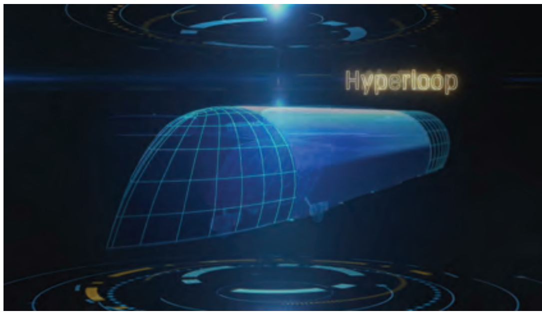
TBARTA
Tampa Bay Area Regional Transit Authority




# Innovative Transit Technologies Study

## FINAL DOCUMENT

Prepared for:

TAMPA BAY AREA REGIONAL TRANSIT AUTHORITY

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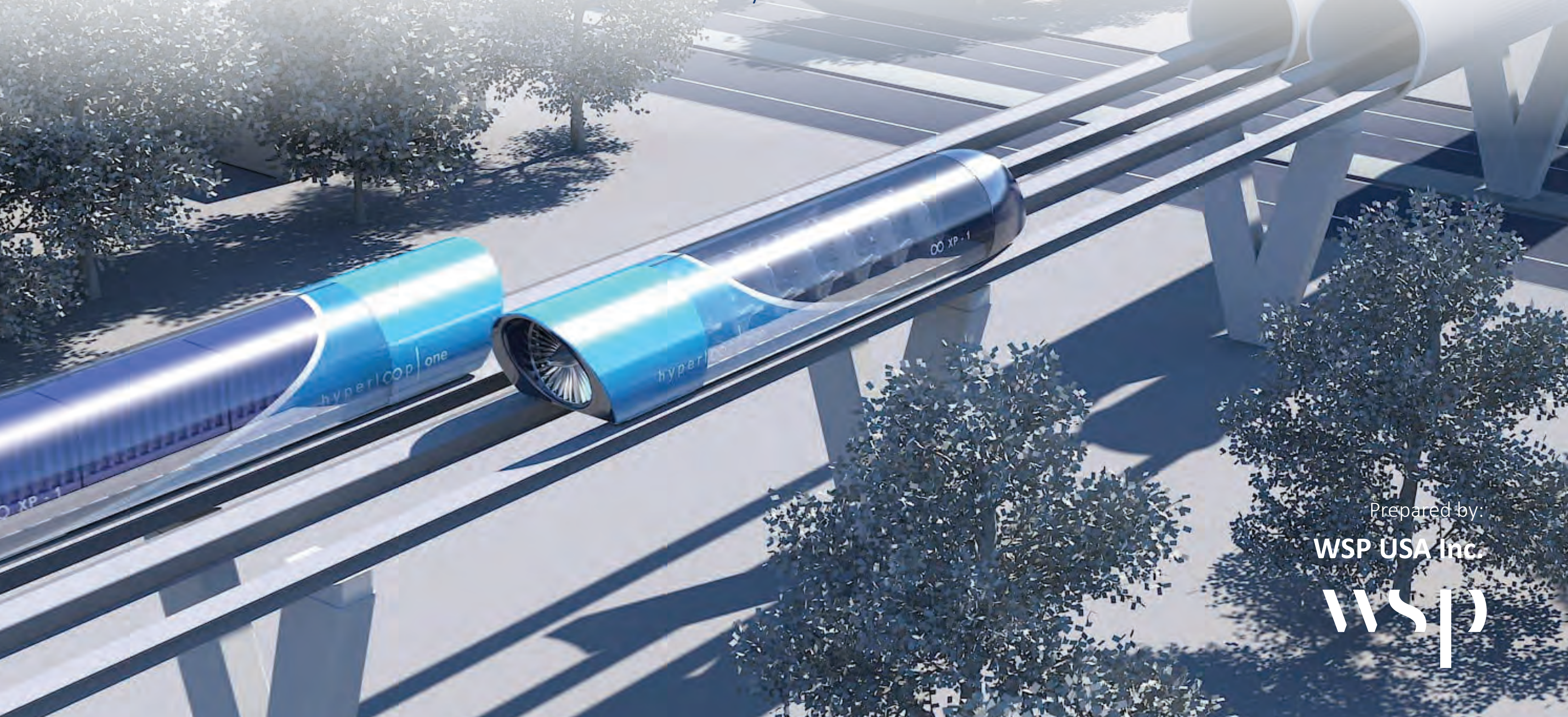

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# Acronyms and Abbreviations

AADT – Annual Average Daily Traffic

ADA – Americans with Disabilities Act

AMM – Automated Mission Management

ATC – Air Traffic Control

ATM – Air Traffic Management

CIG – Capital Investment Grant

ConOp – Concept of Operations

CPT – Cable Propelled Transit

DAA – Detect and Avoid

DOT – Department of Transportation

eVTOL – electric vertical take-off and landing

FAA – Federal Aviation Administration

FRA – Federal Railroad Administration

FTA – Federal Transit Administration

FDOT – Florida Department of Transportation

FHWA – Federal Highway Administration

HTT – Hyperloop Transportation Technologies

IPP – Integration Pilot Program

ITT – Innovative Transit Technologies

LRTP – Long Range Transportation Plan

NASA – National Aeronautics and Space Administration

NEPA – National Environmental Policy Act

NETT – Non-traditional and Emerging Transportation Technology

NOACA – Northeast Ohio Areawide Coordinating Agency

OHSU – Oregon Health and Science University

OSHA – Occupational Safety and Health Administration

PFC – Passenger Facilities Charges

R&D – Research and Development

SIS – Strategic Intermodal System

SVO – Simplified Vehicle Operations

SWOT – Strengths, Weaknesses, Opportunities and Threats

TBARTA – Tampa Bay Area Regional Transit Authority

TIA – Tampa international airport

TNC – Transportation Network Companies

TOD – Transit-Oriented Development

TP – TransPod

UAM – Urban Air Mobility

UAS – Unmanned Aircraft Systems

USF – University of South Florida

UTM – Unmanned Traffic Management

VHO – Virgin Hyperloop One

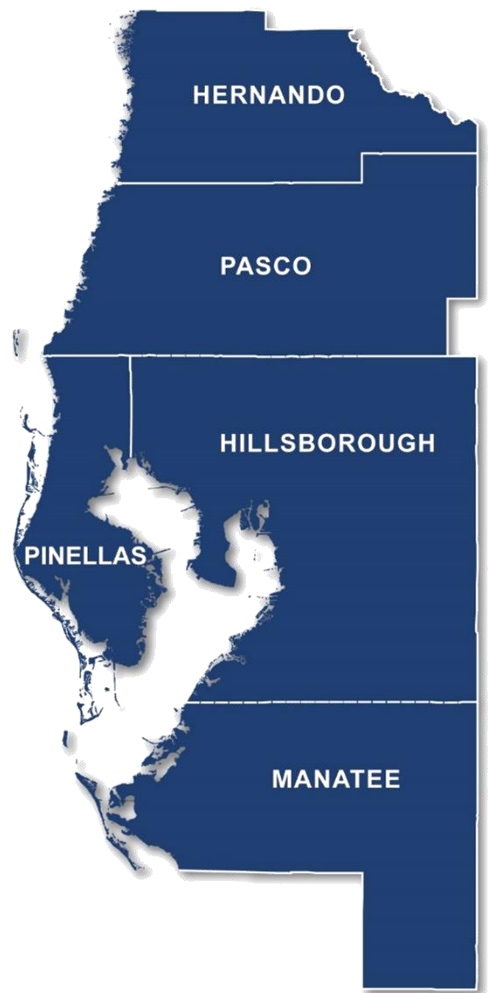
VHM - Vehicle Health Management

# 1 Introduction

## 1.1 Study Background

In 2019, the Florida Legislature asked the Tampa Bay Area Regional Transit Authority (TBARTA) to study and develop innovative transit technologies. The TBARTA Innovative Transit Technologies (ITT) Study kicked off in November 2019 to examine aerial gondolas, air taxis and hyperloop technologies. The intent of the high-level study is to identify the state of each of the technologies, evaluate the issues and opportunities related to each technology, assess the regulatory status, and identify key market connections appropriate for each technology.

*Figure 1: TBARTA Region*




As part of the travel market connections, the portion of the study related to aerial gondolas and air taxis is focused within the five-county TBARTA region (shown in Figure 1). Hyperloop will consider connections throughout the State of Florida.

## 1.2 Study Approach

The transportation industry has experienced significant changes in recent years as technology and transportation industries come together to redefine mobility as a service and enhance the user experience, safety, and efficiency. As TBARTA plans for the future of transit in the Tampa Bay region, there is recognition that new technologies and perhaps even new transit modes such as air taxis and hyperloop will play an important role.

The ITT study is a high-level study that included research and literature review, interviews with industry experts, evaluation of regulatory and governance structures for each of the technologies, and an analysis of potential areas of opportunity for connection in the Tampa Bay region. The work for this study has been documented in a series of technical memoranda.

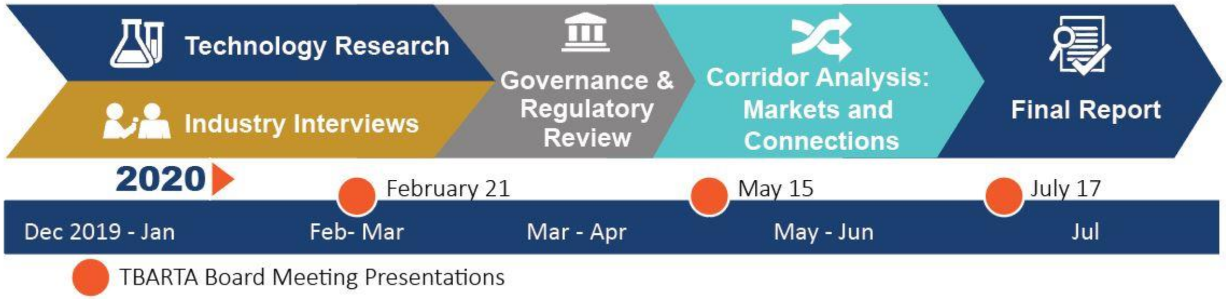
The technical memoranda include:

- Tech Memo 1 (Literature Review)
- Tech Memo 2 (Industry Interviews)
- Tech Memo 3 (Governance and Regulatory Framework)
- Tech Memo 4 (Corridor Travel Market Connections)

The information from these technical memoranda was used for this final summary document, and additional data can be found within those documents. Figure 2 shows the study process and schedule.

The study was divided into four main areas of evaluation: Technology Research, Industry Interviews, Governance and Regulatory Review, and Corridor Analysis: Markets and Connections.

*Figure 2: TBARTA ITT Study Process*




## Technology Research

A literature review was conducted to shed light on the capabilities of each of the technologies, and understand the overall readiness of the technology for deployment. The study team evaluated developer and manufacturer reports, agency studies, academic reports, and journals to pull key transit characteristics, issues and opportunities, state of the industry, and factors influencing the transit mode development and deployment in the future.

The literature reviewed is discussed in *Technical Memorandum 1: Literature Reviews*.

## Industry Interviews

Industry interviews provided supplemental input to the literature review. Interviews were held with agencies, developers, manufacturers, operators, mobility providers, technology providers, researchers and academia. The interviews provided additional understanding of where each of the three transportation technologies currently stands in development. The interviews also provided some insight from developers as to their current and envisioned goals for the three technologies.

The list of the interviews and their takeaways are provided in *Technical Memorandum 2: Industry Interviews.*

## Governance/Regulatory Reviews

The governance and regulatory review provided an understanding of where each of the technologies are in the regulatory process, important regulatory considerations to determine in order to implement the technologies, and what governmental bodies must develop in order to certify and implement the emerging technologies. Of the three technologies reviewed, aerial gondolas are the only existing technology in operation. Air taxis and hyperloop still need critical regulatory development before they can become a real mobility option. For air taxis and hyperloop, issues and constraints to their regulatory development were identified, as well as potential paths forward.

A comprehensive review of governance and regulatory frameworks is provided in *Technical Memorandum 3: Governance and Regulatory Frameworks*

## Markets and Connections

An evaluation of potential transit markets and connections in the Tampa Bay region was conducted for aerial gondolas and air taxis, and connections were identified throughout the state for hyperloop given its operational characteristics. A three-step evaluation process was used for identifying potential travel market connections. First, a technology profile was established for each technology based on its operating characteristics, known market connections, and infrastructure requirements. Second, a regional needs assessment was conducted utilizing activity centers, a travel market analysis, and constrained corridors. Finally, a qualitative assessment was conducted to align key travel characteristics and assumptions with destinations based on infrastructure, right of way, geography, and connectivity needs.

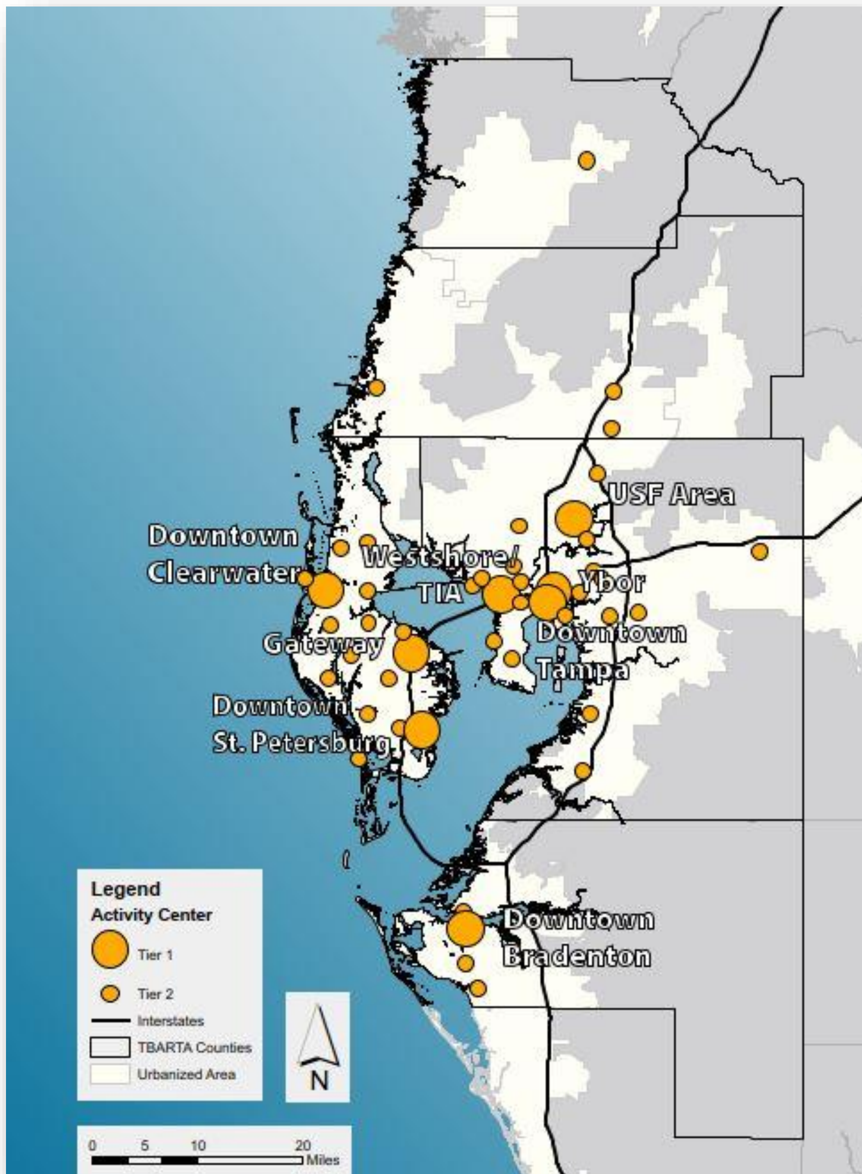
*Technical Memorandum 4: Corridor Travel Market Connections* provides the methodology, analysis and corridor connection findings.

In November 2019, the TBARTA Board held a workshop focused on the development of the region's first Regional Transit Development Plan (RTDP): Envision 2030. As part of the workshop, the TBARTA Board defined regional transit as that which crosses county lines (or contributes to a phase of an intercounty project) or connects regional activity and employment centers. These same criteria were applied to identify potential regional opportunities in Tampa Bay for aerial gondolas, air taxis and hyperloop. The ITT Study travel market analysis focused on regional activity centers, and the travel demands and characteristics between those activity centers. The activity centers serve as regional anchors for trips based on their density of population, employment, healthcare facilities, tourist attractions, entertainment, shopping and more. The analysis focused on Tier 1 and Tier 2, with the greatest levels of attractions, as defined through regional coordination (illustrated in Figure 3). The top ten travel markets between Tier 1 and 2 activity centers in each county were used as the bases to align technology capabilities with travel need.

For counties where there were not 10 Tier 1 or Tier 2 activity centers, Tier 3 activity centers were used to provide geographic equity of potential technology travel markets.

Specific qualitative factors for each technology are provided within the technology sections of this report. Additional methodology and details of the analysis process are provided in Technical Memorandum 4.

*Figure 3: Tier 1 and Tier 2 Regional Activity Centers*



# 2 Aerial Gondolas

## 2.1 Technology Overview


Cable Propelled Transit (CPT) technology is simply a motor-less vehicle that travels across a steel cable. The two main configurations for CPT are based on the physical location of the system's support base. CPT systems can be either top supported or bottom supported. This study specifically examines top supported CPT technologies which are often referred to as aerial gondolas or aerial trams (as shown in Figure 4).

