2020 HYPERLOOP FEASIBILITY STUDY

MID-OHIO REGIONAL
MORPC
PLANNING COMMISSION

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EXECUTIVE SUMMARY

The purpose of this study was to determine if a Chicago-Columbus-Pittsburgh corridor is feasible for hyperloop technology at optimal average speeds of 500 miles per hour. This included considerations for route alignments that needed to have limited curves since the technology needs straight alignments to achieve the desired speeds.

AECOM was the consultant that led the technical work of this study. The first task was to analyze the existing rail corridor between the three anchor cities to determine if a hyperloop route could be constructed within existing rail corridors. Hyperloop technology experts worked with the study team to determine that, while some portions of the route could be built within existing rail corridors, the route would also need new right-of-way in order to achieve optimal speeds.

Once technical feasibility was confirmed, the study team completed preliminary screenings of the best route and station locations. For route screening, the study looked at environmental constraints, engineering complexity, and right-of-way ownership. For station location screening, the study focused on local preference from community officials, population centers, and adjacent land uses. Potential stations in Ohio were identified in Lima, Marysville, Dublin and Columbus. This does not mean other stations are not feasible – rather, that for this initial study, station locations were limited to those communities which have been working and funding projects under MORPC's Rapid Speed Transportation Initiative.

The study also focused on demonstrating the freight benefits and economic impacts of a hyperloop corridor between Chicago, Columbus and Pittsburgh. These were the findings:

- There is currently no passenger rail service connecting the Fort Wayne-Lima-Columbus-Pittsburgh market. Columbus is currently the second largest metro area in the United States with no passenger rail service.
- Strong ridership market: The study analyzed current (year 2015) and forecasted (year 2040) population and employment for the cities of Chicago, Fort Wayne, Lima, Columbus and Pittsburgh only. Fort Wayne and Pittsburgh are expected to grow in population by at least 10 percent between 2015 and 2040, with Chicago and Columbus seeing the highest increase of over 20 percent population growth. All five cities are expected to grow in employment, with at least 12 percent employment growth in Lima and Pittsburgh, and over 15 percent employment growth in Chicago, Fort Wayne and Columbus.
- The study found that, over 30 years, a hyperloop route would result in the following:
    - 1.9 billion autos shifted to hyperloop passengers
    - 2.4 million tons of reduced CO_2 emissions (over $126 million in emissions savings)
    - 450 million commercial truck vehicle hours traveled will be eliminated
    - $300 billion in overall economic benefits (nearly $19 billion of that in direct transportation benefits)

Lastly, the study identified next steps of: collaborating with stakeholders to advance a certification corridor segment for Virgin Hyperloop One technology in Central Ohio; creating a travel and economic demand advisory panel to improve and further refine the high-level analyses developed under the feasibility study; and working with state and federal transportation officials to advance a regulatory framework for hyperloop technology.

1.0 OVERVIEW:
RAPID SPEED TRANSPORTATION INITIATIVE (RSTI)

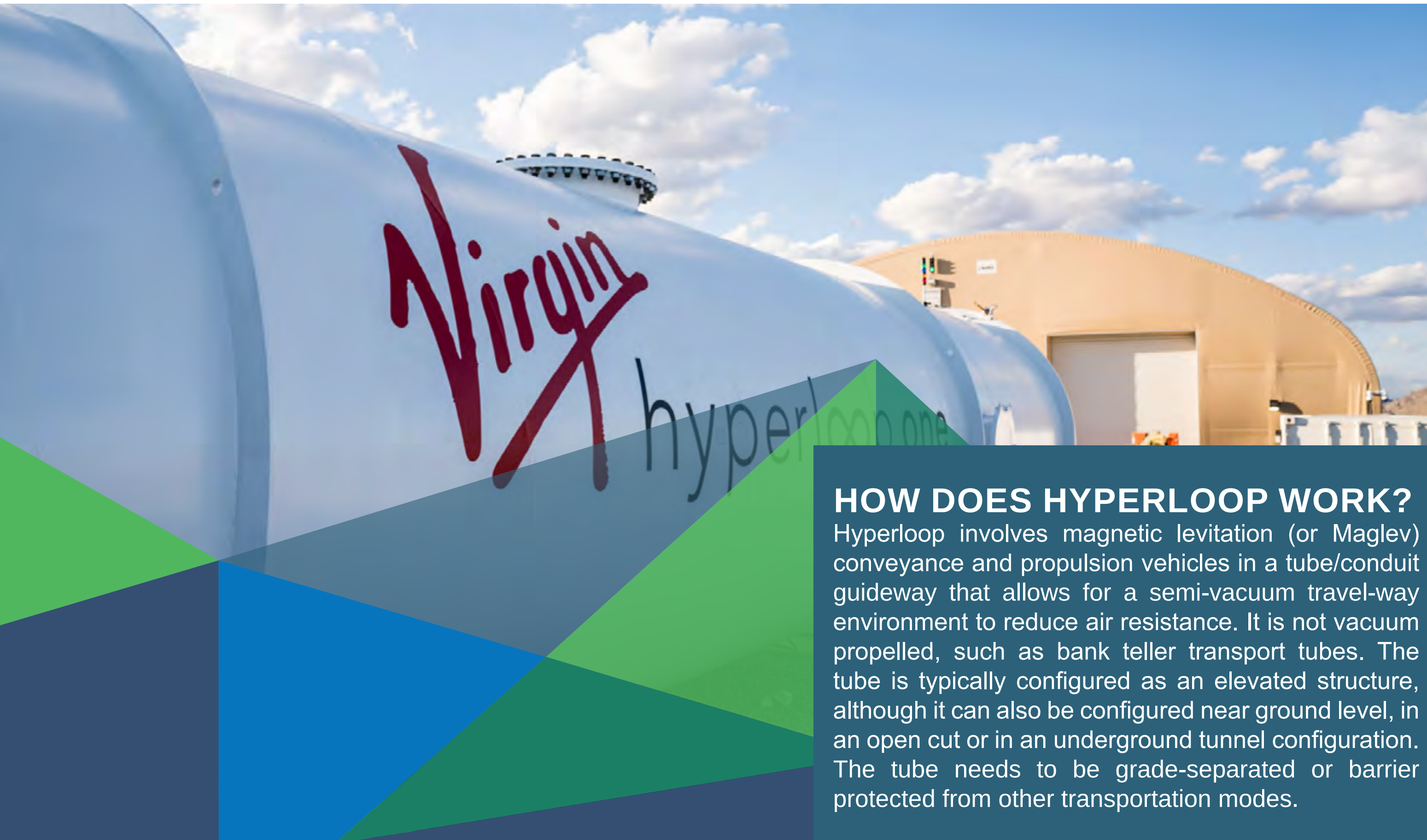
In 2018, the Mid-Ohio Regional Planning Commission (MORPC) launched the Rapid Speed Transportation Initiative (RSTI). This initiative seeks to find better, faster connections between Columbus and the cities of Chicago and Pittsburgh. The RSTI considers two modes-passenger rail and hyperloop-for potential intercity services.

