (Werner 2016). Whilst the advantages to such a technology is significant, potentially revolutionizing the ways cargo and people are transported, actual implementations of the hyperloop remain to be seen and hence, a level of uncertainty exists surrounding the real capabilities of the hyperloop.

Using real world data, this paper includes a preliminary investigation that aims to examine the significance of the potential supply chain capability improvement provided by the hyperloop, given that limited research and development has been completed surrounding the hyperloop since its announcement in 2013. Using data which describes hyperloop capabilities in terms of its travel speed and cargo-carrying capacity amongst other variables, the time needed to transport a specified volume of cargo using the hyperloop as opposed to that having been transported using existing transportation modes is compared. Hence, a figure representing the extent to which hyperloops can enhance existing supply chains is achieved.

With multiple hyperloop projects currently in development worldwide, some of them having reached the late phase of testing/development, it would be appropriate to initially determine how such an upcoming technology compares to existing transportation modes theoretically and hence, studying the extent to which the hyperloop can affect existing supply chains. Specifically, the aim is to examine whether the hyperloop can integrate into existing supply chains and transportation modes and as such, empower supply chains by offering improvements in costs, delivery time, volume delivered, amongst other indicators.

This study seeks to suggest a means to which performance indicators of today's supply chain systems can be significantly improved. With variables such as location, inventory, and demand affecting current supply chain networks (Chopra and Meindi 2015) the primary and secondary research presented in this paper aims to tackle the constraints developed by these variables. Moreover, stakeholders might alter their business decision-making processes based on the development and implementation of hyperloops.

2. Literature Review

Supply chains of the future are smart. A smart supply chain is one that is fluid, clean, safe, secure, and cost efficient, where one way that a supply chain can fulfill all such mentioned criteria is by being autonomous (Lehmacher 2017). The hyperloop is an upcoming technology that can act as the main driving factor of building an autonomous supply chain. The hyperloop is a high-speed intercity transportation mode, consisting of two elevated parallel tubes that extend across the surface, being supported intermittently by pylons (Taylor et al. 2016). Most of the air inside the tubes are pumped out, creating a partial vacuum that allows for small pods to travel across the length of the tube at high speed as air resistance is significantly reduced, where the whole system can be powered using solar panels (Taylor et al. 2016).

2.1 Comparison of the Hyperloop Against Current Transportation Technologies

Whilst such pods of the hyperloop can transport both passengers and cargo, this paper will focus on the analysis of the hyperloop in a supply chain in terms of its cargo-carrying ability. As such, it would be important to initially compare how the hyperloop would compete with existing transportation technologies across the different transportation media: air, land, and sea.

In reference to air transportation, it is the most probable case that freight which is transported by air would most likely benefit from the emergence of the hyperloop. This is since air transport is usually utilized to deliver goods quickly over long distances, where such deliveries are time sensitive, highly valuable, or perishable (Taylor et al. 2016). As such, the speed of the hyperloop, in addition to its point-to-point movement represents a good match to transport such types of cargo, especially considering the significant cost associated with air transportation as compared to other traditional transportation modes. In this context, the hyperloop represents a more economical alternative to air transportation.

On the other hand, it is not probable that the hyperloop can replace trucks in reference to land transportation modes, as the latter would form a critical component surrounding the functioning of the hyperloop in the first place. Using trucks, cargo will be transported and unloaded at the hyperloop origin stations, where trucks will also be needed to load and transport the same cargo to its destination, adding much time to a roughly 800km trip (the maximum length of a hyperloop track), that of which can be covered by a truck in one day anyway (Taylor et al. 2016). Similarly, cargo weight and volume remain to be at the advantage of other land-based transportation modes such as trains, especially so in the case that such cargo is not time sensitive (Taylor et al. 2016).

Finally, whilst the only possible modes of transportation across the sea are either by planes or ships, indicating that this transportation medium can benefit significantly from an additional transportation mode, the range limit of a hyperloop track makes it unlikely for the hyperloop to compete in this medium (Taylor et al. 2016). Yet, 'Hyperloop one' describe a potential use of the hyperloop to expand on the normally capacity-strained ports, by unloading cargo from ships directly onto a hyperloop track to be taken to an off-shore facility for sorting and hence, increasing the sorting capacity of the port (Taylor et al. 2016) and indirectly empowering sea transportation.