### CPT Components

Components of aerial CPT Systems include:

- ***Cabins*** are the structural and mechanical assemblage in which passengers are carried. They protect users from the environment and can include various amenities.[1]
- ***Grips*** attach the cabin to the cable/rope and are classified as one of two typologies: Detachable Grip and Fixed Grip.

  A detachable grip allows for the cabin to separate itself from the propulsion cable when entering a station. When detached, the cabin slows as it enters the station allowing for passenger pickup and drop off. This feature allows for boardings without stopping the entire system. The result is increased system capacity in comparison to non-detachable grip technology. Without detachable grip technology, cabins would be incapable of turning at angle stations. Detachable grip systems are generally classified by the number of cables used in the system. Alternatively, with a fixed grip system, the cabins are affixed to the cable via a clamp. Aerial Trams are the most common style of fixed grip systems. While gondolas can be either fixed or detachable grip, the technology has moved towards detachable grips in urban transit applications due to their higher capacity.

*Figure 4: Hakone Ropeway*

*Source:* https://www.hakoneropeway.co.jp/

- ***Towers:*** Towers support the propulsion and trackage cable (if required) between terminals and allow for the movement of the propulsion rope through wheels. Towers (depicted in Figure 5) are typically constructed as

[1] Alshalalfah 2012; Dale 2013

either a cylindrical column or a lattice style structure. Additional architectural elements can be added to towers. These additions can help to improve the image and public acceptance of a system but can greatly increase cost.[2]

- ***Cable Rope***: There are two types of cables:
    - **Propulsion** (Haulage) cable: A propulsion rope propels and supports the cabin.
    - **Track Cable**: A track cable does not move but provides additional support. Track cables are instrumental to stabilization in windy environments.
- ***Bullwheel***: A bullwheel is a large metal wheel on which the propulsion cable turns. It transfers energy from the engine to the rope thereby moving the cabins.
- ***Sheaves*** (Assembly): Sheaves are typically found on towers and consist of wheels which support and depress the propulsion cables.
- ***Loops***: A loop is when one cable is connected to itself forming a loop. More complex systems rely on multiple loops for turns at stations.

***Figure 5: Portland Aerial Tram Tower***

Source: http://leitner-poma.com//

## Stations

There are different types of stations (like the CPT station shown in Figure 6 in London) that support CPT operations, based on where it is located along the system and the function:

- ***Drive Station***: The drive station houses the major system components including cable propulsion infrastructure (bullwheel and engine) and cabin storage.
- ***Intermediate Station***: Intermediate stations are located between the drive and return stations. These stations are typically constructed to allow for passenger boarding at various point in a larger system.
- ***Angle Station***: Angle stations allow gondola systems to change direction between destinations. Intermediate stations can also function as angle stations.

***Figure 6: MGD Emirates Air Line, London***

*Source:* https://www.doppelmayr.com/

[2] Alshalalfah 2012; Dale 2013

- ***Return Station***: The return station is where the cable loop circulates around a bullwheel and begins to return to the drive station.

## Gondola and Tram Types

**Detachable Grips**

- **Monocable Detachable Gondolas (MDG):** MDGs are the most basic and common system for urban aerial gondola transit. The one cable provides both propulsion and support for the cabins. As a continuously circulating system, the cable circulates around two end terminals in a loop. When entering stations, the cabins detach from the cable, slow down to a stop, and allow for passenger loading and unloading. Figure 7 depicts a MDG system.

***Figure 7: Monocable Gondola***

Source: https://www.cbs58.com/

- **Bicable Detachable Gondola (BDG):** BDGs use two cables. One is for propulsion, and the other is for support. BDGs were developed with support ropes to provide more wind stability than early MDGs. However, MDG technologies have advanced to the point where there is no discernable difference between the technologies. Therefore, this is no longer used. Figure 8 depicts a BDG system.

***Figure 8: Bicable Gondola***

Source: https://www.leitner-ropeways.com/

- **Tricable Detachable Gondola (TDG/3S):** TDGs use three cables- one for propulsion, and two for support. Considered the most technologically advanced systems, TDGs operate similarly to MDGs, just with more cables. TDG technology, in comparison with other detachable technologies, allows for operations in the highest wind speeds, transports larger cabins, operates at the highest speeds, and allows for the largest tower spacing. TDGs are likely to remain the leading technology in the field for the foreseeable future. TDGs are the most expensive detachable system to implement. Figure 9 depicts a TDG system.

***Figure 9: Tricable Gondola***

Source: https://www. Koblenz-toursim.com/

**Non-Detachable Grips (Fixed Grips)**

In non-detachable grip systems, the cabin is clamped to a fixed position on the propulsion rope. Due to this configuration, when a cabin arrives at a station the entire system must come to a stop to allow for boardings. This stopping requirement greatly reduces capacities and speeds. It is rare to find any non-detachable systems that have intermediate stations (including turning).

## Aerial Tram

An Aerial Tram's utilization of fixed grips greatly reduces system capacity in comparisons to detachable systems despite offering the highest speeds and largest cabin sizes of the CPT technologies. The system operates by sending two cabins between two terminals in tandem (there is an option to add a "dual haul" configuration that allows the trams to operate independently). Dual haul systems offer greater flexibility in case of needed maintenance and demand responsive operations. The Portland Aerial Tram in Portland, Oregon is an example of an urban aerial tram (shown in Figure 10)

*Figure 10: Aerial Tram*

Source: https://www.biketownpdx.com/

## Amenities

CPT systems feature cabins which at a minimum provide seating or handrails for user comfort. However, as the technology has continued to improve, additional passenger amenities have been developed. Amenities include:

- **Glass Floors**: Glass floors allow passengers a downward view of the CPT's path. This feature is generally used in tourist destinations (as shown in Figure 11 of the Koblenz cable car interior).
- **Accessible Cabins**: For passengers with mobility limitations, cabins can be removed from the moving ropeway and transitioned to a side platform for boarding at a passenger defined pace.
- **Privacy (Smart Glass)**: In areas of privacy concerns, windows of CPT cabins can be "frosted" to obscure passenger view of homes, businesses, and other sensitive uses.
- **Lighting**: Battery powered lighting of cabins.
- **Wi-Fi**: Cabins can include access to Wi-Fi.
- **Air Conditioning**: Battery powered air conditioning units can be used to cool cabins. However, their effectiveness remains limited at this time.
- **Cabin Recovery Systems**: These systems allow for cabins to be brought back to the stations, while passengers remain in the cabin.
- **Electrical Grounding Systems:** CPT systems have been designed to protect passengers and the system from lightning strikes through the implementation of an electrical grounding system.
- **Real Time Passenger Information Screens:** Systems may include real time passenger information systems in cabins to inform passengers of arrival times and travel times.
- **Camera and Intercom Systems:** Cabins may be outfitted with intercoms and cameras to allow passengers to reach an attendant and better ensure safety.

*Figure 11: Koblenz Cable Car Interior*

Source: https://www.seilbahn-koblenz.de/

## Operational Characteristics

Though aerial gondolas and aerial trams utilize the same fundamental technology, there are differences in their operational characteristics.

**Aerial Gondolas (detachable grip)**

Aerial Gondolas feature a cable that creates a loop. This loop allows for the continuous movement of cabins along the ropeway from the drive station to the return station and back to the drive station. This loop allows for many cabins to be gripped to the cable, increasing capacity, and negating the need to stop system for boardings and alighting's. This results in a system with high capacities and low headway times.

**Aerial Trams (fixed grip)**

Aerial Trams feature a cable that the tram is permanently affixed to during operations. The fixed grip nature of aerial trams means they must stop at a station to allow for boardings and alighting's. These systems are made up of a total of two cabins that ferry passengers back and forth between the drive station and return station, stopping at each end. Though trams feature the largest cabins sizes, the stopping at stations greatly reduces the hourly capacity of these systems. However, it should be noted, that tram systems have the highest speeds and allow for the greatest span length (space required between towers).

**Operations & Maintenance**

In general, both systems do not require large staffs to operate. At an individual station, most systems afford for approximately five staff members with positions including station attendants, mechanics, and supervisors. Depending on the hours of operations, systems may utilize two to three shifts of workers throughout a day.

Maintenance cost and system replacement timeframes are highly dependent on system utilization. Historically these systems have been used seasonally (ski resorts) and less so as an urban transit solution which requires much greater operating timeframes. These increased operating windows result in greater system wearing. As such, operation's cost is an evolving field specifically in transit applications. However, 10% of system implementation cost may be utilized for planning level operations cost.

Generalized characteristics of the various CPT systems are summarized in Table 1.

*Table 1: CPT Technology Generalized Operations Characteristics*

| | Monocable Gondola | Bicable Gondola | Tricable Gondola | Aerial Tram |
|---|---|---|---|---|
| Maximum Speed (mph) | 14 | 16 | 17 | 28 |
| Maximum Capacity (pphpd) | Up to 4,000 | Up to 4,000 | Above 6,000 | Up to 2,000 |
| Maximum Wind Speed Operation (mph) | Up to 45 | Up to 45 | 62+ | 50+ |
| Capital Cost (Compared to other CPTs) | Low | Low-Medium | High | Medium High |
| Grip Type | Detachable | Detachable | Detachable | Fixed |

### 2.1.1 Benefits and Concerns

As with any proposed transit solution there are benefits and concerns to consider for implementation.

**Benefits**

- ***Geographic Barriers***: CPT technologies provide transport over geographic barriers such as rivers, mountains, and manmade obstacles.
- ***Limited Required Right of Way***: CPT systems require much less right of way in comparison with other fixed guideway systems. Systems only need right of way at station locations and at towers.
- ***Low Capital & Operating Cost***: Due to the simple technology involved (electric motor), these systems experience lower capital and operating costs in comparison to other transit modes
- ***All Electric***: CPT systems operate on electricity only.
- ***Travel Above Congested Corridors***: Due to the limited required right of way and grade separation of CPT systems, they can travel above and along congested corridors.
- ***Speed***: Along congested corridors, speeds of CPT systems can be faster than the traffic that is at grade level.
- ***Safety***: CPT systems have extremely low incident rates per hour (much lower than bus and fixed guideway).
- ***Accessibility***: CPT systems are designed to meet all ADA standards.

**Concerns**

- ***Weather***: Extreme weather conditions such as high wind and lighting can require temporary system shutdowns. These shutdowns negatively affect CPT system capacity.
- ***Privacy***: CPT systems can cause privacy concerns if they travel over private property.
- ***System Flexibility & Expansion***: System expansion is difficult if not planned for in advance.
- ***Perceptions/Politicization***: CPT systems may experience negative perceptions from the public, and projects have become politicized in other communities. CPT systems may be perceived as only a tourist attraction.
- ***Viewshed***: CPT systems affect viewsheds, which may be considered a negative by a community.
- ***Low operating speeds:*** Operating speeds are low compared to other transit modes.
- ***Maximum Speed***: Though CPT systems can achieve higher speeds in congested corridors, speeds may not be fast enough for other applications.

### 2.1.2 Vendors

Doppelmayr Garaventa Group (Doppelmayr) is one of the two main CPT manufacturers. Doppelmayr manufactures and operates CPT systems for ski areas as well as urban transit applications. The aerial gondola styles offered by Doppelmayr include Reversible Aerial Tramway, 3S Gondola Lift, and the Detachable Gondola Lift.

Leitner Poma (Leitner) is the other main CPT manufacturer. Like Doppelmayr, Leitner manufactures and operates CPT systems for ski areas as well as urban transit applications. Leitner's urban gondola ropeways include the Detachable Gondola Lift, Tricable and Bicable gondola lifts, and Reversible Gondola Ropeways.

## 2.2 Costs

Construction costs for CPT varies by type and system complexity. To date there are several systems that have been implemented across the world for which capital costs are available (provided for illustrative purposes only). However, manufacturers caution against generalizing per mile cost from implemented systems. There are too many variables that may influence a system cost to compare among projects. System variables include:

- Aesthetic Treatments
  - Towers
  - Stations
- Cabin Complexity
  - Real Time Information
  - WI-FI
  - Quantity
  - Amenities
- Engineering Needs
  - Tower Spacing
  - System Length
  - Station Quantity
  - Cabin Quantity

The CPT industry typically evaluates cost within a spectrum of Low-Medium-High between the different types of CPT technologies. This provides a high level planning level of magnitude when considering different technology options and services. The consensus across the industry regarding costs between the different technology are provided in Table 2.

*Table 2: CPT Technology Cost Levels*

| CPT Technology | Relative Cost |
|---|---|
| Monocable | Low |
| Bi-Cable | Low-Medium |
| Tri-Cable | High |
| Aerial Tram | Medium-High |

Historical system implementation costs are provided for illustrative purposes only in Table 3. These show the wide range of costs by system type.

*Table 3: Historical CPT System Costs*

| CPT System | Year | Location | Type | Length (miles) | Cost | Cost (per mile) | Stations |
|---|---|---|---|---|---|---|---|
| Medellin Line K | 2004 | Colombia | MDG | 1.24 | $26,000,000 | $20,967,742 | 4 |
| Medellin Line J | 2008 | Colombia | MDG | 1.62 | $50,000,000 | $30,864,198 | 4 |

| CPT System | Year | Location | Type | Length (miles) | Cost | Cost (per mile) | Stations |
|---|---|---|---|---|---|---|---|
| Caracas Metrocable | 2010 | Venezuela | MDG | 1.12 | $21,000,000 | $ 18,750,000 | 5 |
| Teleferico Do Alemao | 2011 | Brazil | MDG | 2.17 | $133,000,000 | $ 61,290,323 | 6 |
| Constantine, Telecabine | 2008 | Algeria | MDG | 0.93 | $14,000,000 | $15,053,763 | 3 |
| Tlemcen Telecabine | 2009 | Algeria | MDG | 0.99 | $14,700,000 | $14,848,485 | 3 |
| Skikda Telecabine | 2009 | Algeria | MDG | 1.18 | $16,200,000 | $ 13,728,814 | 3 |
| Medellin Line L | 2012 | Colombia | MDG | 2.98 | $25,000,000 | $8,389,262 | 2 |
| Emirates Air Line | 2012 | United Kingdom | MDG | 0.68 | $90,000,000 | $132,352,941 | 2 |
| Teleferico Warairarepano | 2000 | Venezuela | MDG | 2.17 | $45,000,000 | $20,737,327 | 2 |
| Singapore Cable Car | 2010 | Singapore | MDG | 1.06 | $14,700,000 | $13,867,925 | 3 |
| Ngong Ping 360 | 2006 | China | BDG | 3.54 | $128,000,000 | $36,158,192 | 2 |
| Koblenz Rheinsteilbahn | 2010 | Germany | TDG/3S | 0.56 | $17,900,000 | $31,964,286 | 2 |
| Funivia Del Renon | 2009 | Italy | TDG/3S | 2.8 | $22,230,000 | $7,939,286 | 2 |
| Roosevelt Island Tram | 2010 | New York, NY | Aerial Tram | 0.62 | $25,000,000 | $40,322,581 | 2 |
| Portland Aerial Tram | 2007 | Portland, OR | Aerial Tram | 0.62 | $57,000,000 | $ 91,935,484 | 2 |
| Funivia Del Renon | 2009 | Italy | TDG/3S | 2.8 | $22,230,000 | $7,939,286 | 2 |

## 2.3 Regulatory Considerations

There are no apparent direct Federal regulations related to the design, construction, operation, maintenance, or inspection of aerial gondolas. However, Americans with Disabilities Act (ADA) and Occupational Safety and Health Administration (OSHA) regulations do apply for any public transit system. There are also pathways through the Federal Transit Administration (FTA) for funding.

At the state level, most states with ski areas have Passenger Tramway Safety Boards, which regulate new or renovated aerial gondolas with respect to design, construction, and inspection. In several states, these Boards report to their Department of Labor. However, the state of Florida does not have any legislation covering aerial gondolas.

In the absence of state defined standards, American National Standards Institute (ANSI) Standard B77.1 is universally applied to both public and private aerial gondola systems, for design, construction, operations, maintenance, and inspection. Standard B77.1 was developed by the ANSI Standards for Passenger Aerial Ropeways Committee (ASC B77). Its membership is composed of representatives from state safety boards, manufacturers, and gondola system operators which has led to general conformity in standards across the United States.

There are a variety of potential funding sources at the federal and state level that could be used to contribute to the cost of construction, equipment procurement, operations, and maintenance. At the federal level, this includes several categories of funds: the USDOT's Better Utilizing Investments to Leverage Development (BUILD) Grant, the FTA's Capital Investment Grant (CIG) Program, Section 5307 funds, and the FHWA's Surface Transportation Program. Meeting the requirements of the Buy America Act may require the application for a waiver given that most gondola equipment is built in Europe.

At the state level, the FDOT New Starts Transit Program, Public Transit Block Grant Program, Transit Corridor Program, and Service Development Program are all potential funding sources to help cover capital and operations and maintenance costs for aerial gondolas.

Local government involvement in gondola development will include inspection, certification, and in many cases ownership of the gondola facility. Local zoning and site development standards will also need to be followed in the location and configuration of terminals and intermediate stations for gondola facilities. Potential local funding sources, other than taxation mechanisms, which could help cover operating costs, include special assessments, joint development, naming rights, and private contributions.

The existing aerial gondolas in Portland, Oregon; New York City, New York; and at Walt Disney World follow the ANSI B77.1 standards in regards to agreements and responsibilities among public and private parties. The systems in Portland and New York City are owned by the cities. Intermediate entities such as the Oregon Health and Science University (OHSU) in Portland and the Roosevelt Island Operating Corporation in New York contract with private vendors to operate and maintain their systems. All three systems undergo regular inspections.