The first phase of the RSTI involved the completion of two studies. One study, relevant to hyperloop and passenger rail, evaluates initial elements of a Tier I Environmental Impact Statement (EIS), a federal environmental approval process required for all federally funded infrastructure projects per the National Environmental Policy Act (NEPA). This NEPA evaluation is guided by a document known as the Purpose and Need Statement, which identifies why the federal agencies are responding to the project being proposed and provides the foundations of a defensible NEPA analysis process.

The first study resulted in separate draft Purpose & Need Statements for the hyperloop and passenger rail projects.The second study, the Midwest Connect Hyperloop Feasibility Study, is summarized in this report. This feasibility study also informed the draft Purpose & Need Statement for the hyperloop project.

WHAT IS HYPERLOOP?

- An automated, ultra-high-speed transportation mode for passengers and lightweight, palleted freight
- Operates in a low-pressure tube environment, on a fixed-guideway
- Operates in long-distance corridors between major metropolitan areas at cruising speeds in excess of 500 MPH
- Provides point-to-point service between major metropolitan areas, international airports and transportation centers
- Different from other mass transportation – designed for individual origin-destination travel. A main hyperloop tube (or express line) is accessed by portal connector lines, similar to how highway access ramps connect local communities to the main highway system.
- Designed to be integrated with other modes of transportation to enhance the existing multimodal freight and passenger transportation system.



HOW DOES HYPERLOOP WORK?

Hyperloop involves magnetic levitation (or Maglev) conveyance and propulsion vehicles in a tube/conduit guideway that allows for a semi-vacuum travel-way environment to reduce air resistance. It is not vacuum propelled, such as bank teller transport tubes. The tube is typically configured as an elevated structure, although it can also be configured near ground level, in an open cut or in an underground tunnel configuration. The tube needs to be grade-separated or barrier protected from other transportation modes.

The Midwest Connect Hyperloop Feasibility Study identifies and evaluates potential hyperloop routes for goods movement and passenger transport between Chicago, Columbus and Pittsburgh. This study included collaboration with hyperloop technology experts and includes the use of proprietary hyperloop technology information that has influenced route alignments and right-of-way requirements based on the technology needs.

WHY CHICAGO, COLUMBUS, PITTSBURGH?

The RSTI evolved from the Chicago-Fort-Wayne-Columbus passenger rail project. As such, communities between Columbus and Chicago spearheaded the creation of the RSTI and were all included as route criterias. Future phases will prioritize engaging communities between Columbus and Pittsburgh. While hyperloop portals between Columbus and Pittsburgh were not considered in this study, it should not be interpreted that portals in these communities are not feasible.

The first task in this feasibility study was to understand the technology needs for the right-of-way so the consultant team, AECOM, could determine if the existing rail corridor was feasible for an optimal speed hyperloop route of 500 miles-per-hour or more. If the rail corridor was found to be unsuitable, the consultant team was tasked with finding a feasible hyperloop route that can sustain the desired optimal hyperloop speeds. The feasibility study also includes travel demand and economic analysis of the feasible route. Finally, this study reviews conditions under which an intercity hyperloop service could be implemented. Figure 1 shows the largest cities with proposed hyperloop stations (portals). When Chicago O'Hare and downtown Pittsburgh are included, the corridor extends roughly 525 miles across five states.

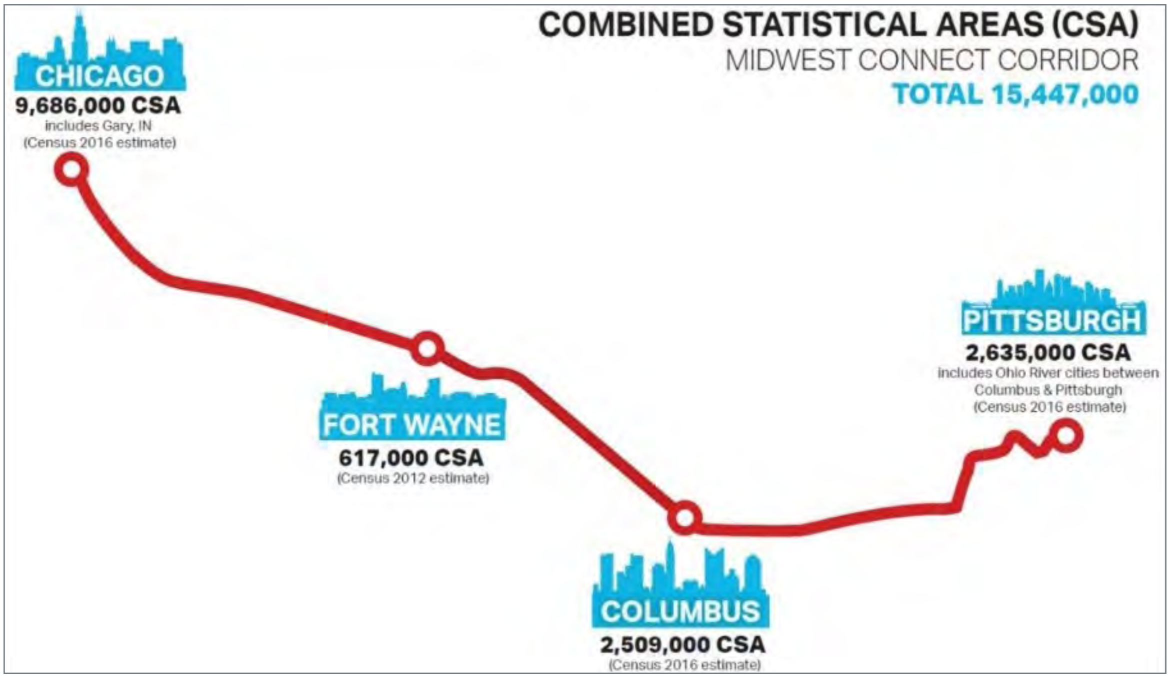
WHAT IS A HYPERLOOP PORTAL?

Hyperloop portals are passenger/freight access points with station-like features. Portals allow hyperloop passengers and cargo shippers to have the advantage of direct travel to individual destinations, instead of stopping at each community along the corridor, the way air and rail travelers do.

WHAT IS A HYPERLOOP POD?

Hyperloop pods are on-demand vehicles that move to and from passenger portals or freight intermodal facilities with freight portals that link to a mainline via branches. These branches are sometimes referred to as on/off ramps.

