Executive Summary

On February 26, 2018, Hyperloop Transportation Technologies (HyperloopTT) signed an agreement with the Northeast Ohio Areawide Coordinating Agency (NOACA) alongside a broader consortium of public and private organizations kicking off the Great Lakes Hyperloop Feasibility Study (GLHFS). The purpose of the study was to perform a comprehensive examination of a Hyperloop network connecting Cleveland and Chicago. Pittsburgh was added to the study earlier in 2019.

On December 16, 2019, the study was released to the public for the first time and will be undergoing peer review. The project involves over 80 organizations in the government, private, and public sectors throughout Illinois, Ohio, and Pennsylvania. Over 40 elected officials at the local, state, and national levels also provided their support for the project. Through a public competitive procurement process, NOACA hired transportation infrastructure analysis firm Transportation Economics and Management Systems, Inc. (TEMS). Since 1989, TEMS has conducted over fifty rail feasibility studies throughout North America and is widely accepted as one of the foremost ground transportation planning firms.

Project partners HyperloopTT, NOACA, and TEMS, along with the support of the larger Great Lakes Hyperloop Consortium analyzed route options, ridership estimates, construction and operation costs, construction timeframes, and the broader economic impact of the system. The results of the study revealed a positive cost-benefit ratio meaning the project operates at a profit, removing the need for government operating subsidies.

The GLHFS will continue through successive project phases, including a formalization of the operational entity/ies to facilitate further coordination among the localities along the route corridor, and advancing with a final environmental study prior to moving into full implementation of the HyperloopTT system. construction.

1. Background

We have an opportunity to influence the direction of the future through safe, sustainable, and efficient ultra high-speed mobility. The Great Lakes Hyperloop Feasibility Study evaluates the suitability for an interstate hyperloop corridor connecting Cleveland, Chicago, Pittsburgh, as well as other cities throughout the Great Lakes Megaregion.

Hyperloop is a tube-based mobility system that travels at airplane speeds along the ground-level in a safe, sustainable, and efficient manner.

Many of the hyperloop's concepts are not really new, but rather integrate already-proven technologies in a new way.

This is why the hyperloop has been called a “fifth mode” of transportation -- since it doesn’t fit neatly into any of the existing models, but rather integrates design and operational concepts from a number of different existing transportation modes.

As a first step, NOACA and HyperloopTT formed an innovative public private partnership to perform a feasibility study evaluating a potential Cleveland to Chicago hyperloop route. The study was later extended to include Pittsburgh.

NOACA is the federally designated metropolitan planning organization (MPO) for Cuyahoga, Geauga, Lake, Lorain and Medina counties. NOACA performs planning for highways, bridges, public transit, bikeways and pedestrian facilities.

Hyperloop Transportation Technologies Inc. (HyperloopTT) is a transportation and technology innovation and systems integration company focused on realizing the hyperloop. Through the use of unique, patented technology and an advanced business model of lean collaboration, open innovation and integrated partnership, HyperloopTT is creating and licensing technologies and all the other means that allow infrastructure operators and transportation operators to build and operate the hyperloop.

The Ohio Turnpike and Infrastructure Commission has collaborated with the Project Partners since the outset of the Study. The Turnpike participated as a funding partner for the Project, providing $100,000 and offered to collaborate with Project Partners on the use of the Turnpike’s right-of-way. Representatives of the Ohio Turnpike and Infrastructure Commission regularly participated in meetings and made the Commission’s resources available to the Project Partners to complete the Project.

On February 16, 2018, the Northeast Ohio Areawide Coordinating Agency (NOACA) signed an interagency agreement with the Illinois Department of Transportation as a partner on the Cleveland to Chicago Feasibility Study.

The Project Partners created Technical Advisory Committees for local stakeholders in Cleveland, Chicago, and Pittsburgh.

- Cleveland TAC membership includes all the northern Ohio MPO’s, City of Cleveland, City of Toledo, City of Youngstown, as well as Ohio DOT, Regional FHWA, and Ohio Turnpike and Infrastructure Commission.