2.2 Comparison of the Hyperloop Against Supply Chain Drivers

Supply chains have many drivers of which affect its performance, leading industries to continually strive to reduce costs and maintain a competitive advantage. The supply chain cost drivers to be discussed in this paper are pricing (broken down into investment and transportation costs) and inventory, where the hyperloop is examined in reference to its potential effect on such drivers.

2.2.1 Transportation costs

A factor to consider within the design of a supply chain is such that each stage of the chain must add value to its flow of goods. This factor can also be translated as being the total value added to the product at the end of the supply chain (Chopra and Meindi 2015). Value added can be maximized by minimizing costs, where the hyperloop is positioned to be the best transportation mode in minimizing costs at a marginal level, in reference to the transportation costs per kilometer as per Table 1 below:

Table 1: Costs for high-performance transportation technologies (Markvica et al. 2018)

	Station Costs	Track Costs	Transport Costs
Hyperloop	€ 200 mio	€ 40 mio per km	€ 0.05 per ton per km
Freight airships	€ 100 mio	€ 1 mio per km	€ 0.45 per ton per km
Cargo-Sous-Terrain	€ 150 mio	€ 45 mio per km	€ 1.10 per ton per km

2.2.2 Investment Costs

One of the main strategic decisions that must be made in the design of a supply chain network is the location of the suppliers, manufacturers, distributors, retailers, and customers. Performing changes to a supply chain design even when within the early stages of development is difficult, as significant time and money resources would have already been invested (Chopra and Meindi 2015). Furthermore, an alteration of decision making may incur additional costs. To help with such, mathematical models can be developed and designed such that the distances travelled between all supply chain nodes are minimized to achieve an optimal design. This approach requires factors such as the environment, demand, frequency of shipments, warehousing costs, and many more to be considered as constraints whilst building the model. The extents of such constraints seem to vary based on the available capital and ensuing operating costs, and it is from this angle that the introduction of hyperloops in a supply chain network may enhance such mathematical models.

This is since Markvica et al. (2018) developed a model to compare freight airships and cargo-sous-terrain, to high-speed modes of transportation such as hyperloops. The mathematical model was subject to a small scenario experiment which has shown that due to the required high investment costs of hyperloops, cargo air shipping is the cheapest method of transportation, whereas taking investment costs out of the equation results in the hyperloop being the lowest cost transportation mode.

2.2.3 Inventory

Uncertainty is a key aspect in supply chain management as the response to supply and demand is heavily dependent on forecasting. As such, inventory is employed to handle demand uncertainty, although such a solution adds additional costs due to the warehousing and transportation needed to accommodate such excess stock.

As a result, inventory management techniques such as just in time (JIT) have been developed to help eliminate waste and associated costs. This is since JIT focuses on increasing efficiency by optimizing order cycles such that a goods shipment always arrives at the exact point when warehouse stock decreases to zero (Nahmias 2015). Good data analysis of demand is vital in producing accurate forecasts of which determine the extent of success of JIT. Given the nature of any forecast however, a certain level of safety stock is required to help satisfy unpredicted demand (Meng 2006).

Research has been conducted on the effectiveness of high-speed networks using an adaptive genetic algorithm. For instance, Zhang et al. (2020) focuses on “an integrated optimization model of the location–inventory problem for EMU [electric multiple-component] component distribution that incorporates the location cost of a DC [distribution center], inventory cost, the linear transportation cost from the distribution center to the EMU depot, and the penalty cost.” EMU refers to autonomous trains that use electricity to travel – such trains are known for their high speeds and pollution-free operations, akin to the hyperloop. The research was tasked to answer the following three questions:

- The number and locations of distribution centers (DC)
- The allocations from suppliers to the distribution centers and from the distribution centers to the EMU depots, and the choice of transportation modes
- The distribution center optimal order quantity, reorder point, and safety stock.