Figure 1: Major Markets in the RSTI Hyperloop Feasibility Study Corridor



2.0 HYPERLOOP TECHNOLOGY ROUTE NEEDS

Hyperloop technology is designed for mainline speeds comparable to commercial airliners. Therefore the technology necessitates specific route conditions to operate at optimal speeds. In ideal conditions where the horizontal and vertical curvature of the corridor does not constrain vehicle speed, vehicles glide at high cruising speeds for long distances due to ultra-low aerodynamic drag. With both friction and air resistance greatly reduced, the vehicles are projected to travel up to 670 mph (1,080 km/h). While the mainline is designed to maintain optimal speeds, the local access branch lines are designed for travel at slower speeds and offer more flexibility for vertical and horizontal curvature. Given these technology and system characteristics, the sections below describe how route alternatives were analyzed relative to hyperloop technology needs.

2.1 RIGHT-OF-WAY REQUIREMENTS

The hyperloop guideway will be configured so that the exterior of the tube is accessible for routine maintenance with the exception of tunneled segments, where maintenance access is typically provided by vertical shafts that descend to the tunnel. The following primary right-of-way types are anticipated in the Midwest Connect corridor:

- *Highway Alignment,* either in a median or edge configuration. The guideway is preferred to be configured near ground level on short leveling structures. Roadway barriers would protect hyperloop structures from highway traffic.
- *Railroad Alignment,* parallel to or configured above active railroad. Project partners will need to reach agreements with rail right-of-way owners and operating railroads in order to share right-of-way.
- *Greenfield Alignment,* along acquired right-of-way between urbanized areas.
- *Tunnel Alignment,* which may be required to navigate through hills or under urbanized communities.

All right-of-way design will require safety and technical considerations, which will involve input from technical experts for any alignment that shares a right-of-way with another mode (such as highways or railroads).

2.2 ROUTE PLANNING GOALS

To assist in the selection of route alternatives, the study team identified the overarching goals for the route planning. These goals include the following:

- Connect the communities previously engaged in the Chicago-Fort Wayne-Lima-Marysville-Columbus passenger rail project, and extend the terminus to Pittsburgh;
- Connect potential portals (stations or freight access points) using a straight-line path to the extent possible;
- Provide a mainline designed for average speeds of 500 MPH, and provide point-to-point service along the entire corridor, with local access branches or “ramps” required to access portals;
- Maximize opportunities for fast travel times and system efficiencies by minimizing elevation changes and alignment curves, particularly along the mainline;
- Minimize impact on neighborhoods and businesses;
- Minimize impact to potential environmentally sensitive areas;
- Choose alignments that will minimize infrastructure costs, including minimizing the need for tunneling and complex construction methods. Elevated and near at-grade guideway configurations are generally preferred;
- Identify opportunities for using existing public rights-of-way.

The route planning goals above informed discussions as the study team and hyperloop technology experts assessed possible corridor alignments. Section 3 below details how these goals were incorporated into the corridor alternatives analysis.

3.0 CORRIDOR ALIGNMENT ALTERNATIVES

The initial alternatives identification followed specific requirements of the scope of work, including the directive to analyze two potential route alternatives for the entire proposed corridor and to include system access in the following cities: Chicago, Fort Wayne, Lima, Marysville, Columbus and Pittsburgh. One of the key objectives of this study was to determine if the existing rail corridors between the Midwest Connect communities are feasible for a hyperloop route. The railroad corridors analyzed are shown in Figure 2.

Other right-of-way opportunities explored for the alignment alternatives include highway corridors, abandoned railroad alignments, utility rights-of-way, and greenfield alignments. Straight-line alignments through urbanized areas were assumed to require tunneling.

3.1 ROUTE ALTERNATIVES – EVALUATION CRITERIA

As background to the route planning, descriptive information provided by a prominent hyperloop technology company on engineering and operational characteristics and performance levels was needed to ensure that system design criteria were met in the route analysis. An iterative process with hyperloop engineering experts included the use of proprietary design tools to model operations along a small set of identified alternatives. The evaluation criteria used to reduce the large set of initial alternatives included:

- **Geographic Alignment:** Is the alignment compatible with the mainline hyperloop requirement of gentle horizontal and vertical variation in order to provide premium passenger comfort at very fast travel speeds? Is the alignment reasonably accessible to the partner cities, major transportation and/or logistics centers, and preferred portal locations?
- **Comparative Cost:** Capital cost estimates are not prepared for each of the initial alternatives. Engineering complexity will make the cost of an alternative relatively high compared to less complex alignments.
- **Engineering Complexity:** Is it likely the alignment can fit with relative predictability within a host/public right-of-way (such as in a highway median area or within railroad right-of-way), or is a complex mix of engineering features such as tunnel segments, high bridges or water crossings required?
- **Public Right-of-Way:** Does the alignment generally follow public right-of-way, or would property acquisition, railroad agreements or similar be required?
- **Environmental Constraints:** Potentially impacted environmental resources would include not just communities, parklands, natural features, endangered species and historic resources, but also transportation facilities (public and private) and other vulnerable resources. The environmental review for this study is very high-level. A thorough identification of environmental resources will be required along the preferred general alignment and will lead to refinements to that alignment. That level of detail is documented in a Tier 1 Environmental Impact Statement (EIS) or other necessary National Environmental Policy Act (NEPA) Class of Action for the for the environmental review of the corridor. Further conceptual engineering of a hyperloop alignment will be required before the corridor is ready for NEPA environmental review.

The sections below describe how the preferred route was developed – starting with an analysis of the existing rail corridor (Route Alternative 1) and ending with Route Alternative 2, which allows for hyperloop optimal average speeds of 500 miles per hour.

3.2 ROUTE ALTERNATIVE 1 – EXISTING RAIL CORRIDORS

For Route Alternative 1, existing rail corridors were analyzed to determine if optimal hyperloop speeds were possible (Figure 2).

Figure 2: Route Alternative 1 - Alignment Within Existing Rail Corridors

The study team found that the rail corridor in its entirety is not feasible for optimal hyperloop speeds. However, portions of the rail corridor, in combination with road rights-of-way, tunneling and some greenfield alignment, would allow for optimal speeds of 500 MPH or more.

Having concluded that a hyperloop corridor within the existing rail right-of-way was not feasible for the technology to achieve optimal speeds, the study team determined which portions of the rail corridor were suitable for hyperloop and analyzed other potential alignments as described in the next section.