- Chicago TAC membership includes the Chicago MPO, Chicago Metropolitan Agency for Planning (CMAP), Illinois DOT, Chicago Regional Transit Authority, City of Chicago, Metra, PACE, Illinois Tollway and Amtrak.

- Pittsburgh TAC membership includes the Southwestern Planning Commission (SPC), City of Pittsburgh, Pittsburgh Airport, RK Mellon Foundation, Beaver County, Allegheny County, and Pennsylvania Turnpike Commission.

In addition, Consortium members joined the movement to build this emerging mode of transportation because the Great Lakes Megaregion is an ideal part of the country for intensive R&D efforts and hosts a large part of the supply chain required to build the hyperloop.

The proposed hyperloop corridor between Cleveland, Chicago, and Pittsburgh concentrates local knowledge and industry specializations that are directly applicable to the emerging industry. These local economic clusters throughout the megaregion provide skills, knowledge, specialized workers, and supply chain stability for the emerging ultra high-speed mobility industry.

Members of the local Consortium are contributing specialization within their area of expertise including aspects of planning, design, and engineering for route embodiments. Understanding the geotechnical landscape along the alignment corridors allowed the Project Partners to identify a cost-effective means of constructing the corridor.

Following a competitive procurement process, NOACA chose Transportation Economics and Management Systems (TEMS) as the Project Consultant to perform a technical and economic analysis of the hyperloop infrastructure. TEMS is widely accepted as one of the foremost ground transportation planning firms in North America. Since 1989, TEMS provides specialized management, planning, market research, economic and systems technology consulting services for the transportation industry using certified standards and methodology accepted by Federal transportation authorities.

TEMS uses the **RENTS™ 2.0 Financial and Economic Analysis Model** which uses outputs from the **COMPASS™** and **GOODS™ Demand Forecasting Systems** to estimate the financial and economic benefits of a project. These outputs include **Financial Return** made up of Operating Ratio, NPV and IRR; **Economic Return** including Gross and Net Consumer Surplus, NPV, and Cost-Benefit Ratio; and **Economic Rent** which includes Community Benefits (such as changes in household income, employment by sector, property values, and population) that result from infrastructure and technology improvements or timetable and fare modifications. TEMS' economists, systems analysts, engineers, and professional managers have extensive experience with projects of all scopes and sizes throughout North America and abroad.

2. Great Lakes Hyperloop Feasibility Study

The Great Lakes Hyperloop Feasibility Study (GLHFS) evaluates the feasibility of an interstate hyperloop network using the benefit-cost analysis guidance developed by the Federal Railroad Administration (FRA). The study considers a Hyperloop Transportation System between Cleveland, Chicago and Pittsburgh as well as other cities within the Great Lakes Megaregion.

Great Lakes Megaregion Principal Cities | Chicago, Detroit, Pittsburgh, Cleveland, St. Louis, Minneapolis, Indianapolis

Population 2010 | 55,525,296
Percent of U.S. Population | 18%
Population 2025 | 60,678,100
Population 2050 | 71,263,185
Projected Growth (2010 - 2050) | 28.3% (15,737,889)
2005 GDP | $2,072,869,000,000
Percent of US GDP | 17%

NOACA and HyperloopTT entered into a formal public private partnership on February 26, 2018 and NOACA issued a Request For Proposal (RFP) for a Consultant Study to consider the technical and financial aspects of the feasibility study.

The Project Partners divided the Feasibility Study into four successive parts to conduct the essential analyses for the route corridor.

- Part 1 | Project Objectives and Organization included the assessment of the technical, financial, and regulatory review for the Project, and approval requirements for the development of the Project.

- Part 2 | Site Reconnaissance and Preliminary Route Analysis is the consideration of corridor and routing characteristics based on overall project requirements, and a high-level analysis of a potential hyperloop transport regional network. This initial high-level analysis of potential corridors connecting population centers in the Great Lakes Megaregion would create a network of metropolitan areas connected by accessible ultra high-speed transportation resources.