## 2.4 Technology Readiness

CPT technology has been implemented in the U.S. as well as other countries as an urban transit solution. There is no technological reason that CPT technology could not be implemented within the TBARTA region. However, considering the novelty of this technology as a transit solution in the State of Florida, close coordination with FDOT and the service implementer is recommended. Coordination will be increasingly important if any state or federal funding is sought for a CPT project.

## 2.5 Market Connections

Urban aerial gondolas have the ability to provide a high capacity, short distance transit solution. Potential connections were identified based on several factors including a transit profile developed based on the proposed operating characteristics of urban aerial gondolas (shown in Table 4).

*Table 4: Urban Aerial Gondola Transit Profile*

| Aerial Gondola Technology: | Monocable | Tricable | Tram |
|---|---|---|---|
| Example Location | Emirates Air Line, London | Funivia Del Renon, Italy | Roosevelt Island Tramp, NY |
| *Images are only for examples of technology, data within profile is a summation of various sources, not just for the example vehicle shown.* |  |  |  |
| Photo Credit | https://www.doppelmayr.com/ | www.ritten.com | https://rioc.ny.gov/302/Tram |
| Corridor Length | 0.7 to 3 miles | 0.5 to 3 miles | 0.5 to 3 miles |
| Trip Profile (short/mid/ long haul) | Short | Short | Short |
| Speed (mph) (max) | 14 | 17 | 28 |
| Headway | 0:10 to 0:30 | 0:15 to 0:45 | 5:00 to 6:30 |
| Capacity (per vehicle) | 4-15 | 38 | 200 |
| Capacity (per hour) | 4,000 | 6,000 | 2,000 |
| Corridor/Infrastructure Requirements | Air (Towers, Drive station, Angle Station, Turn Station) | Air (Towers, Drive station, Angle Station, Turn Station) | Air (Towers, Drive station, Angle Station, Turn Station) |

*Data sources are ranges and averages based on various sources: Cable Car Confidential, 2013, https://rioc.ny.gov/302/Tram; http://www.gobytram.com/; individual system information, Doppelmayr and Leitner Ropeways Manufacturer Materials, as well as interviews.*

Research on the urban aerial gondolas proves that the technology has capabilities to solve unique transportation challenges. Each of the qualitative criteria to consider when identifying opportunities for aerial gondolas could ultimately provide guidance on when to evaluate urban aerial gondolas as a potential transit option. Additional qualitative factors utilized within the analysis included:

- **Geographic Barriers**: Locations (such as beach connections/barrier island connections) where aerial gondolas can traverse water, potentially alleviating capacity constraints along bridges that connect to island and beach communities.
- **Airport Connections**: Aerial gondolas are particularly productive in providing point-to-point transportation between two destinations. An airport could be a good connection point for an urban aerial gondola if the connection point at the other end is a large enough trip origin and destination.

- **City Circulators**: Urban aerial gondolas can provide a distributer system at the end of transit systems, and connect residents, employees and visitors throughout a downtown core, whether they arrived by transit or parked in a garage.
- **Transit Connectivity**: Urban aerial gondolas can serve as an extension to existing premium transit services where additional distribution is needed on an end of the line, within a dense area. Regional intermodal centers connectivity could be enhanced with urban aerial gondolas.
- **Campus Connections**: The Tampa Bay region is home to several colleges and universities, including but not limited to, the University of South Florida (USF) in Hillsborough County and Downtown St. Petersburg, USF Medical in Downtown Tampa and St. Petersburg College.

The following travel market connections were identified through the travel demand analysis as well as qualitative assessment based on the Transit Profile.

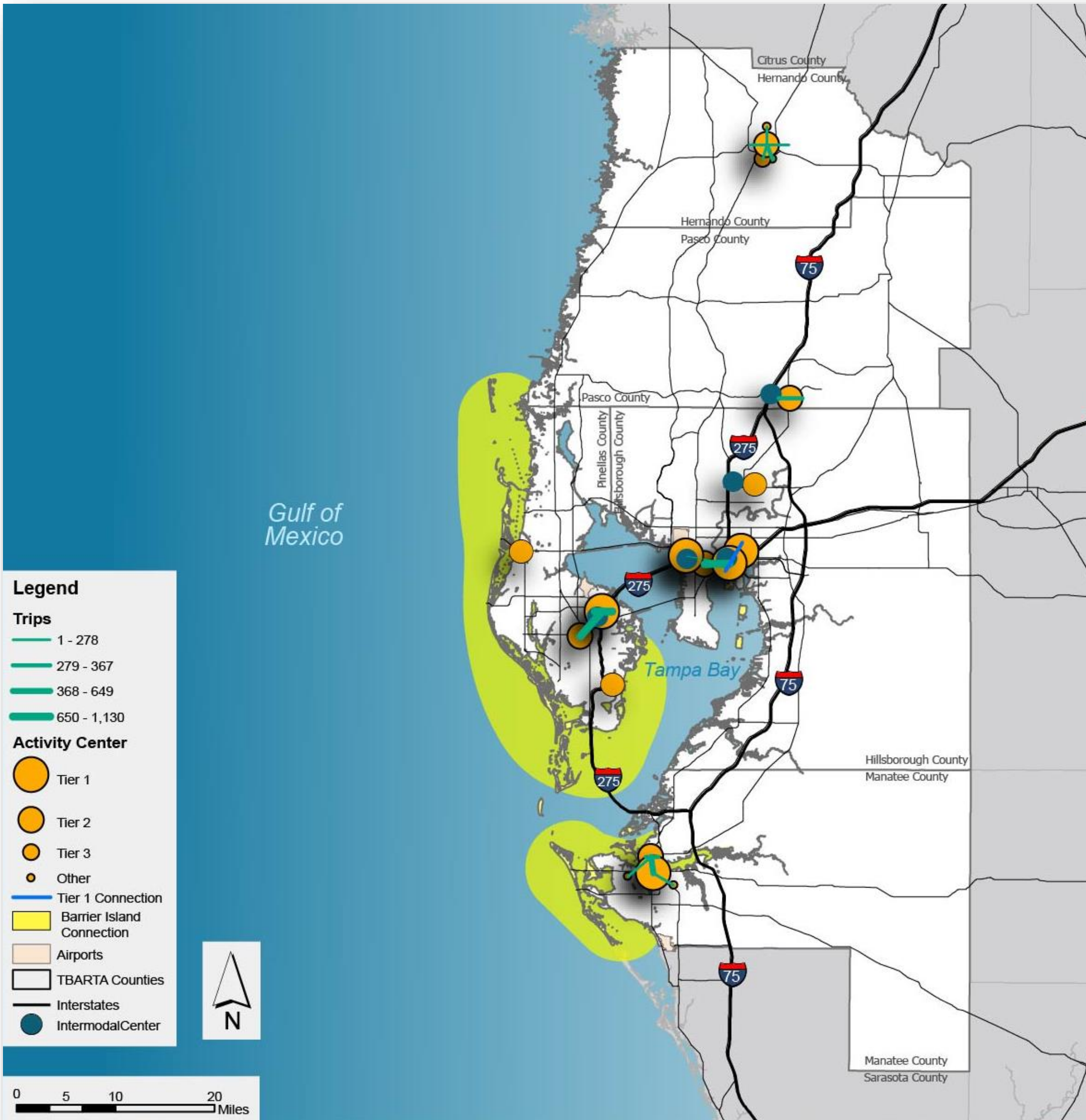
- **Travel between Activity Centers (by County)**: Following the evaluation of travel demand within each county, the following potential connections were selected based on the profile characteristics of urban aerial gondolas.
    - Kennedy Boulevard Corridor to Downtown Tampa (Hillsborough County)
    - Gateway to Gateway (Pinellas County)
    - Gateway to Pinellas Park (Pinellas County)
    - Wesley Chapel to Advent Health Hospital (Pasco County)
    - Brooksville to South Brooksville (Hernando County)
    - Brooksville to North Brooksville (Hernando County)
    - Brooksville to Brooksville (Hernando County)
    - Palmetto to Bradenton (Manatee County)
    - Palmetto to Palmetto (Manatee County)
    - Palmetto to East Bradenton (Manatee County)
    - Bradenton to Samoset (Manatee County)
- **Tier 1 Activity Center Connections:**
    - Downtown Tampa to Ybor City
- **Travel within Tier 1 Activity Centers**: Urban aerial gondolas can serve urban areas where there may be constrained roads and limited space. Each of the Tier 1 Activity Centers were noted as being potential locations based on their population and employment characteristics, as well as their attractions of regional significance that can support a circulator transport option for residents and visitors. This includes potential for consideration within Downtown Bradenton (Manatee), Downtown Clearwater (Pinellas), Gateway area (Pinellas), Downtown St. Petersburg (Pinellas), Downtown Tampa (Hillsborough), USF area (Hillsborough), Westshore/Tampa International Airport (TIA) (Hillsborough), and Ybor City (Hillsborough).
    - Downtown areas as downtown circulators are included within the Tier 1 Activity Centers identified.
    - Major campus connections are included within the Tier 1 Activity Centers identified.
- **Beach and barrier island connections:** As part of the qualitative assessment, it was determined that there are substantial opportunities to utilize urban aerial gondolas along beach communities and to connect barrier islands where bridges and infrastructure pose constraints. These features are most apparent in Pinellas County and Manatee County where there are several bridges connecting to the beach communities. These areas are also surrounded by

significant activity centers. In addition, there may be opportunities in northern Pinellas and southern Pasco County along the coastal communities where there is significant residential and tourist population to support the service. (See Figure 12)

- **Airport connectors within Tier 1 Activity Centers**: Urban aerial gondolas can provide airports with constant service to transport passengers to and from the facilities. Each of the airports within major activity centers are identified, including Tampa International Airport, St. Pete-Clearwater International Airport, and Sarasota-Bradenton International Airport. Some of these may already have ground transport options (such as the newly constructed automated people mover system at TIA), and additional opportunities could be assessed for connecting to and from the airport.
- **Intermodal center connectivity:** Aerial gondolas can serve as an extension of existing premium transit systems to enhance connectivity. Intermodal centers are currently being assessed throughout the region, and have been included as opportunities for potential aerial gondolas to connect first and last mile destinations where appropriate.

Aerial gondola opportunities based on the demand analysis are provided in Figure 12.

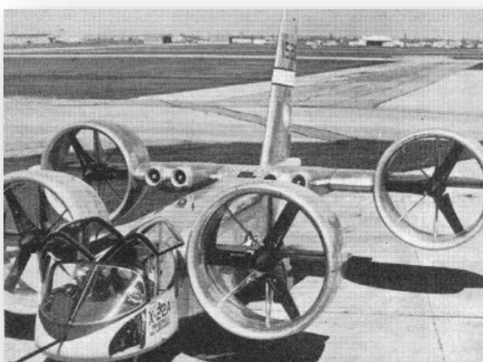
*Figure 12: Potential Urban Aerial Gondola Connections*



# 3 Air Taxis

The concept of developing and implementing an air taxi system using innovative aircraft is not a new concept. Since the 1960's, aviation manufacturers and suppliers have been working on various vehicle concepts that can enable an air taxi network – a phenomenon commonly referred to as Urban Air Mobility (UAM), in which vertical takeoff and landing (VTOL) technology enables shorter distance, lower capacity flight operations. Various examples of mainstream expectations of the technology can be seen in multiple issues of Popular Mechanics through the years, as illustrated in Figure 13. The high cost, noise, and emissions profile of VTOL aircraft, notably helicopters, has historically been an obstacle to UAM's development. Nevertheless, UAM has widely and consistently been an aspirational operational model for aircraft services to the point that the Federal Aviation Administration (FAA) conducted comprehensive vertiport studies as early as 1994. [3]


*Figure 13: "Prediction 1965: Vertical Takeoff and Landing Planes", Popular Mechanics, 1965*



The introduction and development of new electric vertical take-off and landing (eVTOL) aircraft that rely on electric propulsions systems instead of combustion engines has created new possibilities for the development of UAM. This is due to their lower cost, noise, and emissions profiles.

## 3.1 Technology Overview

It is estimated that between 100 and 170 new electric aircraft (both eVTOL and fixed wing) are currently in different stages of development worldwide. The designs are somewhat unique in terms of their configurations and capabilities. This study focused on eVTOL aircraft because of their compatibility with the UAM/air taxi concept. These vehicles are intended to provide services that connect urban centers to other urban or suburban centers, or to the existing transportation infrastructure.

[3] http://www.tc.faa.gov/its/worldpac/techrpt/rd94-23.pdf

eVTOL aircraft can be grouped into three broad categories. They include: multirotor, lift and cruise, and vertical thrust. Multirotor aircraft (illustrated in Figure 14) have a circulating actuator which provides efficient hovering capacity. These aircraft have no wings so they are not ideal for cruising. They can cruise up to 50-80 mph and have a range between 10-25 miles.

*Figure 14: Multirotor Aircraft*

Source: "Pioneering the Urban Air Taxi Revolution 1.0", Volocopter

Lift and cruise technology has two different types of propulsions systems. One is used for hovering and the other for cruising. Their cruising speed is between 110-180 mph, and they have a range of 50-60 miles. An example of a Lift and Cruise aircraft is shown in Figure 15. Vectored thrust aircraft have similar cruising speeds and ranges to the vertical thrust aircraft, but have either fixed or tilt wings with only one propulsion system used for both hovering and cruising. Given the similarities of the lift and cruise and vectored thrust technologies, they were evaluated for similar markets. Figure 16 shows an example of a Vectored Thrust aircraft.

*Figure 15: Lift and Cruise Aircraft*

Source: Jaunt Air Mobility, Rosa: https://www.jauntairmobility.com/

The current literature on UAM aircraft indicates that there are five primary sub-segment systems that will be a priority for aircraft designers:

*Figure 16: Vectored Thrust Aircraft*

Source: Lilium https://lilium.com/the-jet

- **Detect and Avoid (DAA):** A performance-based standard for DAA has yet to be put into place for UAM operations. Compared to ground-based radar, existing onboard DAA systems are significantly less powerful. This poses a major challenge to the industry that needs to be addressed ahead of UAM.
- **Automated Mission Management (AMM):** Algorithms will control a variety of mission-critical functions aboard UAM passenger vehicles. The UAM industry will need to take further steps to enhance real-time data processing capabilities to achieve algorithm reliability.
- **Vehicle Health Management (VHM):** UAM will rely heavily on real-time vehicle health assessments inputted into the AMM and unmanned traffic management (UTM) systems, in contrast to the supplemental role that VHM plays for conventional aircraft. Fleets may ultimately benefit from a lower total cost of ownership and longer service life from VMH-enabled predictive maintenance.
- **Simplified Vehicle Operations (SVO):** Mature market forecasts for UAM presume an evolution from full cockpit to single pilot to fully autonomous vehicle operations.

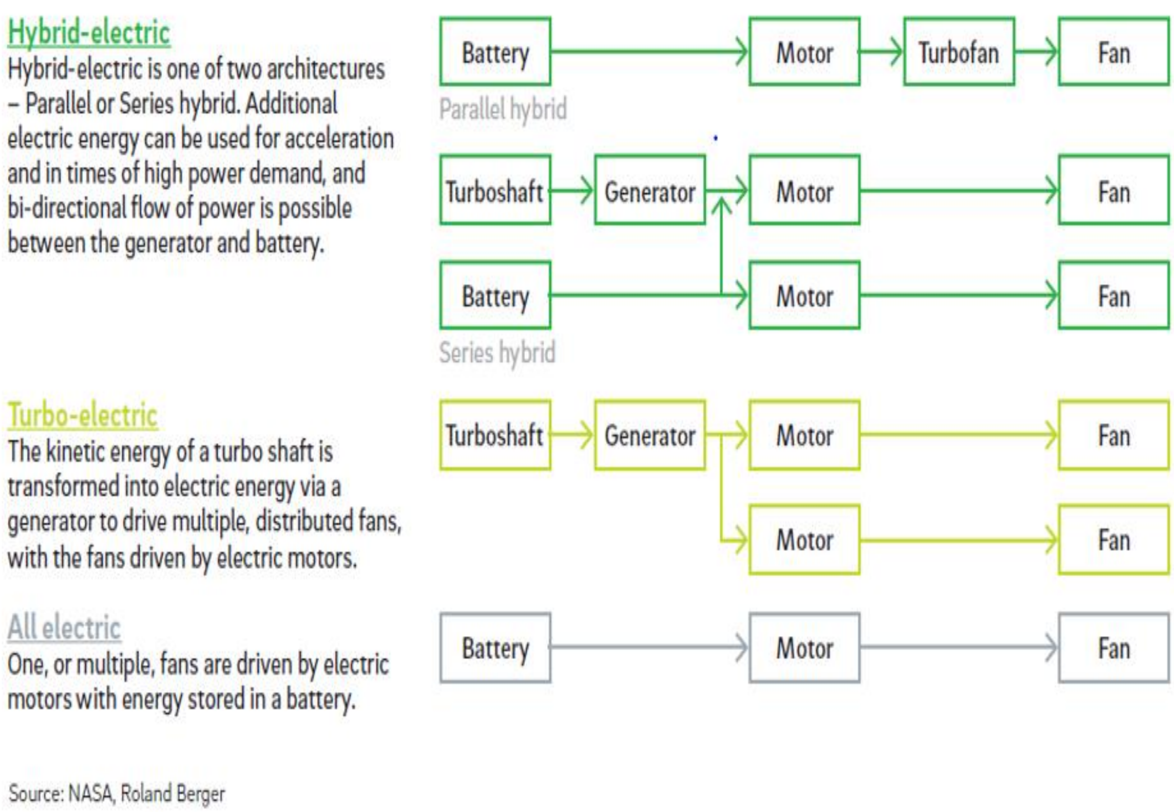
- **Electric Power***:* Vehicles in the UAM market are expected to use electric propulsion to reduce noise and impact on the environment. Further improvements in battery technology including the increase of specific energy and life cycle are required for sustainable UAM operations. Standards will ultimately need to be determined for the batteries powering propulsion systems.