3.3 ROUTE ALTERNATIVE 2 – HYPERLOOP TECHNOLOGY FEASIBILITY

For Route Alternative 2, the study team used an iterative alignment evaluation review with the assigned engineering lead from a prominent hyperloop technology company. Project team members agreed Alternative 1 alignments provided an appropriate basic framework for a preferred mainline alignment, though further revision was required, including:

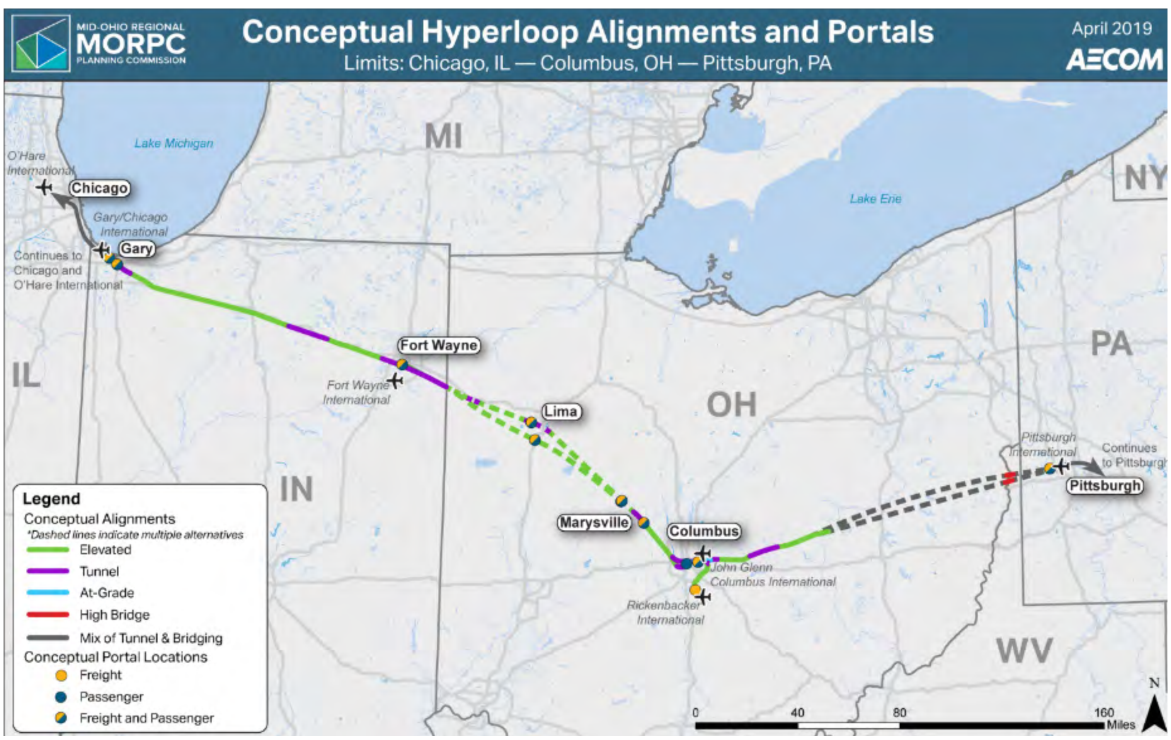
- Identification of both mainline segments and portal access ramps;
- Right-of-way acquisition or tunneling to reduce curvature at strategic locations, particularly for the mainline alignment;
- Emphasis on greenfield straight-line alignment options for the entire corridor between Fort Wayne and Marysville, with the least complex alignment passing Lima just south of the city limits;
- Mainline tunneling through Columbus, roughly between I-270 in the west outerbelt and Alum Creek. Such an alignment is not required until a full network is completed between Chicago and Pittsburgh and market for trips through Columbus established; and
- A straight-line greenfield alignment between the Panhandle Line near the Muskingum River (village of Adams Mills, Ohio) and Pittsburgh International Airport.

Figure 3 shows the preferred hyperloop alignment and highlights the hyperloop corridor portions that are rail rights-of-way.

Figure 3: Route Alternative 2 - Feasible Corridor for Hyperloop Optimal Speeds

Figure 4 is a corridor-wide representation of the preferred alignment, and presents one of the key findings in the study: The hyperloop route is not feasible to be built entirely on existing rail corridors for optimal hyperloop speeds of 500+ MPH. The mainline alignment proposed in this study is a combination of existing rail and road/highway corridors, as well as some tunneling and greenfield portions for which right-of-way will need to be acquired.

Figure 4: Recommended Feasibility Study Alignment



Based on hyperloop technology alignment modeling, the recommended alignment is expected to have the following performance characteristics:

- Point-to-point, on-demand service between portals, with no intermediate stops;
- Chicago O'Hare to Pittsburgh mainline express travel time of roughly one hour;
- Average mainline cruising speeds throughout the corridor slightly higher than 500 MPH;
- Downtown Columbus to the John Glenn Columbus International Airport vicinity in roughly two minutes;
- Travel times between Columbus portals and other metro area destinations:
  - Chicago (downtown or O'Hare) in less than 45 minutes
  - Pittsburgh in less than 30 minutes

4.0 ECONOMIC BENEFITS ANALYSIS

This section summarizes how economic benefits were quantified for this study. This analysis was conducted in accordance with the U.S. Department of Transportation (DOT's) 2019 Benefit-Cost Analysis (BCA) Guidance for a 38 year assessment period beginning with capital outlays in 2022 through to 2029 and 30 years of operations from 2030 to 2059. In terms of transportation benefits as calculated under DOT BCA methodology, the development and operation of the Midwest Connect Hyperloop project is estimated to generate approximately $19.1 billion in current-year dollars at a 3% discount rate, and $300 billion in wider economic benefits, as calculated outside of traditional BCA limitations.

As with all surface transportation projects, this study analyzed ridership volumes and travel behavior as the basis of this economic analysis. Travel choice changes in user behavior are largely related to mode shift to hyperloop from traditional modes of transportation (auto, commercial truck, air, passenger rail). These in turn generate traditional user benefits that are monetarily quantified using formulas as determined by DOT, including:

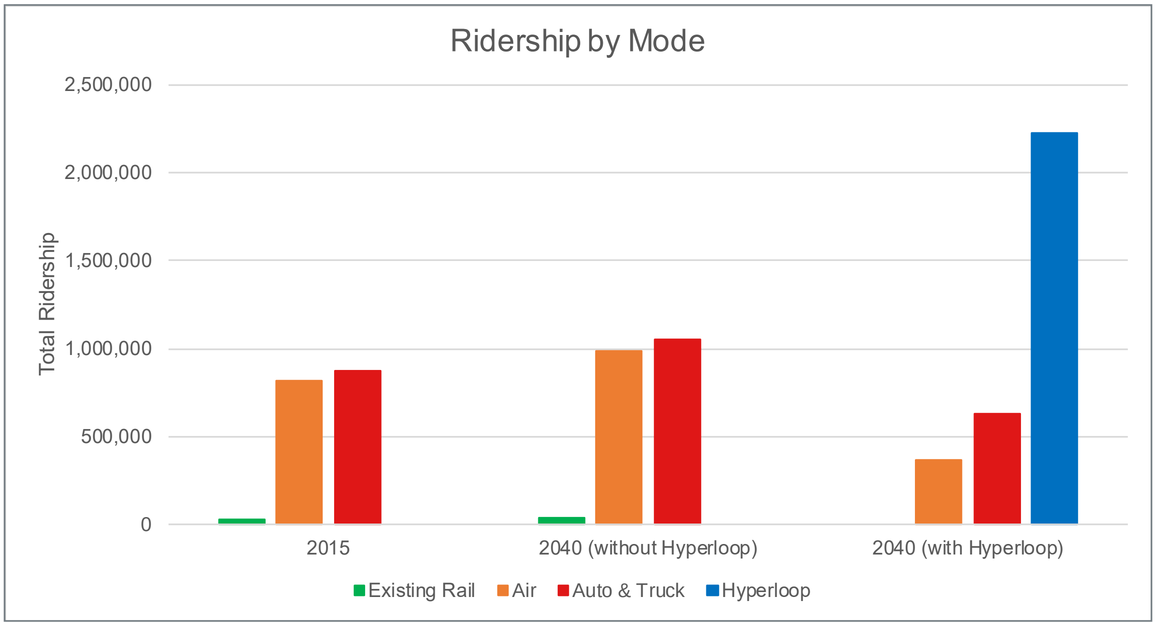
- Travel time savings
- Operating cost reductions
- Accident/injuries/fatalities reduction
- Emissions reduction
- Residual value of the infrastructure

4.1 RIDERSHIP VOLUMES BY TRAVEL MODE

Ridership volumes were estimated for each origin and destination pair ("metro pair') within the proposed alignment for a 2015 base year and for the year 2040. Estimates were developed for both a no-build scenario ("baseline scenario") and a build scenario. The ridership projections for the hyperloop scenario include induced demand, which is estimated to greatly increase ridership given the affordability of hyperloop and the travel time, which would induce travelers to switch to hyperloop and take more frequent trips.

An overview of the ridership estimates for the Midwest Connect corridor by mode of travel is shown in Figure 5. Data tables for this figure can be found in Appendix A.

Figure 5: Ridership by Mode



Ridership volumes for the 2040 base and build scenarios were used to quantify how much auto traffic would be diverted to hyperloop. This helped the study team determine safety, operations, state of good repair (i.e. costs savings associated with less vehicles on existing road systems), and emissions reductions. These variables were quantified using DOT standard formulas to translate these benefits into an economic (dollar) unit.

4.2 TRAVEL TIME SAVINGS – HYPERLOOP AND CONVENTIONAL MODES

Travel time savings associated with the use of hyperloop in place of other conventional modes of transportation were estimated utilizing a variety of sources. Travel times using hyperloop were estimated by AECOM's travel demand team in concert with inputs from hyperloop experts, and they are shown in Figure 6.

Figure 6: Travel Time by Mode*

* Air mode includes security and gate clearance time. Hyperloop mode only includes main trunk line time travel. Security time and pod boarding/offloading time is not included in this comparison.

Table 1: Travel Time Savings: Hyperloop vs. Conventional Modes

METRO PAIR	HYPERLOOP LINE HAUL: TRAVEL TIME (MINUTES)	TRAVEL TIME SAVINGS: AUTO AND TRUCK (MINUTES)	TRAVEL TIME SAVINGS: RAIL (MINUTES)	TRAVEL TIME SAVINGS: AIR (MINUTES)
Entire Corridor	61	406	520	149
Chicago-Fort Wayne	22	127		158
Chicago-Columbus	38	292		157
Chicago-Pittsburgh	56	369	525	154
Fort Wayne-Columbus	19	128		
Fort Wayne-Pittsburgh	37	258		
Columbus-Pittsburgh	20	151		

*Average of the bi-directional travel times between Chicago and Pittsburgh

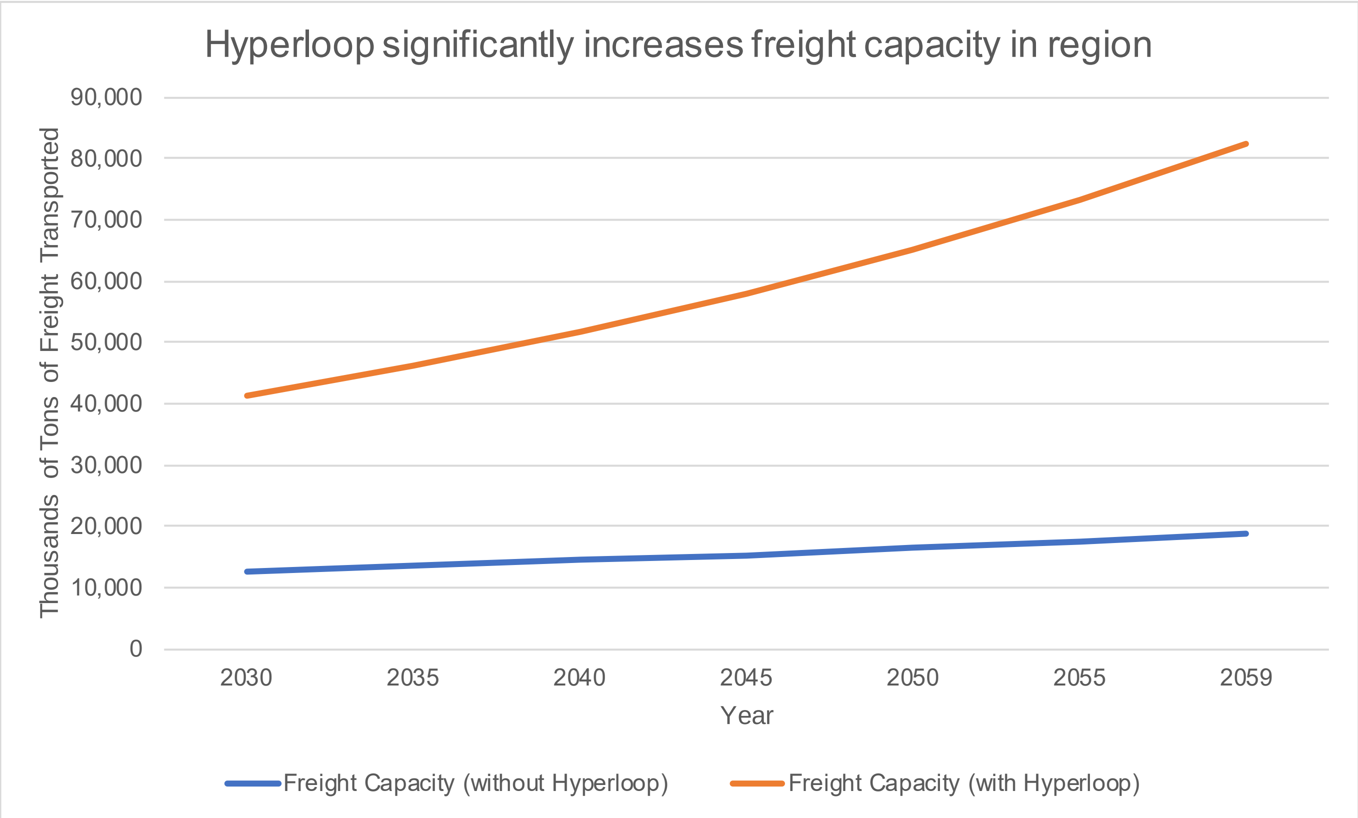
Source: AECOM, Amtrak, American Airlines, United Airlines