The results show that as the service level of an operation increases, stockout costs decrease whilst the transportation costs increase. Additionally, operations with higher stockout costs are better suited for higher speed transportation modes (Zhang et al. 2020). Ultimately, the implications of lower stockout costs are such that safety stock level can also be decreased.

2.3 Current Hyperloop Projects Worldwide

The progress of hyperloop projects around the world follow an almost exponential trend over the years, due to the need and demand for faster transportation methods. The hyperloop idea was first developed by JumpStarter Inc. with the objective of introducing new disruptive innovation to the traditional transportation industry. It was then first proposed by Elon Musk with the idea of travelling between Los Angeles and San Francisco – a trip that would roughly take thirty minutes with a speed of around one-thousand kilometers per hour. As such, several governmental organizations adapted the idea and started funding it to make it viable in their areas. For instance, since March 11th, 2016, the Slovakian government met with JumpStarter Inc. to sign an agreement of exploring the idea of building a local Hyperloop system, with the vision of creating future routes connecting Bratislava with Vienna and Budapest (PR Newswire 2016).

Other projects include that of the Hyperloop Transportation Technology (HTT) announcing the signing of an agreement with the city of Toulouse in France on January 24th, 2017, to open a facility for the development and testing of Hyperloop-related technologies (PR Newswire 2017) where construction was scheduled to have completed by early 2018 at HTT's research and development center in Toulouse, France, for integration and optimization (PR Newswire 2017). Another example lies in the emirate of Abu-Dhabi in the United Arab Emirates (UAE) to start implementing the hyperloop idea since March 28th, 2017, named as Virgin Hyperloop, to connect the cities of all gulf-corporation council (GCC) countries, with the purpose of allowing travel between cities in the GCC in under an hour, enabling new opportunities in manufacturing, warehousing, and supply chain distribution (Virgin Hyperloop 2020). Furthermore, it was predicted from 2018 that the pods will be put into operation as soon as 2020 (Eldredge 2018), but such has not yet materialized.

To shed light on the current infrastructure for transportation in the UAE and the GCC, the UAE only has one railway in the country that connects the emirates of Abu Dhabi, Dubai, and Sharjah, being built slightly over ten years ago (Railway Technology 2011). The Gulf Railway, a project having been announced in 2018, is to be the first railway system between GCC countries, indicating that the region needs vast improvement in freight transportation, as GCC countries are currently limited by if not heavily reliant on road transportation. The Hyperloop has been mostly marketed in the UAE as the fastest mean of transportation for passengers, but investing in it as a freight transportation

mode can result in significant strategic advantage gains.

An equally important hyperloop ambition having been launched since February 21st, 2018 is that by prince Mohammed Bin Salman, of starting a foundation in Riyadh, Saudi Arabia, called MISK, to (Virgin Hyperloop 2020):

provide students with an opportunity to work alongside some of the world's brightest engineers as they develop and build systems for the Hyperloop, a new mode of transportation that moves freight and people quickly, safely, on-demand and direct from origin to destination [pp. 3].

This is since the hyperloop ambition of Saudi Arabia aims to establish a hyperloop link between the cities of Jeddah and Abu-Dhabi (Arab News 2020) with other plans to link the cities of Mecca and Neom, and as such establishing a hyperloop network which allows for all major cities in the GCC area to be between in reach within the hour which is paramount in establishing an even more connected GCC entity (Kumar 2020).

Finally, perhaps the most recent major hyperloop project is currently in the works in India, with the approval of Virgin Hyperloop One's plan of 2019 which plans to link the cities of Mumbai and Pune by means of a direct trip that would span 35 minutes only, compared to that of the current three and a half hours that is otherwise needed when traversing the distance by car (Ravenscroft 2019). Importantly, it is widely believed that this project may be the first of its kind to be completed and as such, become the first real hyperloop project to function worldwide (Ravenscroft 2019).

2.4 Hyperloop in Europe Case Study

Figure 1 below shows, in the context of Europe, how the transportation of freight using rail remains stagnated, compared to a considerable increase of total inland freight as a result of road transportation increasing in that time period (Crozet et al. 2014), suggesting that Europe has been increasingly reliant on road transportation for industry shipments. Europe is a continent that is largely unseparated by bodies of water which facilitates this mode of transport for many industries based in the continent and transport goods on it as well.