- Part 3 | Technical and Financial Feasibility Study reviewed state and federal agency requirements to evaluate the environmental and regulatory clearance required for the Project along with potential procedures under which the study would be developed. The Project Partners and Consultant conducted order-of-magnitude assessments of cost and schedule impacts with an initial assessment of mitigation strategies. In consultation with Consortium members and experienced academic institutions, the Project Partners identified subsurface systems to provide effective mitigation from right-of-way challenges and associated schedule risks. To identify potential constraints along the rights-of-way for the Project corridor, the Consultant, in coordination with the Project Partners, reviewed existing highway alignments, existing structures and maintenance practices.

- Part 4 | Project Development Cost and Schedule developed an order-of-magnitude capital cost estimate for the Project and prepared a preliminary project development schedule. During this part, the Project Partners reviewed and developed implementation strategies, including the identification of potential revenue sources that may reasonably be available for HyperloopTT System development, design and construction.

The Feasibility Study organizes its findings into eleven Chapters:

Chapter 1 | Project

- Background and purpose of the Great Lakes Hyperloop Corridor Feasibility Study
- Outlines the study's goal, the project scope, and the methodologies used

Chapter 2 | Corridor Development Around HyperloopTT Technology

- HyperloopTT System technology and design principles
- Potential state and federal regulations including environmental planning process
- Emerging NETT Council
- Regulatory issues for successive study
- General background discussion

Chapter 3 | Service and Operating Plan

- Identifies route options for the Great Lakes Hyperloop
- Identifies engineering issues in developing corridor alignments
- Estimates point-to-point running times for each route option
- Identify potential hyperloop network hubs with high ridership and cost factors

Chapter 4 | Corridor Demographics, Socioeconomic and Transportation Databases

- Introduces the zone system, which uses representative features within origin-destination pairs to reflect the characteristics of travelers within the system

Chapter 5 | Hyperloop Ridership and Revenue

- Market analysis of the potential for hyperloop ridership
- Travel Demand Forecast for the hyperloop corridor including ridership, revenue and market share results

Chapter 6 | Hyperloop Freight Market

- Possible hyperloop freight target markets for hyperloop freight operations
- Freight market analysis of origin destination data and network data
- Hyperloop freight revenue yield estimates, operating costs and forecasts

Chapter 7 | Capital Costs

- Capital costs for various alignment options based on key system components
- Capital costing issues along with a preliminary estimate of infrastructure capital costs

Chapter 8 | Operating Costs

- Calculated using drivers like passenger volumes, capsule miles and operating hours
- Aim to develop an affordable set of options providing good service at a reasonable cost

Chapter 9 | Financial and Economic Analysis

- Financial and economic analysis including demand-side and supply-side benefits
- Specifically employment, increased income, real property values and expanded tax base

Chapter 10 | Stakeholder Outreach and Public Engagement

- NOACA included two phases of engagement activities: first phase Stakeholder Engagement, second phase Public Engagement
- Aim to inform and gather feedback from community members along the corridor and create ongoing communications to support public participation