4.3 QUANTIFYING HYPERLOOP BENEFITS FOR ROAD FREIGHT

The type of freight that will be moved through hyperloop is expected to be high-value, time-sensitive goods that would traditionally be moved by air or truck. For the Midwest Connect corridor, only road freight was considered. Freight Analysis Framework (FAF) data from the Federal Highway Administration (FHWA) was used to identify current and forecast road freight movements between the four anchor metro pairs of Chicago, Fort Wayne, Columbus and Pittsburgh. The study team used the estimated growth rate between the 2015 and 2045 FAF volumes to extrapolate out the freight estimates to 2060 to allow for an examination of the freight movements during the first 30 years of operation of the proposed hyperloop-type system.

The blue line in Figure 7 shows the gross tonnage of the time sensitive freight moved by road along the proposed alignment in a scenario with no hyperloop corridor to provide a “no build” comparison. To estimate the total weight of time-sensitive freight that could be moved throughout the corridor in a scenario in which hyperloop is built, the study team incorporated the rate at which these goods would be diverted to hyperloop from commercial truck, and estimated the number of truck trips that would be diverted each year from road freight to the Midwest Connect Hyperloop system, including additional time-sensitive freight movements that may be induced as a result of more construction of a hyperloop freight service. The orange line in Figure 7 represents the road freight that would be diverted to hyperloop, including induced demand, which accounts for a drastic increase in freight being moved across the corridor.

Figure 7: Truck Trips - No-Build Scenario vs. Hyperloop Scenario



5.0 ECONOMIC OUTCOMES

5.1 TRAVEL TIME SAVINGS

Travel time savings estimations were derived from forecasts from the ridership modelling and from travel times for traditional modes of transportation as discussed in the previous section. Over the first 30 years of operations, approximately, the implementation of the Midwest Connect Hyperloop is expected to generate approximately 240 million hours of travel time savings across modes of transportation, including commercial road freight. The travel time savings were then converted to a dollar amount based on DOT's Value of Time guidelines. Table 2 summarizes the travel time savings analysis for this project.

Table 2: Economic Competitiveness Benefits Summary (2024-2043)

SOURCE OF SAVINGS	ESTIMATED SAVINGS (MILLIONS)
Travel Time Savings (Auto)	$1,461.4M
Travel Time Savings (Commercial Trucks)	$96.6M
Travel Time Savings (Air)	$1,291.3M
Travel Time Savings (Train)	$219.9M
Travel Time Savings (Induced)	$1,659.8M
Operating Costs Savings (Auto)	$354.2M
Operating Costs Savings (Induced)	$628.9M
Operating Costs Savings (Commercial Trucks)	$150.4M

Source: AECOM

5.2 VEHICLE MILES TRAVELED AVOIDED

User travel time savings are generated by the avoidance of vehicle hours traveled, while some of the user operating costs savings and emissions savings are generated by the avoidance of vehicle miles traveled (VMT). In relation to road travel, the proposed Midwest Connect Hyperloop alignment between any given metro pair is significantly shorter than the distance using established highway and interstate routes, resulting in a reduction of VMT travelled when mode shifting to hyperloop. Air emissions avoided are calculated on passenger air miles avoided. VMT avoided during the assessment period due to mode shift to hyperloop, as well as induced travel, were factored into this analysis.

5.3 SAFETY OUTCOMES

Safety outcomes comprise the reduction in the incidence of road crashes, injuries and fatalities within the assessment corridor due to the implementation of the Midwest Connect Hyperloop project and the associated mode shift away from automobile and commercial truck travel. No safety benefits were calculated related to mode shift to hyperloop from air travel or passenger rail. In this early stage of the project, the hyperloop safety outcomes assume no incidents via hyperloop travel. Under this assumption, the avoidance of crashes associated with the first 30 years of operation of the proposed Midwest Connect Hyperloop project were factored into this study.

5.4 OPERATING COST SAVINGS

Operating Cost Savings – Automobiles

Operating costs savings for automobiles was calculated by multiplying the total Vehicle Miles Traveled (VMT) avoided through both mode shift and induced demand and the operating cost savings per mile, as identified in Section 2. Operating cost savings for automobile users within the assessment corridor total $983 million at a 3% discount over the assessment period.

Operating Costs Savings – Commercial Trucks

Operating costs savings for commercial trucks was calculated by multiplying the total Vehicle Hours Traveled (VHT) avoided by commercial trucks with the average truck operating costs per hour (as per the Department of Transportation Benefit-Cost Analysis methodology). Operating costs for commercial trucks within the assessment corridor total $150 million at a 3% discount over the assessment period.

5.5 SAFETY

The safety benefit represents the monetization of the reduction of crashes, injuries, and fatalities along the assessment corridor roadways as a result of the implementation of the Midwest Connect Hyperloop project and the reduction in VMT associated with mode shift from automobiles and commercial trucks. The net present value of the safety benefits generated by the build scenario is approximately $845M at a 3% discount rate.

5.6 ENVIRONMENTAL SUSTAINABILITY

The emissions reductions generated by the implementation of the Midwest Connect hyperloop project was quantified through evaluation of reduced vehicle miles traveled and reduced operating hours of automobiles, commercial trucks, airplanes, and passenger rail. Apart from VMT emissions, these were then monetized against the National Highway Traffic and Safety Administration's (NHTSA) CAFÉ standards for Model Years (MY) 2021-MY2026 and adjusted to 2019 dollars. CO_2 emissions were monetized following current international pricing of the social cost of carbon at a rate of $40 per ton, which is a divergence from current DOT guidelines. The total benefit of environmental sustainability benefits associated with the implementation of the Midwest Connect Hyperloop project was estimated at approximately $127M at a 3% discount rate across the assessment period.

Table 3: Environmental Sustainability Benefits – Midwest Connect Hyperloop Project (2030-2059)

SOURCE OF SAVINGS	ESTIMATED SAVINGS (MILLIONS)
Mode Shift Emissions Savings (Auto to HL)	$113.9M
Mode Shift Emissions Savings (Air to HL)	$0.3M
Mode Shift Emissions Savings (Train to HL)	$7.8M
Mode Shift Emissions Savings (Comm Truck to HL)	$4.6M

Source: AECOM

5.6 STATE OF GOOD REPAIR

The state of good repair benefits comprise the residual value of the infrastructure of the Midwest Connect Hyperloop project after the end of the 30-year assessment period. This benefit, by far the largest of all benefit categories assessed, is estimated at $11.1 billion at a 3% discount rate.