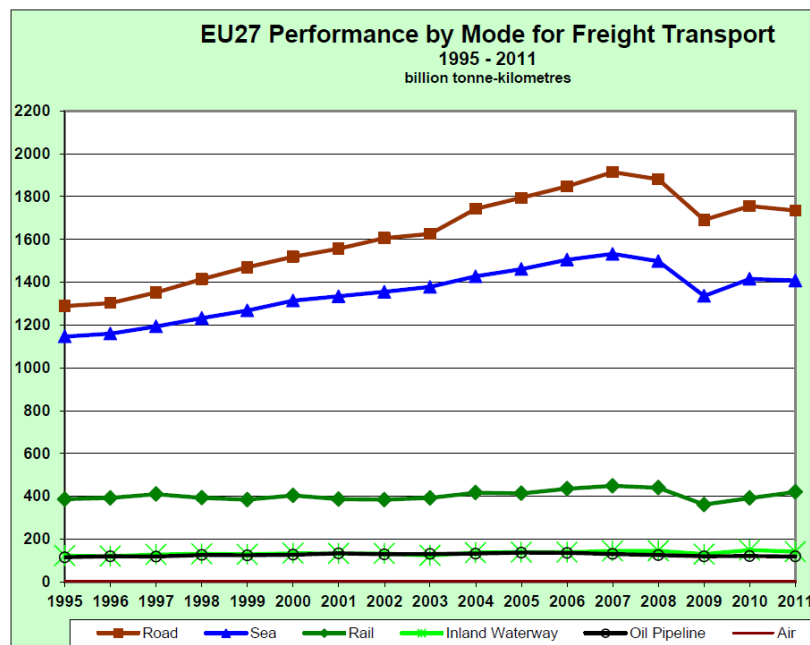


Figure 1: Amount of freight transported by each mode of transport in Europe, being road (red), rail (green), and inland waterways (purple)

Commercially, the expectation is to have 2 million trips worth of unattended demand by the year 2035 according to the EU, which alludes to the shortage of trips that can be on hand at the time in terms of potential goods to be delivered as well (Alves 2020). Whilst flights are currently the fastest way to get people or cargo from points A to B, serving as the silver lining to the financial and environmental costs, distances covered by most trips in Europe are not great

meaning that air travel would only transport cargo in a manner that is marginally faster than the other modes. Consequently, air travel remains unpopular in Europe.

Hyperloops are currently set to be able to cover distances between 300 km – 500 km between city center stations, with a trip departing every 30 seconds to two minutes (Werner 2016). According to Table 2, many of Europe’s major cities lie within 1000 km or less from each other. By the current projection of the hyperloop’s speed, that would take 18 – 30 mins to get between cities that are 300 – 500 kilometers apart. If they are further apart, more stations will be allocated between them due to the distance between stations’ constraint currently estimated.

Table 2: Distances between major European cities (Engineering Toolbox 2020)