Two significant focus areas that impact the timing of implementation are autonomous aviation technology and electric propulsion. Each of these factors are critical to what portions of the UAM concept can be deployed and when. These are discussed later as part of the regulatory considerations related to air taxis.

## Energy Requirements

The use of eVTOL technology for air taxi systems offer lower noise and reduced emissions. Figure 17 provides an overview of the different types of electric propulsion architectures that are currently under development and consideration for supporting air taxis. These propulsion architectures are characterized primarily by their degree of hybridization, which describes how much of their energy source and power comes from batteries and electric motors. Industry consensus generally indicates that pure electric systems are most likely to succeed in the air taxi market, with hybrid propulsion systems being increasingly targeted toward small, fixed wing aircraft that would service regional markets.

*Figure 17: Electric Propulsion Typology for eVTOL*



**Electric Service Requirements**

The current aircraft industry is positioned to target electric or hybrid-electric aircraft models. As a result, air taxi vertiports will need to integrate battery recharging infrastructure into their designs. Given the current limitations on battery technology, the travel range of air taxis is likely to be limited in the early years of UAM. This will require extensive, ubiquitous access to recharging infrastructure.

## Operational Characteristics

A NASA commissioned study identified two primary markets related to passenger UAM: the "Air Metro" model and the "Air Taxi" model. [4] While the purported goal of many private companies in the UAM supply is to enable "on-demand" transportation via air taxis, such a system would require ubiquitous aerial mobility stops (vertistops) throughout a region, which is fundamentally cost-prohibitive in the foreseeable future (at least through 2030).

> The **"Air Taxi"** model assumes on-demand service when requested, and requires ubiquitous vertistops. An **"Air Metro"** model resembles current public transit options such as subways and buses, with pre-determined routes, regular schedules, and a set of stops in high-traffic areas.

While such a model is far-off, research conducted for NASA indicated that an "air metro" model is not viable before 2030. In this use case, the air metro resembles current public transit options such as subways and buses, with pre-determined routes, regular schedules, and set stops in high-traffic areas throughout each city. These services are still likely to be requested via a smartphone application, but they will not have the same "on-demand" characteristics typical of existing transportation network companies (TNCs)[5].

**Capacity (Vehicle Capacity and Carrying Capacity)**

Passenger capacity is projected to be between one and four persons across aircraft configurations and typologies. In some instances, space for a fifth individual is included, with the vision that the fifth seat will be occupied by a pilot until full autonomy is available.

Passenger capacity per hour will vary widely, based on a number of factors such as airspace capacity, electrical capacity, and the technological sophistication of the vehicle. The goal of industry is to accommodate as many operations per hour as possible at a given vertiport. Part of the reason that the air metro model is significantly more feasible than the air taxi model is because it assumes 1) at least three passengers per ride, versus 1 passenger per ride and 2) routes can be determined up-front to maximize the number of seats filled. If urban air mobility is to promise lower costs and true efficiencies to the overall transportation network, focusing on maximizing the capacity of each aircraft needs to be a critical strategy for enabling a profitable business model.

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[4] https://www.nasa.gov/sites/default/files/atoms/files/uam-market-study-executive-summary-v2.pdf
[5] https://www.nasa.gov/sites/default/files/atoms/files/uam-market-study-executive-summary-v2.pdf

**Geographic/Climate Capabilities**

One of the key challenges of UAM vehicles is weather resiliency. In order to create a truly effective urban air mobility environment, aircraft need to be operating regardless of climate conditions[6]. One of the key technical hurdles that companies are currently working on is weather resiliency, as this is a well-established obstacle for existing drone and helicopter technology. This issue is exacerbated in urban settings, where the height profile of buildings creates unique weather patterns that are difficult to predict and even more difficult for pilots to operate in.

**System Operations**

Vertiports are mobility hubs for eVTOL services that provide the necessary landing pads, electrification, and passenger amenities to support operations of one or more aircraft. There are generally three station types for vertical mobility hubs: vertiports, vertistops (at times used interchangeably) and vertihubs. As anticipated by their names, vertiports serve one vehicle at a time, while vertihubs would service multiple aircraft. Vertistops are associated with air metro service and are akin to an aerial bus stop. In order to maximize the network to support air taxiing under an air metro model (pre-determined routes), vertistop networks need to be designed to enable 20-minute door-to-door trips [7].

Vertiports are likely to be constructed in and around the city center, including commercial and office buildings, shopping centers, leisure complexes, residential campuses, top levels of parking garages, and logistics centers. Vertihubs are more likely to be operated near other major transportation hubs, such as airports, passenger rail stations, bus transfer centers, and along commuter beltways. Placing a vertiport in non-residential neighborhoods is likely to be an early strategy for success for UAM operators, as the public acceptance of these new aircraft will need to be built over time.

Operating hours would be driven significantly by what is determined acceptable by adjacent communities.

There is no current mechanism that is approved by the FAA to standardize fare cost or collection mechanisms. Fares will likely be generated based on supply and demand, similar to current TNCs fare structures. Fees in the form of passenger facilities charges (PFCs) may be included, which are common in the aviation industry and are fixed at a price per passenger. Other types of fees could be introduced to support UAM, such as a vehicle miles traveled fee (less likely) or an energy access fee. Currently, the FAA

[6] FAA, 1994

[7] https://www.nasa.gov/sites/default/files/atoms/files/bah_uam_executive_briefing_181005_tagged.pdf

charges drone registration fees, and this model may be applied in the event that eVTOLs become increasingly subject to private ownership models.

Regardless of the way that fees are structured, local municipalities and states will need to work with the FAA to define the boundaries in their abilities to raise revenue from UAM operations. As UAM moves closer to becoming a reality, it will become necessary to create entirely new regulatory or administrative bodies to govern low altitude aviation operations. FAA is already notably understaffed and will likely cede some operational oversight to local/state entities given the impracticality of a single federal agency administering all aspects of governance for the UAM system. Imagine, for example, if all driver's licenses were issued in Washington DC by the USDOT. In addition to fares, it is possible that operating permits will be required at state and local level, which could feature a fee structure. However, there is no current authority to develop this structure outside the FAA, who has primary authority and responsibility over airspace safety and management.

## Supporting Network Needs

**Data Communications Requirements**

Data communications, navigation, and surveillance (CNS) infrastructure will likely play vital roles in the development and operationalization of vertiport infrastructure. A UAM Concept of Operations (ConOps) has yet to be established, and communities will need to engage the aircraft industry and regulators on this topic in the development of vertiport placement and design.

UAM industry consensus is that the level of projected activity from Unmanned Air Systems (UAS) and other eVTOL products will overwhelm the current air traffic control (ATC) system. Significant levels of automation will be needed to manage and integrate UAS into the ATC effectively. In planning for expanded UAS operations, the industry has noted several issues related to the ATC:

- Increased density of operations makes voice communication unworkable as a long-term solution
- Lower altitude operations could lead to poor coverage for surveillance and navigation systems, while making geopositioning vulnerable to multipath errors and interference
- Diversity of pilot and aircraft, as well as varying levels of automation, make interfacing with ATC challenging

There are generally two approaches to managing issues regarding demand and capacity for ATC: increase capacity and reduce demand. Any significant air taxi system will require the establishment of an unmanned traffic management (UTM) system that should lead to an overall increase in capacity. However, there will be increased financial burden on airspace navigation systems providers and operators to adjust staffing, airspace design, or technologies to meet the need for increased capacity. This will likely result in higher fees for service and should be accommodated for in the overall business model development for implementing testing and operational facilities. Planning the future ATC system will depend on the volume and density of planned operations at the eVTOL testing facilities, and the pace of development of a UTM system that can effectively interface with air traffic management.

**Integration into Local Law Enforcement Operations**

Transportation planning has always considered the needs of law enforcement and emergency management operations as a pillar of design principles, and it is critical that any eVTOL testing locations maintain careful coordination during the design process with the needs and priorities of local law enforcement and emergency management operations. Since both law enforcement and emergency management operations often feature multi-jurisdictional partnerships, it will be important to adapt these partnerships into the context of UAS and other UAM operations.

**Long-term Route Planning Considerations**

Given the scale of investment that UAM infrastructure requires, a critical long-term planning consideration will be how vertiport placements and key air taxi corridors influence the broader network of ground-based transportation and economic development investments. By understanding and analyzing current and future transit demand patterns within a specific corridor, and between the corridors and other key destinations, site selection for vertiport locations can be informed with short-term testing in mind, with consideration for a long-term plan for ongoing utilization of for the initial vertiport locations.

Additionally, planning the long-term success of UAM would require analyzing the economic costs and benefits, the potential impacts to other transportation modes, and the development of real estate and financial strategies that leverage other ongoing state and local programs.

## Fleet Management

Fleet management encompasses operational logistics and management of the vehicles, excluding procurement and maintenance. The oversight of deployed vehicles is crucial for maintaining safe UAM operations. Fleet management will include:

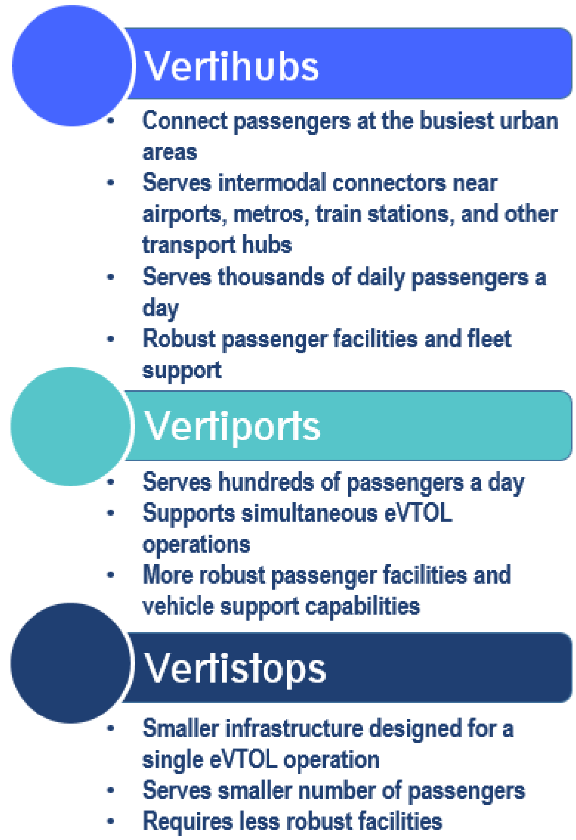
- Ensuring continual airworthiness
- Operator certification and licensing
- Operations management and tracking vehicle data (such as monitoring vehicle energy use)
- Vehicle health and safety monitoring
- Fleet logistics

## Infrastructure Needs and Requirements

**Vertiport (Launch/Recover Area Requirements).**

There are three types of vertiports that are differentiated by size and number of aircraft they can support, and their connectivity to the larger transportation system. These different types of landing infrastructure are outlined in Figure 18. Vertiports are a foundational element of any UAM system and could pose numerous challenges to the operationalization of a UAM market if not adequately addressed early in the planning process. Currently, few industry players have a thorough and viable strategy for vertiport design, development, and implementation. Of the vertiport designs that have been made public, many would either not meet operational requirements or would not align with current regulatory standards.

*Figure 18: eVTOL Air Taxi/Air Metro Infrastructure*




Uber has also recognized that most cities don't have the existing landing infrastructure already built out to support ubiquitous air taxi services, which could hinder the development of services even if eVTOL aircrafts were ready to operate today. Successful deployment will need to consider existing landing infrastructure, infrastructure and operational needs based on existing patterns of demand, modeling, and current infrastructure that may require repurposing. [8] Uber examines infrastructure needs and provides renderings for potential concepts within its white paper *Fast-Forwarding to a Future of On-Demand Urban Air Transportation*, as illustrated in Figure 19.

The Tampa Bay region could evaluate a few key considerations for vertiport development. These considerations can be separated into three primary categories: (1) system requirements, (2) procedural requirements, and (3) design requirements. System requirements would be derived from system demand patterns and UAM ConOps that would indicate key requirements such as proper vertiport placement and other considerations which could affect the efficiency of the system.

[8] https://www.uber.com/elevate.pdf

Procedural requirements would encompass the operations in and around vertiports, and would include procedures for approach and landing, takeoff and departure, taxiing, battery recharging, snow and ice removal, safety, and emergencies. Finally, the design requirements would encompass the end-to-end passenger experience and key needs to support infrastructure functionality, and would include passenger management, arrivals and departures, aircraft parking, fire suppression and mitigation, flight aids, and vehicle support.

*Figure 19: Uber Elevate Vertiport Infrastructure Rendering*


Source: Uber Elevate Whitepaper, https://d1nyezh1ys8wfo.cloudfront.net/static/PDFs/Elevate%2BWhitepaper.pdf?uclick_id=b24026e4-887d-49a1-bb33-0b8ead904d4a

**Facilities**

Adequate facilities for vertiports (e.g. ticketing, security screening, and other passenger facilities and amenities) are essential for safety, efficiency, passenger experience, and security. The size and type of required facilities will depend greatly on the operational mission of a given vertiport, and whether it is a vertistop, vertiport, or vertihubs.

Each type of vertiport would have unique facility considerations, but each would adhere to base minimum standards for passenger and operational safety and security. In terms of footprint, an average vertiport will need to be at least 2,500 square feet per landing area, will require some form of public access to the takeoff/landing area, and will require 1MW of power to charge vehicles.

**Vertiport Personnel Requirements**

Individual vertiport personnel requirements will vary depending on the size and type of vertiport (i.e. vertistop, vertiport, or vertihub). However, as the UAM industry strives toward autonomous flight in aircraft design and air traffic management (ATM), it is likely that vertiport operations will be automated as well. For example, both passenger ticketing and security screenings have seen major advances in recent years in the area of automation. Assuming this evolution in automation continues, it is likely that there would be a reduced need for operational personnel at the vertiports. The aircraft operators are the most likely stakeholders to have the primary staffing role at any given vertiport to manage the various operational requirements.

**Existing Standards for Vertiport Designs**

There is currently no regulatory standard for an eVTOL vertiport design. While there is a 1991 FAA Office of Airports Safety and Standards Advisory Circular (AC) on Vertiport Design, the closest proxy for design standards is the current heliport standard, AC 150/5390-2C. While many of the vertiport designs publicly floated by UAM companies would have difficulty meeting this standard, it still provides a clear and viable path for early stages of UAM implementation. As specific eVTOL aircraft make their way through certification and more robust operational safety data becomes available, the likelihood of FAA adopting a more specific standard for eVTOL vertiports greatly increases. At this time, early planning for UAM implementation would likely utilize the FAA heliport design standard requirements.

One example of preliminary vertiport zoning requirements and standards that have been set forth at a local level include the ***Orlando Vertiport Zoning Districts, Standards for Approval*** (Section 58.850):

- Vertiport is operationally feasible
- Air turbulence during approach and departure will not disperse dust, water or other material to neighboring properties
- Demonstrated need by property owner
- Away from general public
- Away from commercial aircraft
- Minimal disruption to vehicular traffic

**Right of Way Needs**

Some studies indicate that placement of vertiport infrastructure in the right of way can be advantageous in terms of affording local entities increased rights in overseeing UAM operations. Several industry professionals have explored this concept. Corgan developed several design renderings for "Uber Air Skyports"; one of which is illustrated in Figure 20. Placing infrastructure in the right of way may also have benefits from the perspective of rights to generate fees from vertiport development. For example, charging fees for takeoff and landing may be easier to claim inside public rights of way.

***Figure 20: CORGAN Concept for Uber Evolve Air Taxi Service***


Source: CORGAN, https://www.corgan.com/story/uber-connect-evolved/

**Corridor/Service Types**

It is likely that local governments will apply existing land use and zoning regulations for helipads to UAM service. Land use and zoning are the only two areas where local authorities have control over aviation. Therefore, land use policy presents an interesting opportunity for local and state governments to shape the future of UAM in their regions.

## Safety

Aviation safety is a priority of the FAA. For this reason, extensive certification processes and requirements are embedded into the process of developing a new aircraft. The cost of certification is often what creates the high barriers of entry to the aircraft manufacturing sector.

Despite the FAA's emphasis on safety and security, notable gaps exist for regulating new aircraft technologies, especially autonomous aircraft. Currently, it is illegal to interfere with any aircraft's operation. However, with an autonomously operating aircraft, there may be situations where it is necessary for a remote pilot to manually override the control. To allow this would require legislative action. In the interim, it will be less of an issue since start-up air taxi operations are assumed to be piloted.

Vertiports and vertihubs will likely require some form of security screening. Operators may push back on the level of safety screening requirements in order to capture the value of time-savings offered by UAM. Two primary areas of consideration for safety and security include:

- **Physical security**: The ConOps for UAM will need to address the protection of perimeters, passenger screening, and on-board security.
- **Cyber-security**: A ConOps for UAM cyber-security remains undefined for protecting against digital hijacking of aircraft, the accessing of personal identifiable information, and inappropriate surveillance.