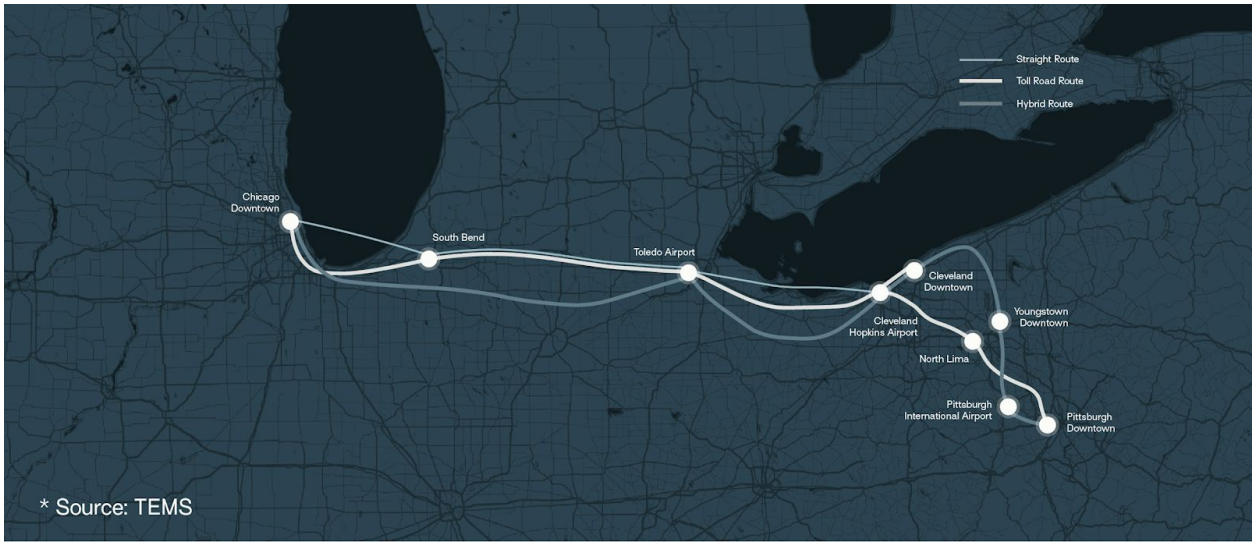
Chapter 11 | Conclusions and Next Steps

- Key findings of the Study
- Next steps for the Project

3. Study Findings

As seen in the map below, three representative routes have been developed from Cleveland to Chicago to Pittsburgh: Straight Line, Toll Road and Hybrid. Specific alignments have been developed for the purpose of this assessment but they should still be considered preliminary. An additional route alternative from Cleveland to Pittsburgh following the Toll Road via the city of Cranberry has been developed diverging from the main line at Cleveland Hopkins International Airport (Berea) so the route into downtown Cleveland became a branch line.

The GLHFS is based on three terminals -- one in Cleveland, Chicago, and Pittsburgh, with additional stations along the corridor depending upon the route. For example, the Toll Road option would offer three additional stations in South Bend, Toledo and Youngstown.



Below are Capital Cost Comparison Charts summarizing all route options. The study reviewed the Cleveland-Chicago corridor with stops and without. Capital costs were also studied for two Cleveland-Pittsburgh extensions, and potential segments for both.

Capital Costs for Cleveland-Chicago					
	No Intermediate Stops			With Intermediate Stops	
Costs in Millions 2018 dollars	Toll Road	Hybrid	Straight Line	Toll Road	Hybrid
Guideway Infrastructure	$8,446	$7,738	$14,095	$8,446	$7,738
Stations & Vehicles	$549	$549	$549	$1,013	$781
Guidance & Propulsion Systems	$7,912	$8,080	$6,131	$7,912	$8,080
TOTAL COST	$16,907	$16,366	$20,774	$17,371	$16,598
Miles	330.0	337.0	315.3	330.0	337.0
Cost Per Mile	$51.23	$48.56	$65.89	$52.64	$49.25

Capital Costs for Cleveland-Pittsburgh						
	To Pittsburgh via Airport(Hybrid)			To Pittsburgh via Cranberry (Toll Road)		
Costs in Millions 2018 dollars	Cleveland-North Lima	North Lima-Pittsburgh	TOTAL	Cleveland-Youngstown	Youngstown-Pittsburgh	TOTAL
Guideway Infrastructure	$2,377	$2,044	$4,421	$2,377	$1,712	$3,921
Stations & Vehicles	$232	$576	$808	$232	$456	$688
Guidance & Propulsion Systems	$2,392	$1,491	$3,883	$2,315	$1,491	$3,796
TOTAL COST	$5,001	$4,111	$9,112	$4,756	$3,648	$8,404
Miles	87.4	54.5	141.9	84.6	54.1	138.7
Cost Per Mile	$57.22	$75.44	$64.22	$56.22	$67.43	$60.59

Below are the Benefit/Cost results for the Cleveland-Chicago-Pittsburgh corridor summarizing the Toll Road option. Most notably are the positive benefit/cost ratios indicating the Project meets Federal funding requirements.