Distance (km)	Amsterdam	Antwerp	Athens	Barcelona	Berlin	Bern	Brussels	Calais	Cologne	Distance (km)	Copenhagen	Edinburgh	Frankfurt	Geneva	Genoa	Hamburg	Le Havre	Lisbon	London
Amsterdam	-	160	3082	1639	649	875	209	385	280	Amsterdam	904	1180	471	1014	1310	455	670	2300	494
Antwerp	160	-	2766	1465	723	704	46	211	237	Antwerp	861	1005	427	840	1136	557	453	2126	337
Athens	3082	2766	-	3312	2552	2627	3021	2976	2562	Athens	3414	3768	2382	2692	2242	2758	3394	4578	3099
Barcelona	1639	1465	3312	-	1899	913	1419	1399	1539	Barcelona	2230	2181	1284	758	946	1856	1336	1266	1512
Berlin	649	723	2552	1899	-	986	782	936	575	Berlin	743	1727	570	1141	1188	291	1189	3165	1059
Bern	875	704	2627	913	986	-	655	854	583	Bern	1392	1643	424	155	448	906	767	2179	975
Brussels	209	46	3021	1419	782	655	-	212	219	Brussels	1035	996	409	674	1090	586	407	2080	328
Calais	385	211	2976	1399	936	854	212	-	431	Calais	1075	792	621	820	1213	798	284	2050	123
Cologne	280	237	2562	1539	575	583	219	431	-	Cologne	730	1206	190	765	1061	446	576	2294	538
Copenhagen	904	861	3414	2230	743	1392	1035	1075	730	Copenhagen	-	1864	799	1531	1552	321	1531	3115	1196
Edinburgh	1180	1005	3768	2181	1727	1643	996	792	1206	Edinburgh	1864	-	1395	1536	1922	1555	1074	2879	656
Frankfurt	471	427	2382	1284	570	424	409	621	190	Frankfurt	799	1395	-	585	881	497	758	2544	727
Geneva	1014	840	2692	758	1141	155	674	820	765	Geneva	1531	1536	585	-	568	1082	757	2024	867
Genoa	1310	1136	2242	946	1188	448	1090	1213	1061	Genoa	1552	1922	881	568	-	1378	1233	2212	1253
Hamburg	455	557	2758	1856	291	906	586	798	446	Hamburg	321	1555	497	1082	1378	-	1082	2666	887
Le Havre	670	453	3494	1336	1189	767	407	284	576	Le Havre	1531	1074	758	757	1233	1082	-	1894	406
Lisbon	2300	2126	4578	1266	3165	2179	2080	2060	2294	Lisbon	3115	2879	2544	2024	2212	2666	1894	-	2210
London	494	337	3099	1512	1059	975	328	123	538	London	1196	656	727	867	1253	887	406	2210	-
Luxembourg	371	280	2744	1137	767	429	233	414	195	Luxembourg	1106	1206	249	484	887	761	512	2165	538
Lyon	995	821	2774	644	1289	317	671	755	830	Lyon	1586	1552	640	162	541	1137	692	1784	884
Madrid	1782	1608	3940	628	2527	1541	1562	1542	1776	Madrid	2597	2372	1906	1386	1574	2409	1376	638	1704
Marseille	1323	1149	2997	515	1584	598	999	1083	1208	Marseille	1914	1860	1004	443	431	1465	1020	1781	1192
Milan	1154	980	2280	1102	1168	347	934	1057	905	Milan	1671	1883	725	412	156	1222	1087	2368	1215
Munich	875	832	2210	1349	604	436	811	998	592	Munich	1204	1743	383	591	707	755	1038	2515	1075
Naples	2070	1894	2784	1704	1806	1261	1848	1971	1819	Naples	2585	2664	1639	1326	758	2136	1991	2970	1996
Nice	1435	1261	2570	685	1610	638	1277	1195	1265	Nice	2014	2015	1085	483	204	1565	1132	1951	1347
Paris	515	340	3140	1125	1094	556	294	274	508	Paris	1329	1082	592	546	1006	880	211	1786	414
Prague	973	870	2198	1679	354	766	911	1082	659	Prague	1033	1872	552	954	1007	1235	1305	2945	1204
Rome	1835	1660	2551	1471	1573	897	1615	1738	1586	Rome	2352	2467	1406	1093	525	1903	1758	2737	1799
Rotterdam	80	100	2826	1565	697	802	146	311	254	Rotterdam	813	1100	444	940	1236	486	553	2226	432
Strasbourg	683	544	2581	1072	801	232	488	627	402	Strasbourg	1158	1412	212	371	667	709	667	2212	744
Stuttgart	703	659	2428	1263	636	350	641	792	395	Stuttgart	1178	1534	205	505	688	729	832	2377	866
The Hague	56	139	3061	1589	712	825	170	352	283	The Hague	960	1142	463	964	510	560	577	2250	473
Turin	1264	1090	2250	892	1172	312	1044	1110	1015	Turin	1527	1786	835	304	186	1332	1047	2158	1118
Venice	1449	1275	1995	1327	1108	642	1229	1352	1072	Venice	1708	2146	1020	707	381	1259	1382	2593	1478
Vienna	1196	1180	1886	1989	666	907	1134	1346	915	Vienna	1345	2098	725	1055	983	896	1496	3255	1233
Zurich	861	687	2449	1036	863	123	641	764	612	Zurich	1378	1631	432	278	641	929	767	2302	963