# 3.2 Impact Considerations

## Noise

Given that UAM is intended to operate at lower altitudes in urban settings where there are large numbers of people, noise abatement will be a major component of public acceptance. One of the closest parallels to what is being proposed with air taxi service and eVTOL aircraft is the on-demand helicopter services market. This market has been plagued by decades of costly noise challenges and efforts to develop noise abatement and mitigation technologies and procedures. Early outreach and research regarding anticipated eVTOL noise levels, alongside public perception, will be a vital element of a successful UAM implementation strategy

## Accessibility and Equity

Accessibility and equity are key considerations in planning for surface transportation, but they are not common factors in planning for aviation. A significant risk to the rise of eVTOL networks is that they will fall into the "trap of the 1%", focusing their business model on high value riders, which has been typical of UAM and new aircraft service routes over the past 40 years. In order to facilitate community and public acceptance, it is critical that regional planning entities set forth expectations around connectivity and accessibility, encouraging operators to consider non-traditional segments of the population so as not to exacerbate the inequities that have characterized 20th century planning. This has been effective for other new technologies, ranging from TNCs to scooter services, but needs to be emphasized in an industry that has not historically interfaced with geographic inequity. Conversely, community planning in airport environments is a well-developed topic, and borrowing from their processes and community engagement methods can be valuable. Primarily, this includes extensive surveying for opportunities to connect communities to an urban air mobility network, in a way that supports the overall functionality of the network.

## 3.3 Costs

### Vehicle Costs

Research shows that the upfront cost per vehicle is anticipated to range between $280-480K, as indicated by early market data made available by several vehicle manufacturers.

### Infrastructure Costs as Needed

Table 5 is derived from an FAA vertiport study through the Airport Improvement Program conducted in 1994. The right two columns present an alternative investment framework that is driven from one infrastructure company's current business model and anticipated development costs (confidential

*Table 5: UAM Vertiport Costs, FAA Vertiport Study*

| Cost Element/ Vertiport Type | Vertiport Rooftop | Vertiport Ground | Vertistop Rooftop | Vertistop Ground |
|---|---|---|---|---|
| **Railway and Apron Paving** | 5,200,000 | 3,000,000 | 1,500,000 | 1,000,000 |
| **Air Rights Acquisition** | 4,000,000 | 5,000,000 | 2,000,000 | 3,000,000 |
| **Acoustical Mitigation** | 2,000,000 | 500,000 | - | - |
| **Railway and Apron Structure** | 650,000 | - | 225,000 | - |
| **Fueling Systems** | 400,000 | 300,000 | - | - |
| **Terminal Facilities** | 380,000 | 380,000 | 60,000 | 5,000 |
| **Vertical Transportation** | 200,000 | - | 100,000 | - |
| **Sitework/Utilities** | 125,000 | 150,000 | 50,000 | 40,000 |
| **Paving-Vehicle/ Pedestrian** | 110,000 | 110,000 | 40,000 | 40,000 |
| **Lighting** | 100,000 | 100,000 | 25,000 | 25,000 |
| **Fire Protection** | 30,000 | 10,000 | 10,000 | 5,000 |
| **Communications** | 10,000 | 10,000 | 5,000 | 5,000 |
| **Land Acquisition** | - | 375,000 | - | 225,000 |
| **ILS** | - | 50,000 | - | - |
| **TOTALS** | 13,205,000 | 10,435,000 | 4,015,000 | 4,345,000 |

*Source: 1994 FAA AIP Report, P. 73*

***Assumptions used in preparing the costs include***:

1. *CBD land estimated at $75.00 acre*
2. *Air rights acquisition costs which depend on siting (estimated costs represent an amount for the lost opportunities of a high rise)*
3. *Order of magnitude estimates to delineate estimated costs of vertistops; and*
4. *Rooftop facilities assume no participation in the purchase of land.*

company): (1) criteria associated with site selection and (2) process to evaluate how these locations can support an overall network of vertiports.

### Long-Term Funding and Financing

Long-term funding and financing considerations will continue to present a major hurdle to the UAS industry, as the FAA is confronted with increasing responsibilities without a corresponding increase in revenue to support expanded operations. Concern remains in the aviation industry, for example, about the diversion of resources away from manned aviation into unmanned aviation, creating a need for a more permanent separate funding source to support the FAA's efforts to integrate new aircraft into the NAS. While USDOT and the FAA are continuing to exercise creative strategies in addressing this challenge, it is likely that Congress will need to look toward additional appropriations as the aviation market continues to grow and new aircraft continue to penetrate the NAS.

The significant infrastructure requirements for scalable UAM operations is another important component. Innovative public private partnerships ($P^3$) and blended capital solutions that effectively pair industry dollars with state, local, and federal funds will be critical to the viability of this market.

## 3.4 Vendors and Manufacturers

Table 6 provides many (but not all) of the most well-known companies and their aircraft (as available).

## 3.5 Regulatory Considerations

### Federal Regulatory Framework

The FAA regulates all aspects of civil aviation and national airspace (NAS). The FAA authority extends to construction and operation of airports, air traffic management, and aircraft and personnel certification.[9] The FAA, with significant support from NASA, has initiated several activities to address the emerging UAM sector, including FAA/Industry Roundtables, NASA Advanced Air Mobility (AAM) Initiative (formerly referred to as the NASA UAM Grand Challenge), industry engagement, and the development of UAM Vehicle Certification Plan. The FAA UAS Integration Office has been established as a central point for stakeholder feedback, licensing considerations, safety considerations, and general UAS activities.

While the FAA will lead the development of national standards and certification requirements, NASA has taken a lead role in developing UAM, with significant work in research and development (R&D), providing the ability to focus on developing a fleshed-out ConOps plan to reflect significant technical and stakeholder engagement. NASA announced on March 3, 2020 that it had signed agreements under the Space Act with 17 companies to participate in technology demonstrations for the AAM Initiative. Simultaneously, NASA is looking for opportunities to work with local communities who are interested in partnering with them to define the systems-level requirements and regulatory framework for UAM implementation. The five focus areas of R&D activities include:

- Airspace System Design and Implementation
- Vehicle Production and Development
- Community Integration
- Airspace & Fleet Operations Management

[9] FAA Website, 2020

*Table 6: Aircraft Companies and Aircrafts*

| Company | Aircraft |
|---|---|
| A3 by Airbus | Vahana |
| Airbus Helicopters | Airbus City Airbus, Pop.Up Next |
| Airspace Experience Technologies | Aurora eVTOL |
| Alakai | Skai |
| Aurora Flight Sciences | AirspaceX MOBi, LightningStrike |
| AutoflightX GmbH | Aurora eVTOL |
| Bartini, Inc. | Bartini Flying Car |
| Bell | Bell Nexus |
| Beta Technologies, Inc | Ava XC |
| Carter Aviation Technologies | Carter Aviation Air Taxi |
| EmbraerX | DreamMaker |
| Kitty Hawk Corporation | Kitty Hawk Cora, Kitty Hawk Flyer |
| Jaunt Air Mobility, LLC | Jaunt |
| JAXA | Hornisse 2B |
| Joby Aviation | Joby S4 |
| Karem Aircraft | Karem Butterfly |
| Leonardo Helicopters | AgustaWestland Project Zero (defunct) |
| LIFT Aircraft, Inc. | Hexa |
| Lilium GmbH | Lilium Jet |
| Neoptera Aero Ltd | Neoptera eOpter |
| NFT Inc | NFT ASKA eVTOL |
| Piasecki Aircraft Corporation | Piasecki eVTOL |
| Pipistrel Vertical Solutions d.o.o. | Pipistrel |
| Sabrewing Aircraft Company Inc | Sabrewing Draco-2 UAS |
| Sikorsky, a Lockheed Martin Company | Sikorsky VERT |
| Skyworks Global | N/A |
| Terrafugia, Inc | Terrafuga TF-X |
| Transcend Air Corporation | Vy400 |
| Uber | N/A (multiple partners) |
| Unither Bioelectrics | N/A |
| Urban Aeronautics, Ltd. | Urban Aeronautics CityHawk |
| Vertical Aerospace Ltd. | Proof of concept |
| Volocopter | Volocopter VC200, Volocopter 2X |
| XTI Aircraft | XTI Aircraft TriFan 600 |
| Zee Aero | Z-P1 |

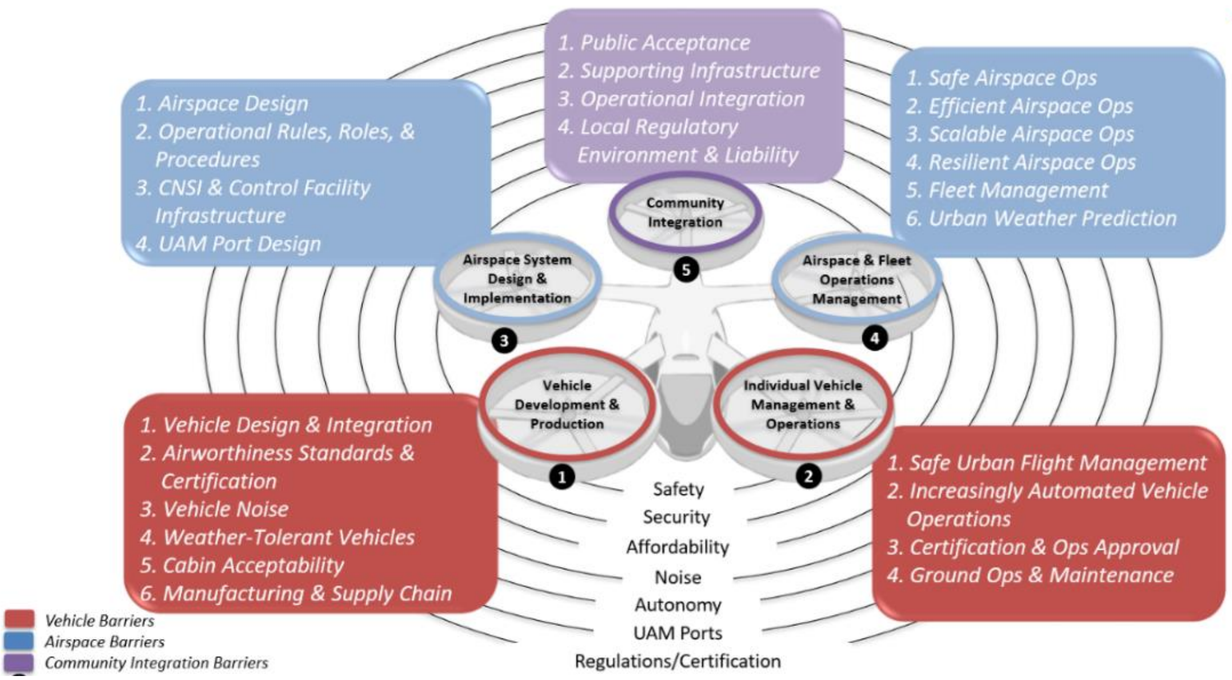
Source: eVTOL News eVTOL Corporate Director (taken from the database of the Vertical Flight Society)

- Individual Vehicle Management and Operations

Figure 21 illustrates these key challenge areas, and the associated sub foci of each overarching component of the UAM ecosystem.

The UAM governance and regulatory framework requires continued technical development and significant coordination efforts. Continued development will be needed to coordinate federal, state and local vehicle and pilot certification process, traffic management, infrastructure needs, and public engagement. Both the public and private sectors are engaged in extensive coordination and analysis to identify the necessary protocols and pathways forward. Currently, the private air taxi and air mobility companies are developing systems to meet existing FAA certifications where applicable.

*Figure 21: Five Key Areas for Regulatory Evolution for Air Taxi and Air Metro Operations*



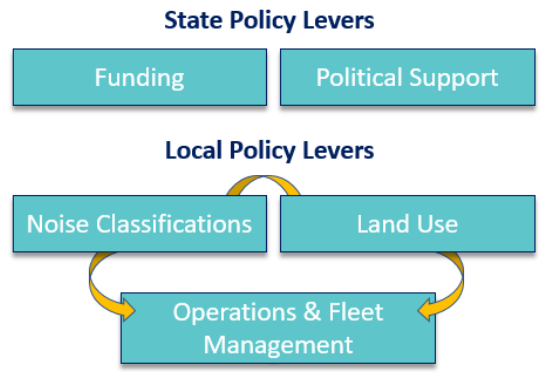

Source: Draft NASA CONOPS Framework (Presented at Community Meeting, February 2020

## Local Governance

While state and local agencies do not have authority over their airspace, they do have authority over areas such as nuisance, privacy, land use, and zoning. Local and state policy areas of focus related to UAM are reflected in Figure 22. UAM would involve a much larger scale of low altitude aircraft operating within an urban setting (more than what is experienced today with helicopters). The impacts to local community with UAM will require significant local coordination to regulate the operational and infrastructure allowances, and will also influence the successful integration of UAM.

A number of state and local authorities have implemented proactive strategies to control how UAS and UAM operate in the community. An example, as discussed in the Governance and Regulatory Framework Technical Memorandum, is the Los Angeles Department of Transportation (LADOT) The LADOT has been working on model land-use and zoning policies, noise classifications, and vehicle classifications based on considerations such as aircraft weight and type of mission or service.

*Figure 22: Local and State Policy Levers*




In Washington State, the Washington State Department of Transportation (WSDOT) is evaluating electric aircraft technology, with a focus on eVTOL, and how it can impact and influence air transportation, environmental sustainability and economic vitality. WSDOT is evaluating the infrastructure needs at airports, as well as the potential demand for electric propulsion in the region.

Figure 23 shows existing and emerging regulatory topics where federal, state and local coordination are discussed and determined. Traditionally, regulatory considerations related to air traffic and fleet operations, vehicle development production, and air traffic and fleet operations are strictly under federal oversight. The community integration (land use and zoning, noise abatement, fleet management and infrastructure requirements) have commonly been considered a coordinated effort between federal, state and local entities. However, the role of local and state integration can expect to be expanded to include fleet management and operations, as well as individual vehicle management and operations, such as registration, surveillance, pilot certification and autonomous operations. Each of these components may be too vast to manage from a federal standpoint.

*Figure 23: Federal, State and Local Regulatory Considerations*

| Federal "Top Down" Regulatory Considerations | | | Federal/State/Local Coordination | |
|---|---|---|---|---|
| Air Traffic & Fleet Operations Management | Vehicle Development Production | Air Traffic & Fleet Operations Management | Individual Vehicle Management & Operations | Community Integration |
| Operator Certification | Vehicle Certification | Zoning Restrictions | Registration | Land Use and Zoning |
| Operator Licensing | Airworthiness | Cybersecurity | Surveillance | Noise Requirements |
| Fleet Management | | Infrastructure Requirements | Pilot Certification | Fleet Management and Operations |
| UAM TM & Airspace Integration | | | Autonomous Operations | Infrastructure Requirements |

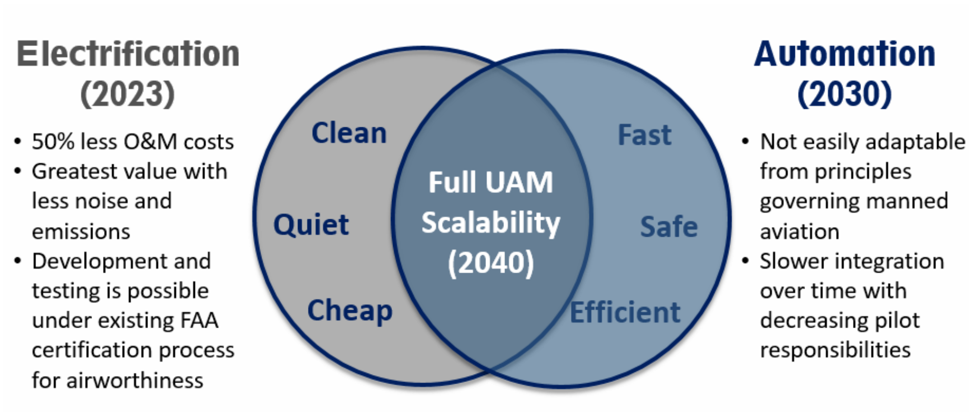
*Data from NASA UAM Market Study, 2018 – incorporating recent updates*

## Technical Influencers

While the long-term goal for air taxis is to operate autonomously without a pilot, current air taxi aircraft designs assume that a pilot will be on board. The principles and regulations governing manned aviation systems will be a challenge to adapt to autonomous aviation systems. For example, air traffic control relies on person-to-person communication between a pilot and air traffic controller. There is generally wide-spread acceptance that autonomy is a more distant and aspirational goal.

Electrification is a significant component to making UAM a competitive mode, due to its quiet, clean, and cost effective systems. Electric powered aircraft have a more straightforward regulatory pathway to commercialization than a fully automated aircraft because manufacturers can utilize the existing FAA certification pathway. As shown in Figure 24, it is likely that the electrification of aircraft will become a reality before automation does.

*Figure 24: Electrification and Automation UAM Aircraft Integration*




## Aircraft Certification

Scalable use of UAS and eVTOLs outside of a test setting will require greater clarity regarding the certification pathways for both types of aircraft. Vehicle certification requires significant time and resources. Forbes has estimated that the cost to certify a new aircraft is upwards of $5 billion, and the process can take up to 10 years. The larger aircraft manufacturers have these resources. Automotive companies such as Hyundai and Toyota have also emerged as partners with the aircraft manufacturers in the development process.