5.7 FREIGHT BENEFITS

In the larger economic analysis of this study, it is assumed that portions of both air freight (belly cargo) and commercial truck freight (road freight) across specific industries would shift to hyperloop for shipment throughout the region. Only freight that has been classified as time sensitive is assumed to have the potential to shift to hyperloop. For this reason, freight moved by traditional rail is not considered as shifting to hyperloop. Time-sensitive freight was defined as being composed of the following industry categories:

- Precision instruments
- Electronics
- Meat/seafood
- Live animals
- Pharmaceuticals
- Textiles

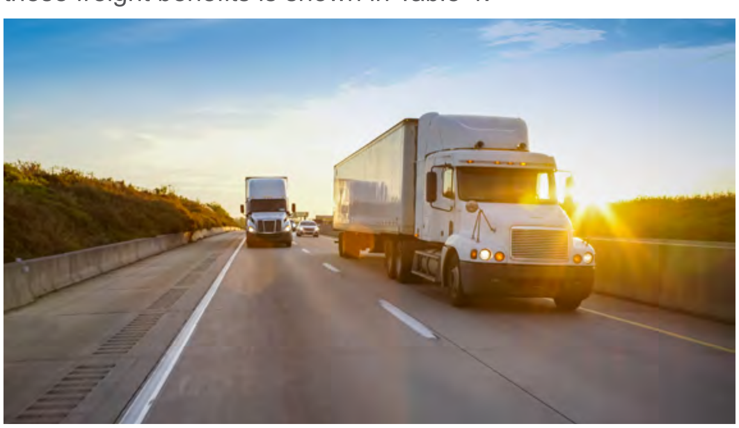
Table 4: Freight Benefits – Midwest Connect Hyperloop (2030-2059)

FREIGHT BENEFITS: COMMERCIAL TRUCKS	ESTIMATED SAVINGS (MILLIONS)
Travel Time Savings	$96.6M
Operating Cost Savings	$150.4M
Safety Savings from VMT Avoidance	$84.6M
Emissions Savings from Mode Shift to Hyperloop	$4.6M
Total Freight Benefits	$336.2M

Sources: AECOM, WSP, DOT, FHWA, EPA

The benefits-costs analysis only quantifies and derives benefits from road freight that would shift modes to hyperloop. Air freight is not assessed in the benefits-costs is used in the rest of the report analysis because much of the intraregional air freight is belly cargo within passenger planes, and the mode shift of this freight would not necessarily entail the avoidance of flights that would otherwise carry this freight.

Freight benefits assessed in this analysis total approximately $336 million over the 30-year assessment period. A summary of these freight benefits is shown in Table 4.



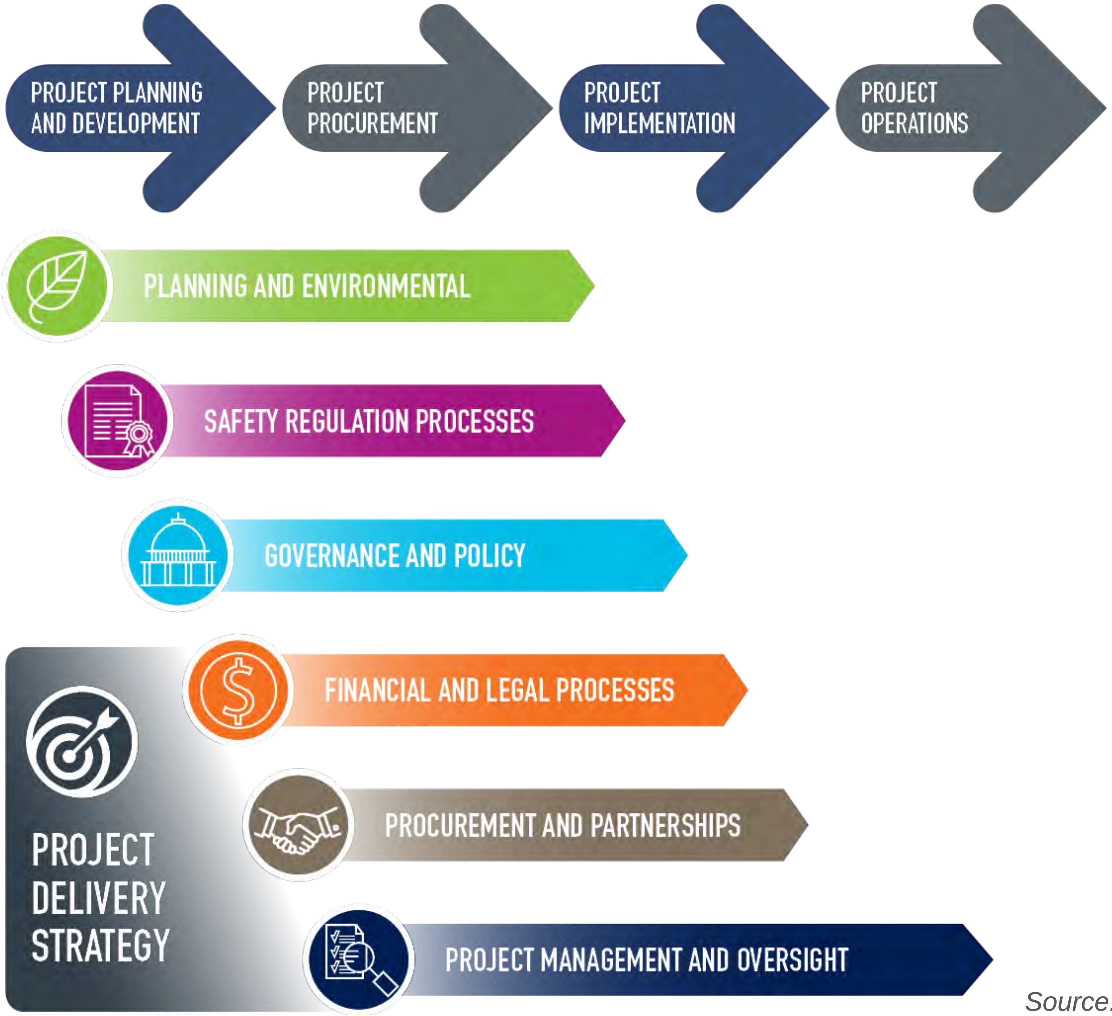
6.0 REGULATORY FRAMEWORK

The Midwest Connect Hyperloop project is among the first hyperloop projects in the world, and will entail complex processes similar to those of any other large-scale transport project constructed in the United States. It is important to note that certain milestones must be met before a system can be developed, such as certification of the technology itself, as well as system development regulations. For the purposes of proving feasibility, this study assumes the corridor is developed and service is in place by 2030, but the actual construction year of the Midwest Connect Hyperloop corridor is subject to milestones that have not been met at the conclusion of this study.