Many privately owned European companies can yield gains from a hyperloop supply chain on the continent. For instance, large hypermarkets seem to follow ‘on shelf availability’ to minimize inventory costs. However, demand uncertainty remains to disrupt such efforts, consequently acting as a force that continually increases inventory costs. If such hypermarkets have access to a mode of transportation that can replenish their needs within the time ranges discussed, then it is then possible for such firms to realize a hefty reduction in inventory costs because of the ability of reducing the number of warehouses that supply the different stores in different cities.

3. Data Collection

Focusing on a specific part of Europe, Werner (2016) provides enough data concerning the hyperloop and trucks in northern Germany, considering three source cities and three destination cities, where each sourcing city can provide for any of the destinations. Moreover, the distance from each source to the destination is given as per Table 3:

Table 3: Distances (Length) and travel time between each of the three source cities (Kiel, Lubeck, and Hamburg), and their intended destinations (Werner 2016)

Course section	Length (km)	Acceleration (m/s ²)	Max speed (km/h)	Acceleration time (s)	Acceleration distance (km)	Travel time (s)	Average speed (km/h)
Kiel-Hamburg	107	4.905	1220	69.09	11.71	384.83	1000.97
Kiel-Bremen	224	4.905	1220	69.09	11.71	730.07	1104.55
Kiel-Bremerhaven	285	4.905	1220	69.09	11.71	910.07	1127.38
Lübeck-Hamburg	76	4.905	1220	69.09	11.71	293.35	932.67
Lübeck-Bremen	177	4.905	1220	69.09	11.71	591.39	1077.47
Lübeck-Bremerhaven	246	4.905	1220	69.09	11.71	794.99	1113.97
Hamburg-Bremen	110	4.905	1220	69.09	11.71	393.68	1005.89
Hamburg-Bremerhaven	165	4.905	1220	69.09	11.71	555.98	1068.39
						Total average	1053.91

Given that the average speed for trucks in Germany is around 69 to 78 Km/h (Werner 2016), the speed of the trucks considered is taken to be the median of that range at 74 Km/h and hence, the time taken for a truck to travel from each source to each destination is calculated and shown in Table 4. Otherwise, the time taken for a hyperloop pod to complete the same trips are previously shown in Table 3.

Table 4: Length and travel time for each route that is being simulated

Course section	Length (km)	Travel Time (Hours)
Kiel – Hamburg	107	1.45
Kiel – Bremen	224	3.03
Kiel – Bremerhaven	285	3.85
Lubeck – Hamburg	76	1.03
Lubeck – Bremen	177	2.39
Lubeck – Bremerhaven	246	3.32
Hamburg – Bremen	110	1.49
Hamburg - Bremerhaven	165	2.23

4. Methodology

To display or simulate the process of comparing between the hyperloop and another transportation mode, the Arena software is utilized.

In the built Arena model of figure 2 which replicates the course sections studied in Werner (2016)'s case study, of which are displayed in tables 3 and 4, the time between arrivals for the entities, in this case tons of freight, are constant and equal to one hour for both the hyperloop pods and trucks, where this is the first assumption made. The second assumption is that a truck can load up to 15 tons of cargo, where one hyperloop pod can load up to 12 tons, as stated by Werner (2016). Batching modules are placed to simulate a launch of a truck or hyperloop pod when the number of entities reaches 15 or 12 respectively. The third assumption made is that the probabilities of a truck or a pod to go to either destination are equal. For instance, the probability to go from Kiel to Hamburg, Kiel to Bremen, or Kiel to Bremerhaven, are all equal to 0.333. However, in the case of the city of Hamburg, there only exists two destinations from this city, meaning that the probability of a truck or pod to be dispatched to either Bremer or Bremerhaven is 0.5. Finally, a processing module is set to be a plain delay for all course sections, where the delay times are based on the time taken for a hyperloop pod or truck to travel from the source to its destination as per tables 3 and 4, simulating the act of the trucks/hyperloop pods travelling.