The FAA uses the Small Unmanned Aircraft Regulations – Part 107 to regulate both commercial and government uses of drones 55 pounds or lighter. However, there is no current UAS aircraft certification requirement for UAS operating under Part 107. Undertaking expanded operations that extend beyond the limitations of the Part 107 will likely require meeting higher aircraft safety standards. eVTOL aircraft certification is still at the very beginnings of its development path. The UAM industry is starting to work closely with regulators to chart an effective course (e.g., explorations of Part 23 and Part 21 options for airworthiness), but clear pathways have yet to be established, with electric propulsion and autonomy posing the most significant challenges to the current regulatory standards and processes.

## 3.6 Technology Readiness

### Challenges

There are several obstacles for achieving implementation of UAM systems. Today, the regulatory environment does not permit the types of vehicles and operations that scalable UAM would require. There are five major categories of regulation that need to be addressed: air traffic and fleet operations management, vehicle development and production, airspace design and implementation, individual vehicle management and operations, and community integration.

Efforts such as the USDOT UAS Integration Pilot Program (IPP) are providing opportunities for productive collaborations between federal regulators (FAA, USDOT), local/state entities, and private industry. To date, 10 pilot programs have been established around the country, with North Carolina actively engaging in testing for eVTOLs, in part due to their relationship with this initiative and level of advancement in UAS operations and capacity inside of North Carolina DOT.

### Estimated Timeframe Readiness

**Anticipated Adoption Rate**

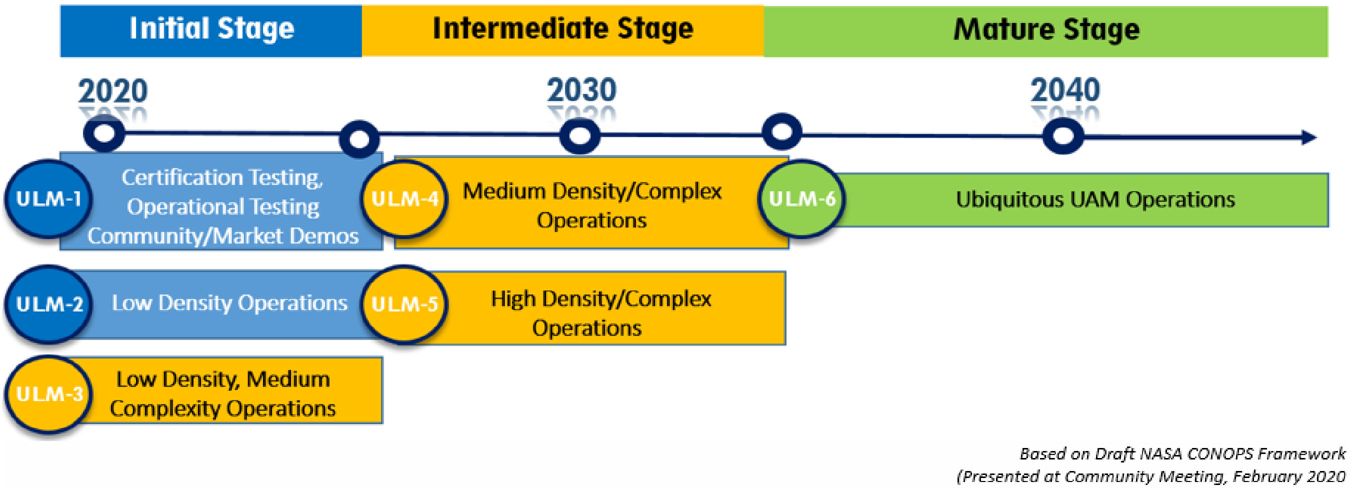
Research indicates that there are generally going to be two key inflection points in the next 10-15 years: 2025 is the date that the industry anticipates the emergence of pilots that are certified to operate UAM vehicles; and 2030 is the date by which the industry anticipates benefits of early UAM scaling efforts.

Market adoption hinges on a number of "unknowns", including: the relationship between volume, ticket price, vehicle capabilities; optimizing vertiport locations to balance access and affordability; identifying innovative financing mechanisms to support UAM infrastructure development; and the ability to tailor UAM operations to unique local conditions.

From a business perspective, UAM does create a network of new economic opportunities for various types of entities, both public and private. The overall economic impact of UAM remains to be quantified, and metrics for monitoring and tracking public perception need to be defined.

Figure 25 provides a general timeframe for various levels of development. NASA has developed various stages of air taxi development called Urban Air Mobility Maturity Levels (ULM), shown along each level of advancement in Figure 25. The diagram aligns NASA's CONOPs plans and stages of development (initial, intermediate and mature), alongside the general timeframes to provide an understanding of the phased integration, and current estimated timeframes. The initial stage from now to 2030 will focus on testing, demonstrations, and eventually some low density pilot projects. Between 2030 and 2040, there will likely be increased complexity of operations in more dense geographies. This illustrates that there is no ubiquitous deployment of air taxis anticipated until 2040.

*Figure 25: UAM Estimated Integration Timeline*




## Customer Experience/Perception

UAM has garnered significant press over the past two years, praised by some as the greatest revolution in the aviation industry since the jet engine, due to its ability to unlock a third dimension of city transit. That said, the negative reputational legacy of helicopter-based operations in cities, the unique noise profile of aerial vehicles, and visual pollution are just a few of the challenges that must be overcome as the air taxi industry embarks on convincing communities that UAM operations should be implemented in their neighborhoods and cities. Another challenge will be meeting high customer expectations, which will likely be shaped by their expectations of TNC service. This challenge is being addressed through partnerships between eVTOL developers and TNC operators like Uber.

## 3.7 Market Connections

Of the three innovative technology modes assessed in this study, air taxis could have the greatest potential to create a high capacity network of point-to-point travel between major activity centers in the TBARTA region. Potential connections were identified based on the technology profile shown in Figure 26. In addition to the technology profile, the analysis of potential market connections for air taxis considered airport connections, helipad locations, and intermodal center connectivity.

*Figure 26: Air Taxi Technology Profile*

| Air Taxi Vehicles | Lift + Cruise<br>Vectored Thrust | Multirotor |
|---|---|---|
| Example Technology | Jaunt Air Mobility (Lift + Cruise)<br>Lilium Jet (Vectored Thrust) | Volocopter |
| ***Images are only for examples of technology, data within profile is a summation of various sources, not just for the example vehicle shown.*** |   |  |
| Photo Credit | https://www.jauntairmobility.com/<br>https://lilium.com/the-jet | *"Pioneering the Urban Air Taxi Revolution 1.0"* |
| Corridor Length | 50 to 70 miles | 10 to 25 miles |
| Trip Profile (short/mid/ long haul) | Mid | Short |
| Speed (mph) (max) | 180 | 80 |
| Headway | n/a | n/a |
| Capacity<br>(per vehicle) | 1-4 | 1-4 |
| Capacity (per hour) | n/a | n/a |
| Corridor /Infrastructure Requirements | Air (vertiports, landing pads), electrification | Air (vertiports, landing pads), electrification |

The methodology and process for identifying the connections is available in the Travel Market Connections Technical Memorandum.

It should be noted that the connection assumptions are based on the technology capabilities today. As technology and efficiencies grow and business cases are established based on performance and cost, the ranges used in this analysis will likely change. Given the insights known at the time of this writing, the connections identified assume the Multirotor technology, serving connections between 10-25 miles. However, future opportunities may exist with Lift and Cruise and Vectored Thrust aircrafts, if developers see a use case for trips that are less or more than the 50-80-mile range estimated at this time. This also leaves a gap that will need to be filled between the typical distances served by each of the technologies.

The following connections were identified:

- **Travel between Activity Centers (by County)**: Following the evaluation of travel demand within each county, the following potential connections were selected based on the profile characteristics for air taxis:
    - Brandon to Westshore (Hillsborough County)
    - Plant City to Downtown Tampa (Hillsborough County)
    - Carrollwood to Westshore (Hillsborough County)
    - USF to Downtown Tampa (Hillsborough County)
    - Brandon to Netpark Fairgrounds (Hillsborough County)

    - Dunedin to Gateway (Pinellas County)
    - Wesley Chapel to Sabal Park Faulkenberg (Pasco County)
    - Wesley Chapel to USF (Pasco County)
    - Wesley Chapel to Westshore (Pasco County)
    - Wesley Chapel to Downtown Tampa (Pasco County)
    - New Port Richey to Connerton (Pasco County)
    - Brooksville to I-75/SR 50 District (Hernando County)
    - Brooksville to SR 589/S. County Line) (Hernando County)
    - Brooksville to SW Hernando (Hernando County)
    - Brooksville to Suncoast Parkway (Hernando County)
    - Brooksville to Weeki Wachee (Hernando County)
    - Bradenton to Foxleigh (Manatee County)
    - Bradenton to North County Gateway (Manatee County)
    - Bradenton to Lakewood Ranch (Manatee County)
- **Tier 1 Activity Center Connections:**
    - USF to Ybor City
    - USF to Downtown St. Petersburg
    - USF to Gateway Area
    - USF to Downtown Clearwater
    - Ybor City to Downtown St. Petersburg
    - Ybor City to Gateway Area
    - Ybor City to Downtown Clearwater
    - Downtown Tampa to Downtown St. Petersburg
    - Downtown Tampa to Gateway Area
    - Downtown Tampa to Downtown Clearwater
    - Westshore/TIA to Downtown St. Petersburg
    - Westshore/TIA to Gateway Area
    - Westshore/TIA to Downtown Clearwater
    - Downtown Bradenton to Downtown St. Petersburg
    - Downtown Bradenton to Gateway Area
    - Downtown St. Petersburg to Gateway Area
    - Downtown St. Petersburg to Downtown Clearwater
- **Airport and Landing Pad Infrastructure**: Areas where there are private and public helipads or airports were identified as potential connections where early deployment of air taxis could take advantage of existing infrastructure to test the technology service. Infrastructure costs for retrofitting or building new vertiports, vertihubs or vertistops could be costly prior to proving the technology and network potential. There were 28 airports identified throughout the Tampa Bay region (17 private and 11 public) and 49 helipads (34 private and 15 public). Figure 27 identifies the locations throughout the region where air taxis could utilize existing helipad and airport infrastructure.
- **Intermodal center connectivity**: Air taxis could provide extensive support for first-mile and last-mile delivery from intermodal centers, and provide point-to-point connectivity where fixed-guideway cannot. Potential intermodal centers have been identified throughout the region. There may be opportunities to incorporate necessary infrastructure within the designs of the

intermodal centers to accommodate the future UAM technology, and support the electrification and maintenance space needed. Each of the potential intermodal centers are identified as opportunities for air taxis.

Figure 28 illustrates the connection opportunities for air taxis.

*Figure 27: Helipad and Airport Locations*

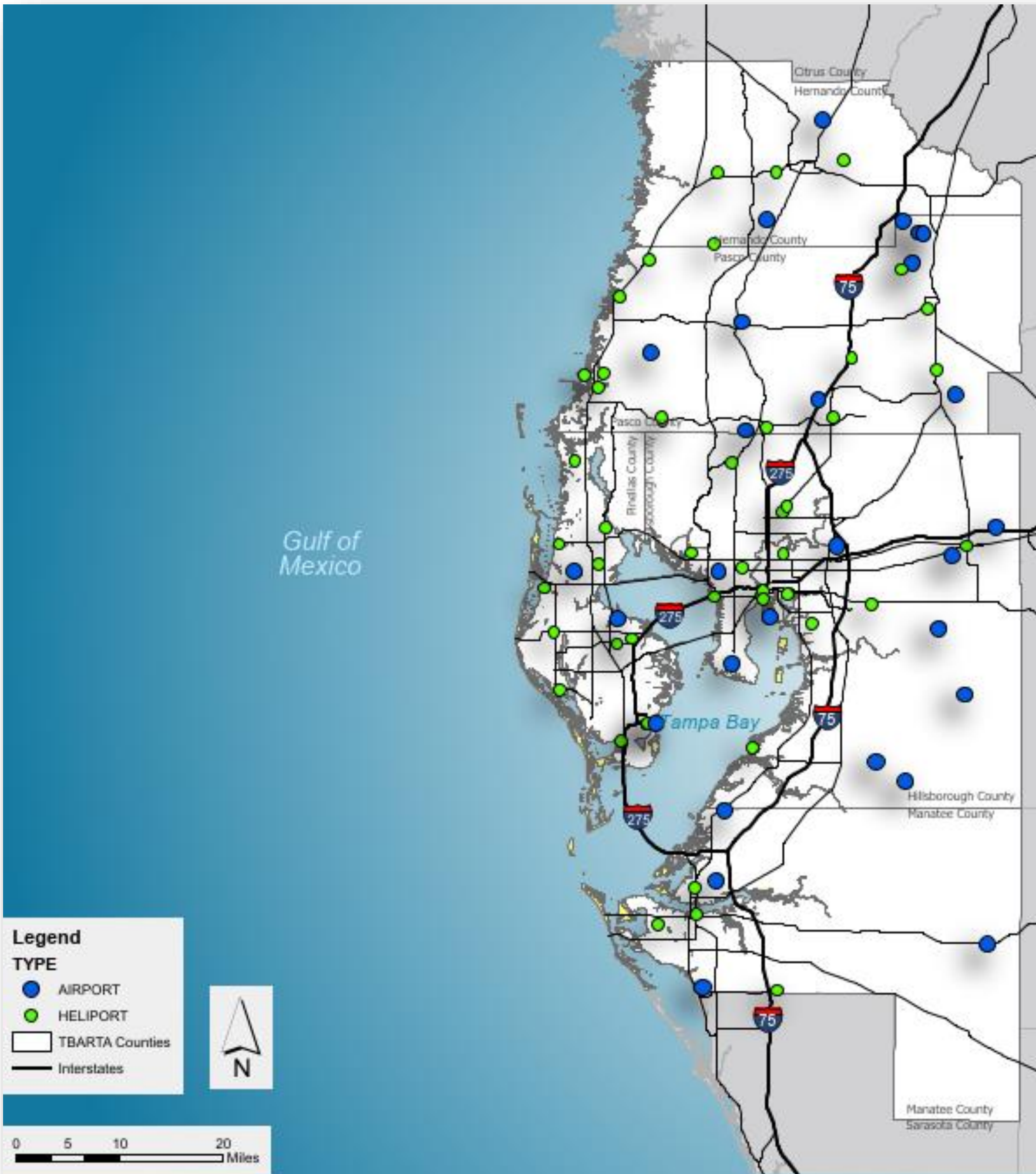
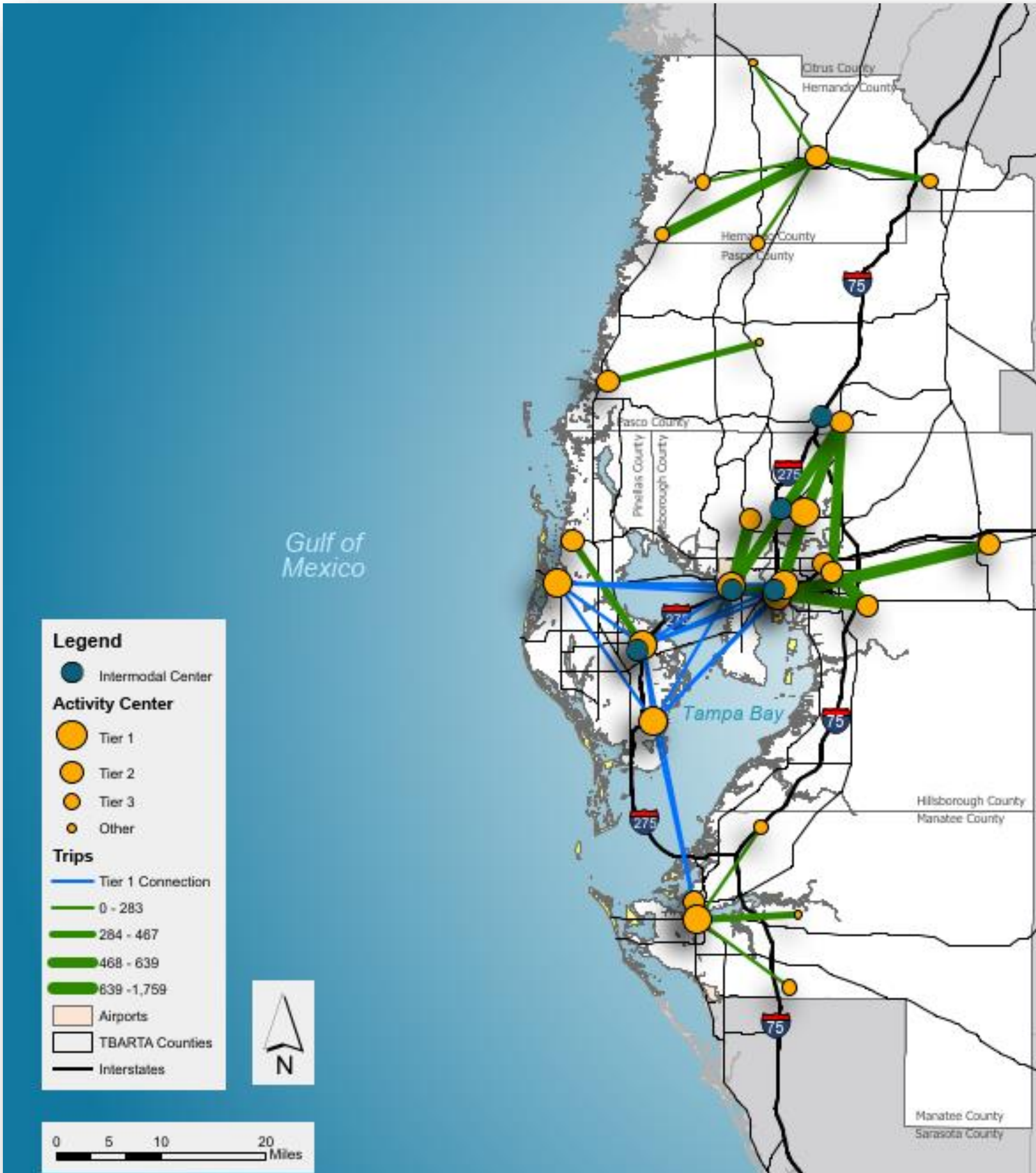
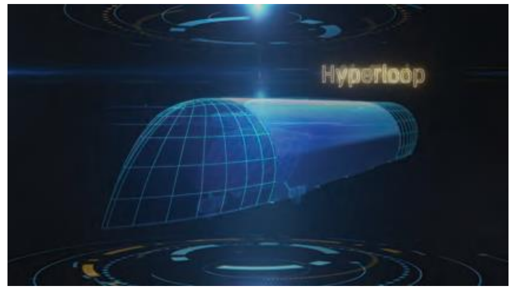