This section discusses key regulatory and approval decision-making processes that are likely to be encountered as the project moves forward. As Midwest Connect Hyperloop advances from planning, through more detailed development, on to procurement and eventually into its implementation phase (final design, construction, commissioning and testing, and operations), the advancement of the project through these phases is dependent on a number of key elements.

In order to advance as a commercially viable transportation alternative, hyperloop will require further development, demonstration, testing and certification. Given Central Ohio's interest in participating in this ultimate certification process, Figure 8 shows generalized hyperloop project delivery steps.

Figure 8: Hyperloop Project Delivery Steps



Source: AECOM, 2019

6.1 PLANNING AND ENVIRONMENTAL PROCESS

Planning and environmental processes are fundamental in defining the overall feasibility, extent of environmental impact, and clearances necessary to advance a project. The first step in project development is typically a feasibility study for the specific technology, which identifies the parameters through which it would operate (physical location, operating characteristics, regulatory oversight, applicable policies, finance structure and other conditions). Following the initial feasibility study phase, additional planning studies may be initiated, and National Environmental Policy Act (NEPA) activities may be launched if the project has a federal nexus (i.e. federal funding or safety certifications). Parallel to this phase, the funding and finance structure is vetted, and a financial plan is initiated. NEPA activities apply to a specifically defined project and project area.

The context of and jurisdiction over the project right-of-way would influence the lead agency and cooperating agencies involved. Assumptions regarding intercity passenger or multi-state freight project oversight are summarized in Table 5.

Table 5: Potential Intercity Environmental Process Lead Agencies

AGENCY	SURFACE TRANSPORTATION BOARD	FEDERAL HIGHWAY ADMINISTRATION	FEDERAL RAILROAD ADMINISTRATION
DESCRIPTION	The Office of Environmental Analysis (OEA) is responsible for directing the environmental review process, conducting independent analysis of all environmental data, and making environmental recommendations to the STB. Follow rules: 49 CFR 1105.	Lead federal agency or cooperating agency for NEPA projects. FHWA generally serves as the lead federal agency for highway projects. The FHWA has been a lead federal agency for a variety of transportation projects, traditionally for projects located within a highway corridor.	Lead federal agency or cooperating agency for NEPA projects. Oversees the Railroad Rehabilitation & Improvement Financing (RRIF) program. Under this program, the FRA administrator is authorized to provide direct loans and loan guarantees up to $35 billion to finance development of railroad infrastructure. Use of RRIF requires NEPA. Follows CEQ for NEPA (40 CFR)
APPLICABILITY TO HYPERLOOP	May oversee NEPA process if STB concurs that the technology type/ function falls within their purview (typically oversee new rail construction/ expansion). Must prove financial viability.	Could serve in lead agency or cooperating agency role, depending on project context. Likely would serve as lead agency if project is generally located within roadway right-of-way.	Could serve in Lead Agency or Cooperating Agency role, depending on project context. FRA implements safety certification (Tiers I-III for transit).

It is important to note that in March 2019, U.S. Secretary of Transportation Elaine Chao announced the formation of the Non-Traditional and Emerging Transportation Technology (NETT) Council, which aims to explore the regulation and permitting of hyperloop technology, among other technologies, to bring this new form of mass transportation to the United States. This includes assisting in defining the appropriate agency to take the lead on NEPA and other, similar federal approvals.

6.2 SAFETY REGULATION PROCESSES

Safety regulation processes determine whether a proposed high-speed technology system is safe to operate, and hence if it can achieve the appropriate safety certifications to move forward into development. Safety certification is required for new high-speed transport systems to operate in the United States. The safety certification process will likely differ by technology depending upon the geographic context of the project and agency jurisdiction. It is important to note that human safety certification will also be required in order to transport passengers at high speeds.

If a new intercity technology, such as hyperloop, were to fall under the purview of the Federal Railroad Administration (FRA), consumer protection will be required in the form of a Rule of General Applicability (RGA) or a Rule of Particular Applicability (RPA). FRA has typically led oversight of high-speed intercity rail initiatives that operate independently from the conventional freight rail network, and this has included technologies such as maglev. An RPA would need to be petitioned to the FRA if hyperloop was to fall under the purview of the FRA. An RPA is necessary to cover safety requirements not addressed by current safety standards. If more hyperloop alignments are to be constructed in different locations, then the process would likely be simpler. An RGA could then be developed for hyperloop in the future.

Ultimately, safety regulation procedures will need to be developed along with all other regulatory needs in the development of this new transportation mode.

7.0 NEXT STEPS

For the hyperloop project, the Rapid Speed Transportation Initiative project partners have identified the following as the next steps upon conclusion of this study:

1. **Collaboration with Pennsylvania Turnpike Commission:** The Pennsylvania Turnpike Commission is undergoing a rapid speed transportation feasibility study between Pittsburgh, Philadelphia and New York that includes hyperloop technology. Findings of this feasibility study are being used for the transportation demand and economic impacts analysis. MORPC will continue to collaborate with Pennsylvania to advance planning for these two hyperloop projects.
2. **Hyperloop Certification Center Proposal:** MORPC, in collaboration with JobsOhio, One Columbus, the Ohio Department of Transportation (ODOT), and the Transportation Research Center, has submitted a proposal to a prominent hyperloop technology company to acquire the world's first hyperloop technology certification center. As of the conclusion of this study, Ohio is competing with nine other states in its bid to bring this facility to the region.
3. **Columbus International Airport-Downtown Columbus-Dublin Maglev Proposal:** In response to the Request for Proposals issued by the FRA in fall 2019, MORPC consulted with ODOT, the Ohio Rail Development Commission and Virgin Hyperloop One to submit a proposal for a hyperloop maglev corridor between John Glenn Columbus International Airport, downtown Columbus, and the City of Dublin. This proposal requests $5 million for planning work leading up to detailed design and construction. In the proposal, MORPC recognized that this project could serve as a pilot to create corridor approval frameworks for future system development and would be informed by the work to take place at the Hyperloop Certification Center (HCC). As of the conclusion of this study, MORPC is awaiting response from FRA.
4. **Federal Regulatory Framework:** Project proponents will continue to monitor activities of the New Emerging Transportation Technologies (NETT) Council to seek opportunities for collaboration with their work (ideally, NETT would use the HCC as a "pilot" to refine regulatory frameworks for hyperloop technology as it pertains to safety, environmental considerations, etc).

FOR MORE INFORMATION CONACT:

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