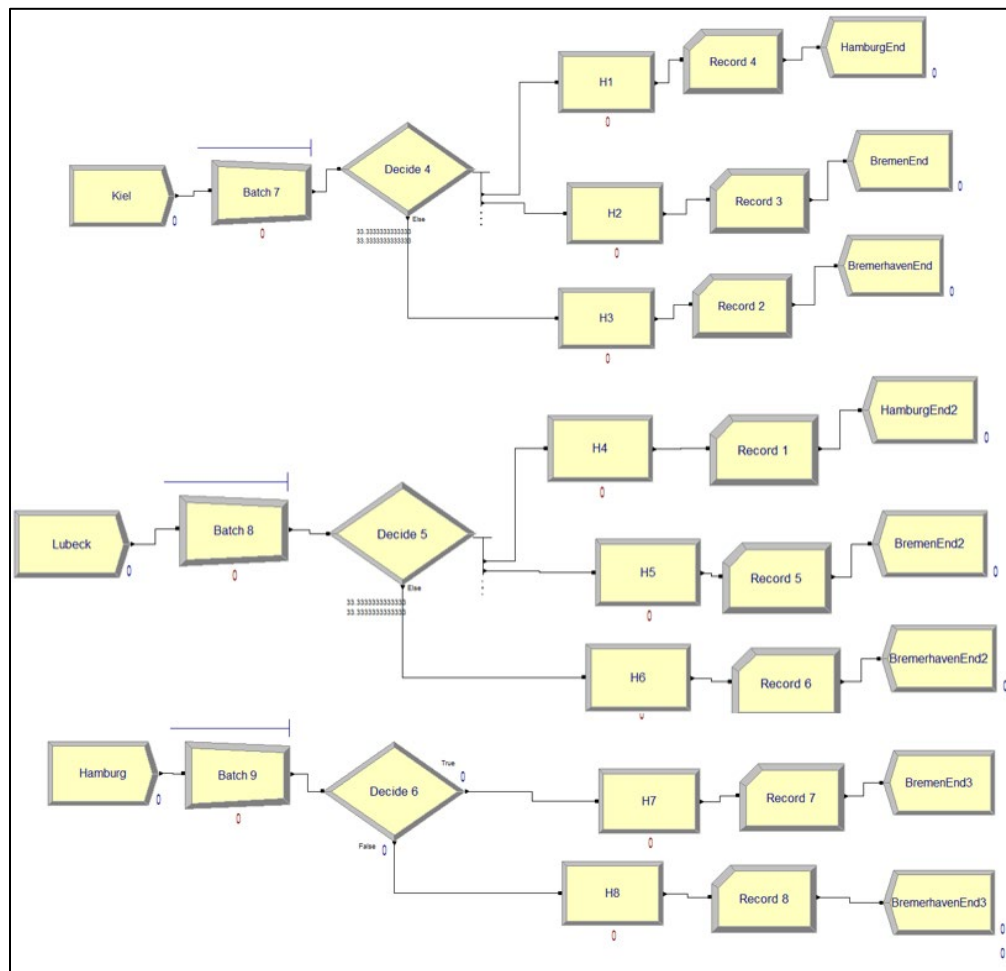


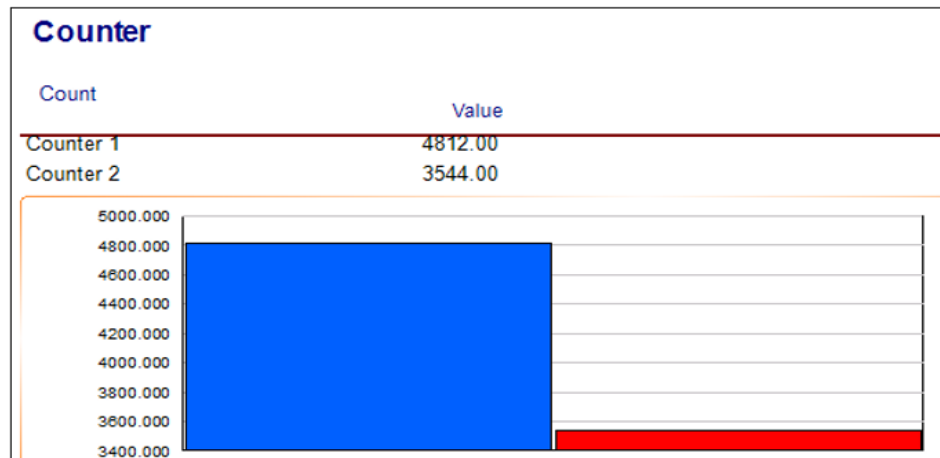
Figure 2: Three source nodes delivering to the appropriate destination end nodes