*Figure 28: Potential Regional Air Taxi Connections*



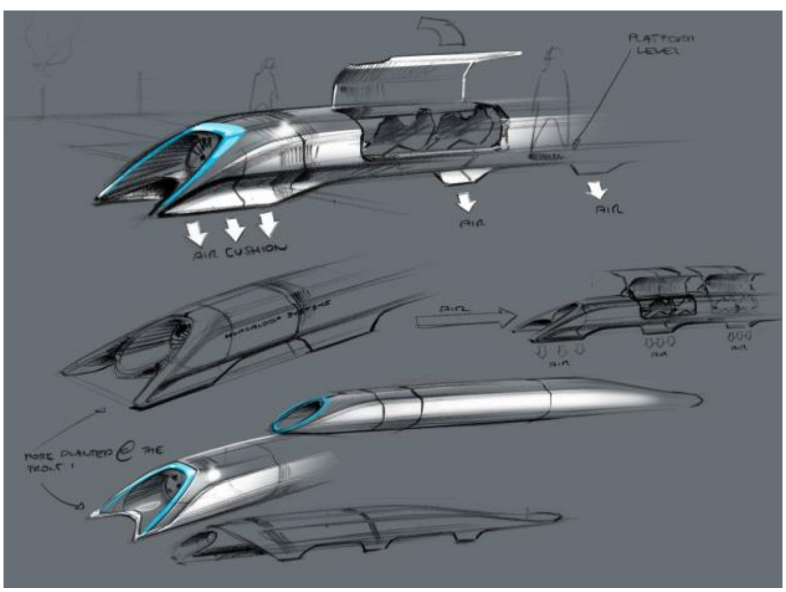
# 4 Hyperloop




Hyperloop has seen a re-emergence of interest over the past decade. In 2013, Elon Musk published his white paper "Hyperloop Alpha" to discuss the application of a pneumatic tube system for intercity mass transportation. Pneumatic transport systems have been used for years to propel relatively small cylindrical containers (containing mail for example) through networks of tubes by compressed air or partial vacuum to various locations within a building complex. As shown in Figure 29, Musk envisioned the creation of a super-sized partial vacuum system that would lead to a 5th mode of public transportation – joining air, rail, road and ship – suitable for linking destinations as far apart as 900 miles. Musk was particularly interested in being able to achieve a transportation service that would attract travelers, be less costly than other forms of mass transportation, and would emit fewer carbon emissions than existing transportation options. In his white paper, Musk focused on critical urban connections that were not well served by existing travel options to demonstrate the transformative power of hyperloop. As an example, he worked out a conceptual hyperloop system that would reduce the journey between downtown Los Angeles and downtown San Francisco to 35 minutes.

Hyperloop is an emerging mode of transport currently under development. It is intended to provide a high-speed transportation service over long distances with speeds and travel times that rival aviation, with connections between major downtowns like high speed rail. However, hyperloop is intended to address the inefficiencies of existing rail service and car travel across the U.S., where long distance passenger rail service is impacted by freight rail service and car travel is impacted by growing traffic and congestion. Air travel also has inefficiencies. It can be unaffordable, environmentally unfriendly, and it often requires a connecting trip to reach destinations. The goal of hyperloop is to address these inefficiencies, with faster speeds and lower emissions.

***Figure 29: Elon Musk Hyperloop Alpha Concept Sketches***




Source: Elon Musk, Hyperloop Alpha White Paper

Hyperloop is envisioned to operate on a fixed guideway system, like traditional rail and high-speed rail systems, but is closer in its service concept to regional aviation. Generally, major passenger rail systems move a set of passenger cars, a "consist," either powered by locomotives or self-powered, through the rail network on a tightly timed schedule. The schedule allows the railroad to maintain safety clearances with other passenger and freight trains and to provide enough service to encourage and/or meet ridership demand. Each passenger car (based on Amtrak's Amfleet) has seats for

60-72 passengers based on its configuration. With an average consist composed of four passenger cars, the total seating available on a traditional rail trip is 240-388 passengers.

There are no consists in hyperloop. In Musk's original concept, passengers would move via a capsule – 28 people to a capsule. Periods of high demand would be achieved by sending capsules at higher frequencies, potentially up to 30 seconds apart, along the mainline of the system.

However, the commercial application of hyperloop technology for freight or passenger transportation is at an early stage. Working hyperloop systems have been limited to short distance test tracks with no passengers or freight onboard. In 2016, the John A. Volpe National Transportation Systems Center developed the *Hyperloop Commercial Feasibility Analysis: High Level Overview*, discussing the commercial viability of the Hyperloop based on Musk's analysis. Since then, three major competitors have emerged to take on the task of developing the Hyperloop system throughout the world. They are Virgin Hyperloop One (VHO), Hyperloop Transportation Technologies (HTT), and TransPod (TP). Most recently, the Northeast Ohio Areawide Coordination Agency (NOACA) prepared a hyperloop feasibility study in partnership with HTT to assess the feasibility of creating a service to connect Cleveland, Chicago, and Pittsburg. Currently Hyperloop One is working with several states in the U.S. via a Request for Proposals process to site and develop a new test track that would be planned to serve as the first commercially operating segment of hyperloop technology.

## 4.1 Technology Overview

### Network

A hyperloop network would be comprised of a series of tubes, grade-separated from surface transportation and other uses. A complete network would have main line tubes and a series of tube ramps that would allow the individual capsules to access various destinations along the spine. An example of a hyperloop network is shown in the concept developed for connecting the Great Lakes Megaregion (see Figure 30).

### Tube and Vacuum

As visualized in Figure 31, the tube system would be constructed to maintain a reduced-pressure environment. A vacuum system would be augmented to the tube system to create and maintain the required low pressure environment within the tube system. The low pressure would allow for the relatively unimpeded levitation and propulsion of the capsules.

Each hyperloop tube would be approximately 4 meters in diameter, requiring a smaller footprint than the right of way necessary for other high-speed rail services.[10] This width allows for both passenger capsules and smaller freight capsules.

[10] Ibid, Page 11-1

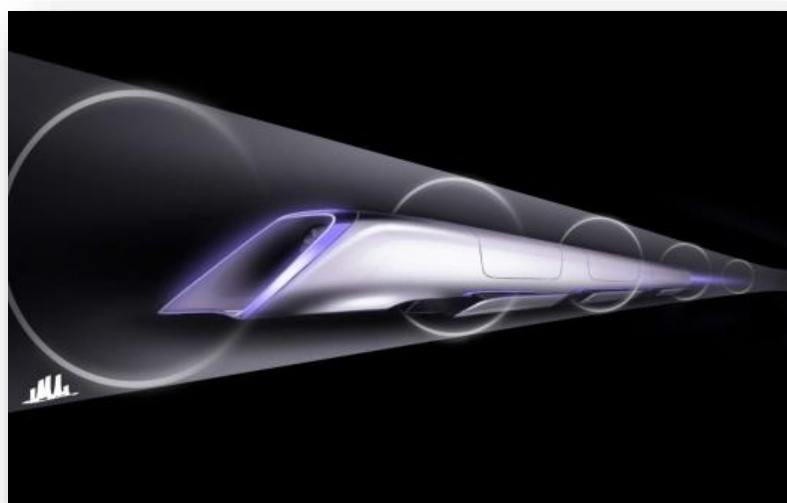
*Figure 30: Great Lakes Megaregion Hyperloop Network*


Source: NOACA, Great Lakes Hyperloop Feasibility Study, December 2019

## Capsule

As shown in Figure 32, the passenger capsule is estimated to be 30 meters in length, 2.7 meters in width, and about 20 tons in weight.[11] The passenger capsule would hold approximately 28 people and utilize best practices from both rail and aerospace transportation to ensure both passenger safety and comfort. The capsule would work similarly to an airplane by maintaining a pressure boundary between passengers and the vacuum tube system.[12] According to the Great Lakes Hyperloop Feasibility Study, rechargeable batteries will be provided on-board to provide power

*Figure 31: Hyperloop Capsule and Tube Rendering*



Source: Elon Musk, Hyperloop Alpha

[11] Great Lakes Hyperloop Feasibility Study, Page 2-3 (referred to as Ibid for future references)
[12] Ibid, Page 2-3

*Figure 32: Hyperloop Transportation Technologies Capsule Concept*


Source: NOACA Great Lakes Hyperloop Feasibility Study, Hyperloop Transportation Technologies Rendering

to the capsule systems.[13] For freight services, the capsule would need to widen to accommodate freight larger than 2.7 meters.[14]

## Levitation and Propulsion

Hyperloop capsules are elevated off the track to reduce friction. Two main levitation technology types have been explored since the publishing of the *Hyperloop Alpha* white paper by Elon Musk in 2013. The first is air-bearing suspension. This system uses compressed air to levitate the capsules within the tube as described in Hyperloop Alpha. The second type is passive magnetic levitation. This type of levitation system was identified in the Great Lakes Hyperloop Feasibility Study and is the preferred levitation technology proposed by HTT, VHO and TP. The difference between active and passive magnetic levitation is that the former requires external power to create levitation from magnetic repulsion while the later creates magnetic repulsion through the movement of the pod. [15]

Each capsule would have its own linear electric motor to provide electro-magnetic propulsion within the low-pressure tube system. Each capsule could carry passengers and/or cargo.[16]

## Autonomous Services

Hyperloop technology would be autonomous and designed for limited human-machine interaction, potentially minimizing the human error typical in existing transportation modes. The service would utilize autonomous control systems, signaling systems, traffic management, and communication system which would be integrated, allowing for control and supervision of all aspects of the system. All information pertinent to users of the hyperloop system would be seamlessly updated through indicator boards and other forms of digital communication. The autonomous nature of hyperloop provides the

[13] Ibid, Page 2-2
[14] Ibid, Page 6-6
[15] https://alankandel.scienceblog.com/2018/03/01/passive-magnetic-levitation-the-future-of-land-based-transport/
[16] Ibid, Page iii

opportunity for a hyperloop system to be a demand-based transportation system. Operations could be dynamically scheduled based on data gathered by the autonomous control system.

## Corridor and Right of Way Needs

A hyperloop service would seek to utilize existing state, federal or utility right of ways as much as possible to minimize environmental and capital cost impacts. With each hyperloop tube approximately 4 meters wide, the required right of way width and tunneling width required would in theory be less extensive than existing transportation options.[17] A hyperloop system would use a combination of elevated guideways and tunnels depending on terrain which would also significantly reduce the surface right of way need.[18] A typical span would be approximately 100 feet and be continuous over multiple spans.[19] An elevated guideway section is indicated to be used only when the elevation difference between the planned profile and ground is less than 65 feet.[20] The tube would also incorporate attachments for communications, power, and safety systems. In high density areas or areas of variable terrain, tunnels would be used to reduce environmental and visual impact; either cut and cover or boring could be used.

Additionally, hyperloop service would need space for emergency escape port stations along all their routes, vacuum pumps and ancillary equipment, solar farms for electricity, stations, parking, and maintenance yards.[21] In the Great Lakes Hyperloop Study, it was suggested that the emergency escape port stations would also house the vacuum pumps and ancillary equipment to minimize land acquisition. Solar farms along the corridor to power the system could provide an opportunity for a hyperloop system to create sustainable partnerships with communities along their corridor.

Hyperloop technology is not interoperable with existing transportation infrastructure such as bus, rail or plane.[22] Therefore, the service would need additional stations and maintenance facilities, or it would need to retrofit existing stations and maintenance facilities. Finding station space in relatively dense cities may pose a challenge for designers of the system as high-density areas tend to have higher land values.

## Corridor/Service Types

Hyperloop service is primarily geared towards providing a more efficient high-speed surface transportation connection between cities that are 200 to 500 miles apart. Based on data gathered by the Great Lakes Hyperloop Study, the target market for the hyperloop system would include business, leisure and other travelers, rather than commuters.[23] Typical regional commuting distances are not long enough to benefit from the travel speeds of hyperloop, as compared to business and leisure trips or other trips types.

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[17] Ibid, Page 2-6
[18] Ibid, Page 2-10
[19] Ibid, Page 2-6
[20] Ibid, Page 2-6
[21] Ibid, Page 2-6
[22] Hyperloop Commercial Feasibility Analysis, Volpe, Page 31
[23] Great Lakes Hyperloop Feasibility Study, Page 5-8

Additionally, hyperloop could be used for freight service between cities. This service would likely be faster than trucking, cheaper than air, and generally better for the environment. The Great Lakes Hyperloop Study suggests that a hyperloop freight service could dominate intercity freight distribution. The proposed 4-meter diameter of the hyperloop tube would accommodate a 10-foot-wide shipping container. It is likely that the first iteration of hyperloop will be for freight connections.

To take full advantage of the high speeds offered by the technology, hyperloop alignments would need to be designed to minimize vertical and horizontal curves even beyond the limits set by existing high speed rail systems. A balance between speed, destinations, and total travel times would need to be sought on a case by case basis to optimize service, attract ridership, and reduce costs.

## Operational Characteristics

Elon Musk theorized that hyperloop would fill a high-speed service niche between cities up to 900 miles apart, with distances beyond that more suited to travel by air.[24] Competition with aviation for connecting cities 200-500 miles is likely as these mid-level distances have become less profitable for aviation. Serving markets that are less than 200 miles away would not be cost or time effective as there is limited time savings between potential hyperloop speeds and an automobile due to extra time needed to access a station.[25]

Hyperloop Alpha states that a hyperloop capsule could accommodate at least 28 people, which is significantly less capacity than a mid-sized airplane or a passenger rail consist. This limitation would be offset by hyperloop's ability to run a service with two and one-half minute headways. This would give hyperloop a capacity of 840 – 3,360 passengers per hour.[26] Hyperloop would likely utilize pre-booked tickets but allow a flexible time frame for using the ticket because of the rapid succession of pods. Access to the hyperloop system would rely upon the local transportation network for first and last mile trips to its station. Additional transit options may need to be implemented by a city if hyperloop stations are not centrally located or easily accessible.

Each of the three major hyperloop competitors have referenced varying potential speed for hyperloop service. VHO has an estimated travel speed of 670 mph.[27] HTT has an estimated top speed of 760 mph.[28] TP has an estimated speed range between 620-740 mph.[29]

Hyperloop service would be designed to be systematically resilient which would increase its overall reliability as a transportation option. The repair of an individual capsule would have a limited impact on service as a single pod could be removed from service without causing serious delays and capacity constraints. At least three tubes in each direction would need to be built to allow for continued service operations during track maintenance.[30] Without additional tubes, service could be halted in one or both

[24] Hyperloop Alpha, Elon Musk, Page 2
[25] Hyperloop Commercial Feasibility Analysis, Volpe, Page 17
[26] Ibid, Page 15
[27] https://hyperloop-one.com/blog/how-and-why-were-levitating
[28] https://www.hyperlooptt.com/technology
[29] https://transpod.com/wp-content/uploads/2019/03/Final_Report_TransPod_Hyperloop_Thailand.pdf, pg 14
[30] Hyperloop Commercial Feasibility Analysis, Volpe, Page 15

directions. Additionally, environmental hazards such as earthquakes and high winds would need to be considered in the development and construction of hyperloop.

## 4.2 Impact Considerations

A project involving the implementation of a proposed hyperloop system is likely to trigger an environmental review under the National Environmental Policy Act (NEPA). Depending on the location or extent of the system, the environmental review would include the preparation of a Categorical Exclusion, an Environmental Assessment, or an Environmental Impact Statement. The Federal Railroad Administration (FRA) is likely to be the lead federal agency overseeing the NEPA process at this time, and FRA has held internal meeting on project delivery[31] and safety. Generally, environmental impacts from the hyperloop system would be similar to other fixed guideway transportation project, such as high speed rail, with viaducts or tunneling.[32] If existing state-owned right of way is used for viaduct segments, impacts could be minimized. For tunneled segments, there may be impacts from construction to utilities, aquifers or drinking water.

The multi-state, multi-agency nature of a new transportation spine or system would raise regulatory and permitting process issues that should be addressed prior to planning and conceptual design.

The potential for high ticket prices may raise equity considerations for lower income communities. If station locations and right of way acquisitions negatively impact lower income communities or if public funds are utilized to construct the system without equal access, equity issues may become contentious.