Benefit/Cost Results for Cleveland-Chicago-Pittsburgh				
Costs in Millions 2018 dollars	To Pittsburgh via Cranberry (Toll Road)		To Pittsburgh via Airport (Hybrid)	
Discount Rate	**3%**	**7%**	**3%**	**7%**
BENEFITS				
Benefits to Users				
Passenger Consumer Surplus	$41,104.44	$20,598.88	$43,177.81	$21,635.41
Freight Consumer Surplus	$16,747.71	$7,485.91	$17,310.09	$7,734.58
Total User Benefits	$57,851.15	$28,084.79	$60,487.90	$29,370.00
Benefits to Public at Large				
Environment and Resource (air)	$3,813.54	$1,917.14	$4,327.52	$1,933.65
Environment and Resource (auto)	$5,546.97	$2,788.56	$4,005.88	$2,013.60
Freight Environment Benefits	$4,186.68	$1,871.48	$5,826.74	$2,928.87
Total Public at Large Benefits	$13,547.19	$6,577.18	$14,160.15	$6,876.11
NPV Total Benefits	**$71,398.33**	**$34,661.96**	**$74,648.05**	**$36,246.11**
COSTS				
Passenger Operating Cost	$8,139.89	$4,118.24	$8,392.09	$4,245.16
Air Cargo Operating Cost	$291.19	$130.75	$291.19	$130.75
LTL Cargo Operating Cost	$1,136.28	$525.23	$1,136.28	$525.23
Capital Cost	$23,483.26	$20,870.97	$24,128.14	$21,444.12
NPV Total Costs	**$33,029.90**	**$25,634.69**	**$33,947.70**	**$26,345.25**
NPV Benefits Less Costs	$38,368.43	$9,027.27	$40,700.35	$9,900.86
Benefit/Cost Ratio (BCR)	**2.16**	**1.35**	**2.20**	**1.38**
Passenger-Only BCR	**1.60**	**1.01**	**1.58**	**1.00**

Regional economic estimates over the 25-year economic life of the Project show:

- Property values are projected to rise by $74.84 billion, which is three times the capital cost of the Project.

- Personal income is projected to increase by $47.57 billion over 25 years throughout the Corridor, which is nearly two times the capital cost of the Project.
- Employment will rise by 931,745 person-years. Jobs will be created in the business services, logistics, maintenance, health care and retail sectors.

Regional Economic Benefits 2025-2050						
Station Name	**Income**	**Property Value**	**Employment**	**Property Tax**	**Local Tax**	**Income Tax**
Unit	$millions	$millions	person year	$millions	$millions	$millions
Chicago, IL	21,555	34,045	425,628	570	919	4,225
South Bend, IN	3,503	5,457	67,755	95	150	682
Toledo, OH	3,189	5,169	64,306	85	136	650
Hopkins Airport, OH	1,946	3,037	37,928	52	82	392
Cleveland, OH	7,890	12,257	153,169	214	336	1,575
Youngstown, OH	1,888	2,994	36,592	50	79	373
Pittsburgh, PA	7,605	11,882	146,367	206	319	1,505
Total	**47,577**	**74,842**	**931,745**	**1,273**	**2,021**	**9,401**

Stakeholder engagement activities allowed the Project Partners to share information about hyperloop technology with defined audiences and obtain feedback to learn about design, technical capacity, land use, environmental impacts, alternative route analysis, proposed station locations, regional connections and economic growth opportunities.

The results included public comments from residents who gave input regarding their concerns and interest of the Great Lakes Hyperloop system. Input ranged from passenger experience use for personal and business travel, future freight movements and capabilities, and the development of a new transportation route connecting communities from Cleveland, Chicago and Pittsburgh.

Stakeholder engagement provided information and messaging targeted to defined stakeholder groups along the hyperloop corridor to ensure their concerns were considered throughout the study analysis process, particularly in the development of decision-making criteria and options.

4. Conclusions

The Toll Road route with stations produced a very strong operating ratio of 4.15 over the 25-year economic life of the Project, making an operating profit of $30 billion over the 25 year period.