According to Werner (2016), 19,396,000 tons of cargo per year were transported among the three destinations in the year 2013. However, attempting to run the developed Arena model for 1 year would be very time consuming. Hence the 19,396,000 tons of cargo transported were divided by the total number of hours in a year (8760 hours per year) to yield 2214 tons of cargo that would have been generated per hour, which is further split as 738 tons being generated per location, per hour. Accounting for the delay modules that would decrease the number of trucks/hyperloop pods reaching their destinations (and therefore counted), it is determined that a value of 802 tons of cargo being generated per location, per hour, is to be used as it resulted in 3538 trucks reaching their destinations as per the Arena model, which is the most precise value to 3542 trucks that should have reached their destinations.

5. Results and Discussion

The results of using the value of 802 when simulating for hyperloop and trucks at the same time ran for one day, are shown in Table 5:

Table 5: Arena output of the number of hyperloop pods (counter 1), and trucks (counter 2) dispatched during the simulation period of 1 day



Counter 1 represents the number of hyperloop pods that have reached the destination whereas counter 2 represents the number of trucks that have reached the same destinations. It is evident that significantly more hyperloop pods can be dispatched than trucks (a difference of 26%). Furthermore, accounting for the space carrying constraint of the hyperloop pod versus the truck, a total of 57744 tons of cargo were transported using the hyperloop as compared to 53160 tons using the truck, marking a difference of 8%. These are significant improvements that the hyperloop could bring to a supply chain.

6. Conclusion

To begin with, it is unrealistic to study a supply chain built only upon the hyperloop, as the hyperloop in itself could not transport goods to all end destinations. For instance, whilst the hyperloop can indirectly improve last mile deliveries due to its sheer speed, it must be combined with other transportation modes such that last mile deliveries can be completed, where such modes could include existing solutions – a popular option being the use of minivans or developing technologies such as the use of delivery drones. Furthermore, the types and quantities of cargo that can be transported in a hyperloop is currently significantly limited, as cargo such as medicines or fruits/vegetables that may require special compartments that would provide an ideal storing environment is simply not currently possible on the hyperloop as no such design exists of a special hyperloop pod that would transport certain cargo types.

What this paper/simulation does show is the significant supply chain capability improvement potential that a hyperloop can provide for existing supply chains, if it is used as a new transportation mode. The importance of performing this exercise lies in showing how advancements in technologies, such as hyperloops, can allow supply chain management to leap forward due to the generation of multiple factors that might help enhance the network. These factors include the speed of travel time, environmental factors, lead time and forecasting methods. Additionally, the research undertaken can have an impact on today's economy: supply chain managements can benefit in globalizing their networks by investing in a hyperloop system. In light of this, the potential creation of new job opportunities and the gain of social exposure globally will be in effect.

7. Future Works

A more accurate figure representing the extent to which supply chain capability can be improved is still unknown, where more sophisticated, supply-chain specific software would be needed to better model another case study of which, portrays its existing supply chain in more detail as well. For instance, supply chain modelling (SCM) globe represents one such software which can simulate supply chains better than Arena, as the latter is a software that specializes in simulating queues. Furthermore, contacting companies that specialize in providing logistics solutions would represent a source of obtaining a more detailed case study to aid with modelling and simulation. Finally, the economic factor of the hyperloop must also be taken into account to gauge the overall attractiveness of the upcoming transportation technology.

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