The intercity Cleveland-Chicago-Pittsburgh travel market is estimated to grow from 40 million trips to 50 million trips by 2050 or by 25 percent. It is calculated that hyperloop market share will be 12 million trips in 2020 rising to 17 million trips by 2050.

Freight traffic has a significant impact on the cash flows for the interstate hyperloop corridor, and effectively doubles the passenger revenues.

The total employment growth will be over 931,000 person years from 2025 to 2050 in the Great Lakes Hyperloop corridor. This implies that over the 25-year economic life of the Project, that nearly 40,000 additional job positions will be created.

Income benefits are derived from the increased attractiveness of the region due to the accessibility improvement. The total income growth in the corridor will be more $47.6 billion from 2025 to 2050. Chicago, Cleveland, and Pittsburgh will have $21.5 billion, $9.8 billion, and $7.6 billion income increase, respectively, during this 25-year period.

Income benefits result from both the increase in the number of households along the corridor and the increase in the average household income per household. Real property value benefits result from the increase of the number of properties in the region as well as the increase in the average value of commercial and residential buildings.

The financial and economic results are unprecedented, illustrating a strong case for the Public Private Partnership to continue working to bring hyperloop to the Great Lakes corridor. Hyperloop will spur the New Economy service industries of finance, software and logistics; thus understanding the needs of the commuter population are paramount to maintaining a responsive service along the corridor.

TEMS reasons that the Project's strong financial performance offers a good return on investment for potential investors. At a 3% discount rate, the project revenue NPV of more than $40 Billion exceeds the total cost NPV of $33+ billion by a considerable margin. The Benefit Cost Ratio of 2.20 (when using a 3% discount rate), and the Net Present Values suggest a very powerful boost to the economy. These strong financial and economic results, along with overwhelmingly positive public responses, indicate a Public Private Partnership would be an appropriate vehicle for continuing to perform the required analyses of the proposed interstate hyperloop corridor.

In addition to the benefits listed above, the Public Sector will receive an improved cash flow bonus from the building of the system in terms of transfer payments from the developed corridors. This benefit consists of increased tax revenue from growth in employment, income, property development, and increased commercial sales of goods and services.

The financial and economic results show a strong case for Public Private Partnership for the hyperloop project in the Great Lakes Hyperloop corridor.

5. Recommendations

The Project Partners recommend that the Parties discuss subsequent steps in the creation of the organization to perform the work in subsequent phases of the study. Formalization of the Great Lakes Hyperloop into an operational entity will enable the coordination and collaboration with state and local planning authorities in subsequent phases of the study along the representative routes. They also recommend further studying the Project's socioeconomic and community impacts and benefits.

The Project Partners recommend a Public Private partnership to develop and operate the Great Lakes Hyperloop system.

The Project Partners recommend to evaluate the array of options for debt and equity offerings at the state, local, and federal levels and recommend pursuing community development initiatives along the route corridor. Additionally, there are diverse funding pools for operating revenue, including the HyperloopTT system's ability to move air, LTL, express freight, and to build Transit Oriented Development around stations and terminals.

6. Next Steps

Key steps for the P3 entity will include:

- Public acceptance of the results of the study and Project Partner recommendations
- An inclusive political framework that enables the Project to reach local communities and individuals within historically underserved or disadvantaged populations
- Developing the operational structure around the obstacles anticipated for the subsequent phases of the Project
- Creating a responsive legal framework that can integrate new developments in regulatory structures and standards
- Maintaining access to competitive and proven technology while continuing the integration-related technology work that aligns with the legal and regulatory environment
- Financial Security and Stability in Cash Flows and Funding Plans

The next steps for the Great Lakes Hyperloop Project would be to undertake an Environmental Impact Statement (EIS) at the Tier 1 level using FAST ACT evaluation procedures. Upon identifying areas requiring additional study, the remaining areas will move forward with Tier 2 EIS.

For a complete copy of the final draft of the Great Lakes Hyperloop Feasibility Study, please go to greatlakeshyperloop.com/results or noaca.org/hyperloop