## 4.3 Costs

Estimates for both the capital cost and operation and maintenance costs for a hyperloop system are limited because the system is untested and few feasibility studies of the service exist. The Great Lakes Hyperloop Feasibility Study evaluated potential corridors connecting Chicago, Cleveland and Pittsburgh. The capital cost for the Cleveland to Chicago segment ranged from $16.4 billion ($48.6 million per mile) to $20.8 billion ($65.9 million per mile). The annual operating cost was estimated to be $436.5 million per year, with the largest operating cost being the capsule crews. The study forecasted that the hyperloop routes would not require any operating subsidies, with farebox revenue able to cover the costs of operations.

For capital cost, funding would need to include:[33]

- Transportation Planning and Environmental Planning
- Permitting
- Land acquisition
- Tube construction
- Pylon construction
- Vacuum pump construction
- Procurement of capsules
- Tunnel construction

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[31] https://cms8.fra.dot.gov/sites/fra.dot.gov/files/fra_net/17782/Ferber%20-%20Hyperloop%20One.pdf.
[32] https://thenewswheel.com/considering-the-environmental-impact-of-hyperloop-routes-in-the-us
[33] Great Lakes Hyperloop Feasibility Study, Chapter 7 & 8

- Station construction
- Maintenance yard construction
- Solar farm construction

Additional space would be needed for a dispatch facility, day to day systems operations, strategic planning, personnel management, IT services, and business development if not housed in the station.

For operating and maintenance costs, the following would need to be funded:

- Equipment operation and maintenance
- Capsule operation and maintenance
- Energy and fuel (dependent on equipment type)
- Insurance liability
- Crew and staff
- Onboard services (includes equipment, labor, and cost of goods sold)
- System overhead
- Guideway operations and maintenance
- Station operations and maintenance
- Maintenance yard operations and maintenance

No third party economic evaluations have been made available to the public.

## 4.4 Vendors and Manufacturers

Current vendors and manufactures of a hyperloop system and pods are limited as this technology is in its initial phase of development. Firms such as VHO, HTT, and TP are all working to develop the technology for a mass market. It is, however, unclear if they will also be the component manufacturers a well.

If existing hyperloop firms are not manufacturers of the technology, the hyperloop would rely upon existing companies to fabricate components of the system. For example, existing vehicle manufactures such as Bombardier or Siemens could manufacture the proposed hyperloop pods. Leybold, who is currently in partnership with HTT, could mass produce the vacuum system for hyperloop.[34]

## 4.5 Regulatory Considerations

At this early phase, the regulatory framework is still unknown. To date, the FRA has been the de facto lead agency within USDOT due to some of the similarities of engineering and service characteristics. However, there are still questions as whether hyperloop will remain under FRA, or fall within the authority of the FTA or the FAA. USDOT has established the Non-Traditional and Emerging Transportation Technology (NETT) council to identify how to address emerging technologies, including hyperloop and the regulatory and certification process.

Federal certification will need to encompass all components including the capsule, the tube and vacuum system, levitation and propulsion system, stations and terminals, system overhead and maintenance facilities. In the absence of a regulatory process, hyperloop developers have sought third party certifiers

[34] Ibid, Page 2-7

to evaluate the engineering and safety processes.[35] There is also work underway to identify a location for a National Certification Test Track to provide a center for R&D for industry partners, government and academia.

Regardless of the USDOT modal administration chosen to oversee hyperloop, safety and certification testing will be necessary with a full-scale, commercially-viable system before hyperloop can roll out for passenger or freight service.

Safety enforcement and certification will likely remain with the federal agencies, with the exception of FTA's deference to safety enforcements through the State Safety Oversight program. Areas where the technology intersects with surface streets and ground transportation may offer instances where the State DOT would have some authority over specifications and design guidelines (similar to a rail crossing on a state highway – or agreements to use state right of way for alignments). States will also play a role in funding mechanisms and partnerships.

Local government can influence hyperloop service and infrastructure through local and regional master plans, zoning and land use ordinances. Local jurisdictions can incorporate mechanisms to enhance public transportation and allow for emerging transportation technology. Designated transit-oriented development (TOD) districts or overlays could be utilized in addition to tax incentives for business and housing adjacent to existing or proposed transportation hubs.

Additional information regarding the regulatory framework for hyperloop can be found in the TBARTA ITT Governance and Regulatory Framework Technical Memorandum.

## 4.6 Technology Readiness

Some estimates had previously indicated that hyperloop could be operational by mid-2020.[36] Since several key obstacles still remain, that timeframe is not likely, and the lack of regulatory development could push the operational timeframe further out. Firstly, this technology has not been commercially deployed.

To date, only three test tracks for hyperloop have been built. Space X's test track, located in Hawthorne, California, is approximately one mile in length and is used for the Hyperloop Pod competition. VHO's test track, located Los Vegas, Nevada, is 500 meters (over 1,600 feet) long. HTT's test track, located in Toulouse, France, is 320 meters (just over 1,000 feet). None of these test tracks are long enough to fully test speed and are not viable options to test a passenger model of the hyperloop service.

Only a handful of feasibility studies for the hyperloop have been published across the world. Currently, only two studies for a U.S. hyperloop have been published. The first is the Missouri Hyperloop Feasibility Study by Black & Vetch and Olsson in partnership with VHO. This study looked at the feasibility to connect Kansas City, Columbia, and St. Louis via a hyperloop system. This study is not available to the public. The second U.S. hyperloop feasibility study is the Great Lakes Hyperloop Feasibility Study developed by the NOACA and HTT. This feasibility study looks at connecting Cleveland, Chicago, and Pittsburg via a hyperloop system. This feasibility study is available to the public. Additionally, there have

[35] https://hyperloop-one.com/certifer-confirms-virgin-hyperloop-one-technology-ready-independent-third-party-safety-assessment

[36] Virgin One Hyperloop, FAQ

been a few feasibility studies developed for Europe and Asia that have been published. These include a feasibility study for Stockholm, Sweden to Helsinki, Finland and a feasibility study for a connection between Bangkok, Chiang Mai, and Phuket in Thailand.

As mentioned previously, there is limited information on how long it would take to implement the system from a regulatory perspective and there are still many unknowns, especially since the technology has not been adopted by the USDOT. Implementation of the project across multiple states would likely require significant coordination and time. Funding for the project would likely come from many sources, including the federal government, which would also add additional coordination and review duration to a project timeline, and would likely require a consortium.

## 4.7 Market Connection Opportunities

Hyperloop connections were evaluated from a statewide perspective given the interregional travel characteristics assumed for hyperloop (a service profile for hyperloop is provided in Figure 33). The state has significant Strategic Intermodal System (SIS) facilities that provide insights into the priority movements for people and freight throughout the state. As seen from other studies, interstate highways can be important corridors to consider first for hyperloop, in the event that hyperloop can share the public right of way and reduce the capital costs.

*Figure 33: Hyperloop Transit Profile*

| | Hyperloop |
|---|---|
| Example Technology | Virgin Hyperloop (VHO) Hyperloop Transportation Technologies (HTT) |
| ***Images are only for examples of technology, data within profile is a summation of various sources, not just for the example vehicle shown.*** |  |
| Photo Credit | https://hyperloop-one.com/ |
| Corridor Length | 200-500 miles (average studies around 315 miles) |
| Trip Profile (short/mid/ long haul) | Long |
| Speed (mph) (max) | 760 |
| Headway | 0:30 to 2:00 |
| Capacity (per vehicle) | 28 |
| Capacity (per hour) | 840-3360 |
| Corridor /Infrastructure Requirements | 131 feet needed for corridor width, enclosed tubes, stations |

Florida's two most significant north-south highways are Interstate 95 (I-95) and Interstate 75 (I-75). I-95 follows along the eastern side of the state. Virgin's Brightline inter-city rail service operates in an alignment parallel to I-95. While hyperloop would offer much higher speeds than Brightline, there could be some competing demands by having two high speed services in such close proximity to one another. The AADT data indicates that the northern half of the state experiences high vehicle and truck volumes through the central and eastern portions of the state where I-75 and I-95 traverse, respectively. The greatest east-west volumes are between the Tampa Bay and Greater Orlando regions. These connections have been identified previously within high speed rail studies. The southern half of the state has centrally located rural lands, with significant volumes along the eastern side of the state (along I-95) all the way to Miami, and along the western side of the state along I-75. The largest cities in the state have one of these SIS highways traversing their cities, as well as major SIS airports and ports.

The largest cities along I-95 and I-75 were identified for potential connections for hyperloop. These connections were identified due to their proximity to SIS facilities, and because they have the necessary population and employment to support a high speed transit investment. Since hyperloop would have its own fixed-guideway separate from rail, corridors could be assumed along interstates or as all new infrastructure. A Florida team led by AECOM identified a completely new alignment as part of the Virgin Hyperloop One Global Challenge that explored utilizing the central portions of the state. Still, the major connections were identified as Miami and Orlando.

Investments in hyperloop, similar to considerations for high speed rail transit, would likely consider interstate travel to fulfill a U.S. network of high speed travel. The next largest economic hub in the southeast is Atlanta, Georgia which could also serve as a major connection for future systems. This will be an important factor for future evaluation to consider the straightest alignment that meets the critical markets within Florida. Figure 34 provides an illustration of the critical connections in the State of Florida, along with the distances between the connections. As stated previously, ideal hyperloop routes will travel between 200 to 500 miles and frequent stops could reduce the benefit of the overall service. Any shorter market identified for a hyperloop connection in the future will need to provide significant ridership to meet the costs of the project, and determinations would need to be made on whether the shorter segments are part of the main alignment or connected from a spur.

Figure 35 illustrates the potential hyperloop connections, along with their regional population and employment contributing to the potential market. Dotted circles surround the five largest cities in the state that have continuously been referenced for high speed connectivity through the years. Key connections are included for SIS ports and airports for freight and passenger connectivity. The last alignment evaluated for high speed rail is shown for comparative purposes, along with the Miami hyperloop route to Orlando submitted to VHO’s Global Challenge. A general swath of potential connection to maintain a straight connection to the southeast is shaded across the state

*Figure 34: Distances between major city connections*

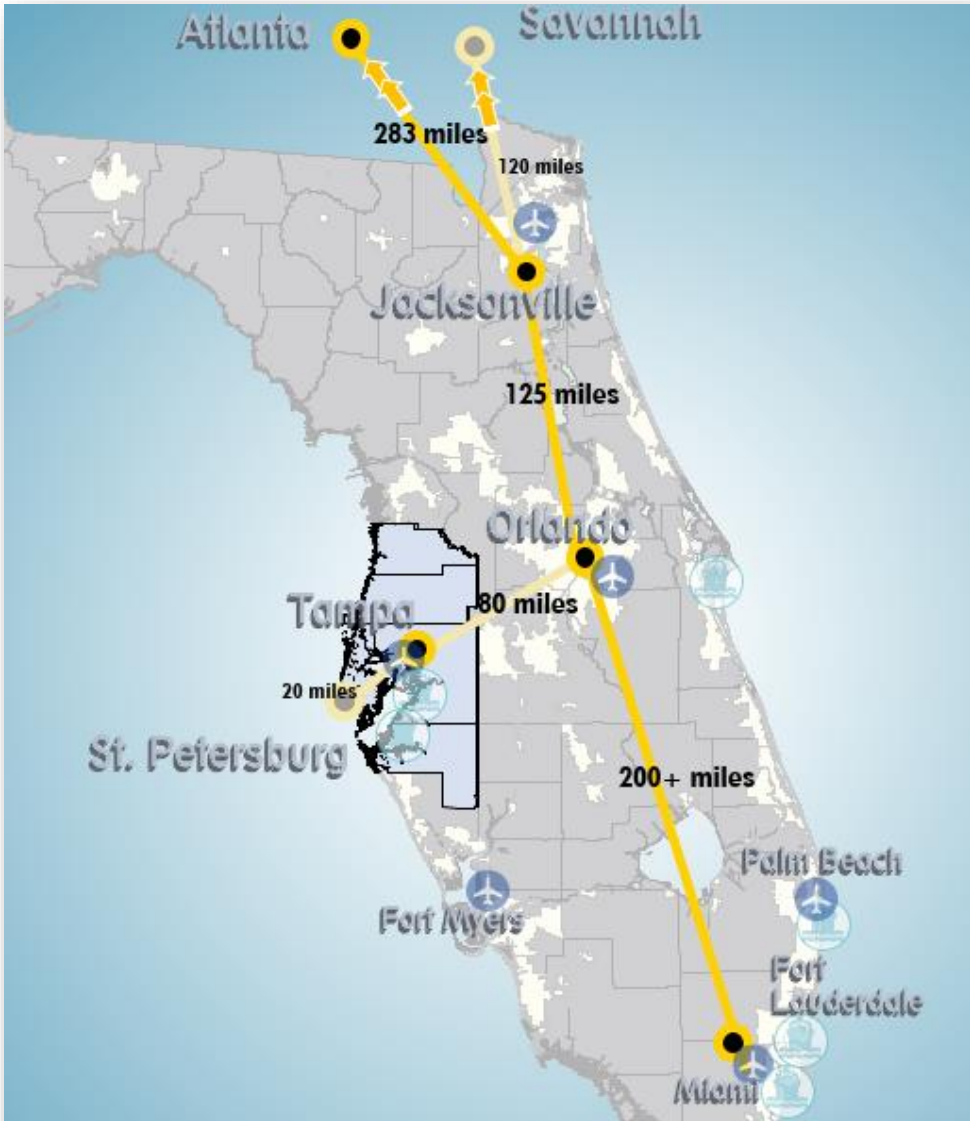
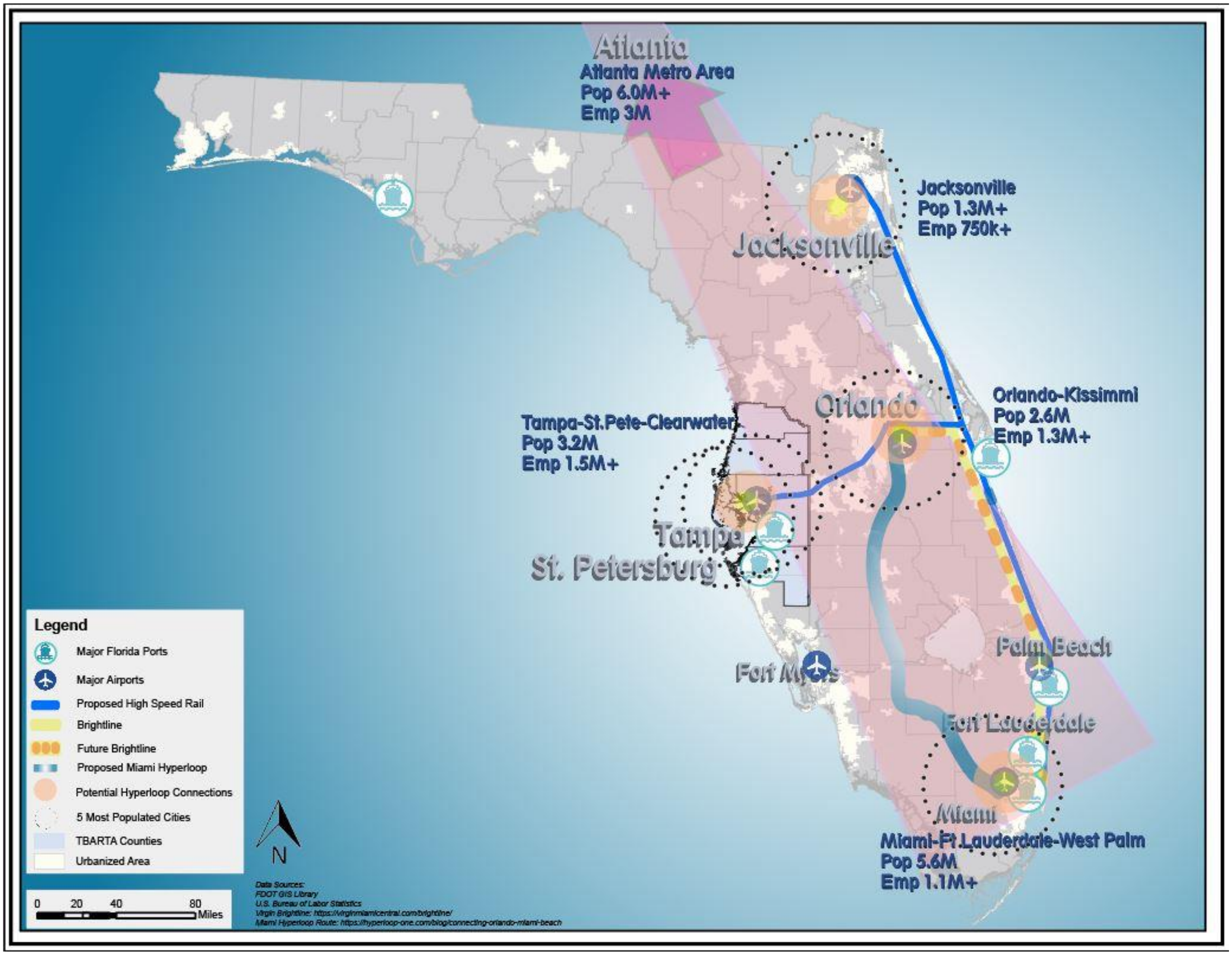



Illustration depicts connections and **not an actual corridor alignment**. Various alignments can be assessed to determine a preferred corridor alignment.

*Figure 35: Potential Hyperloop Connections*

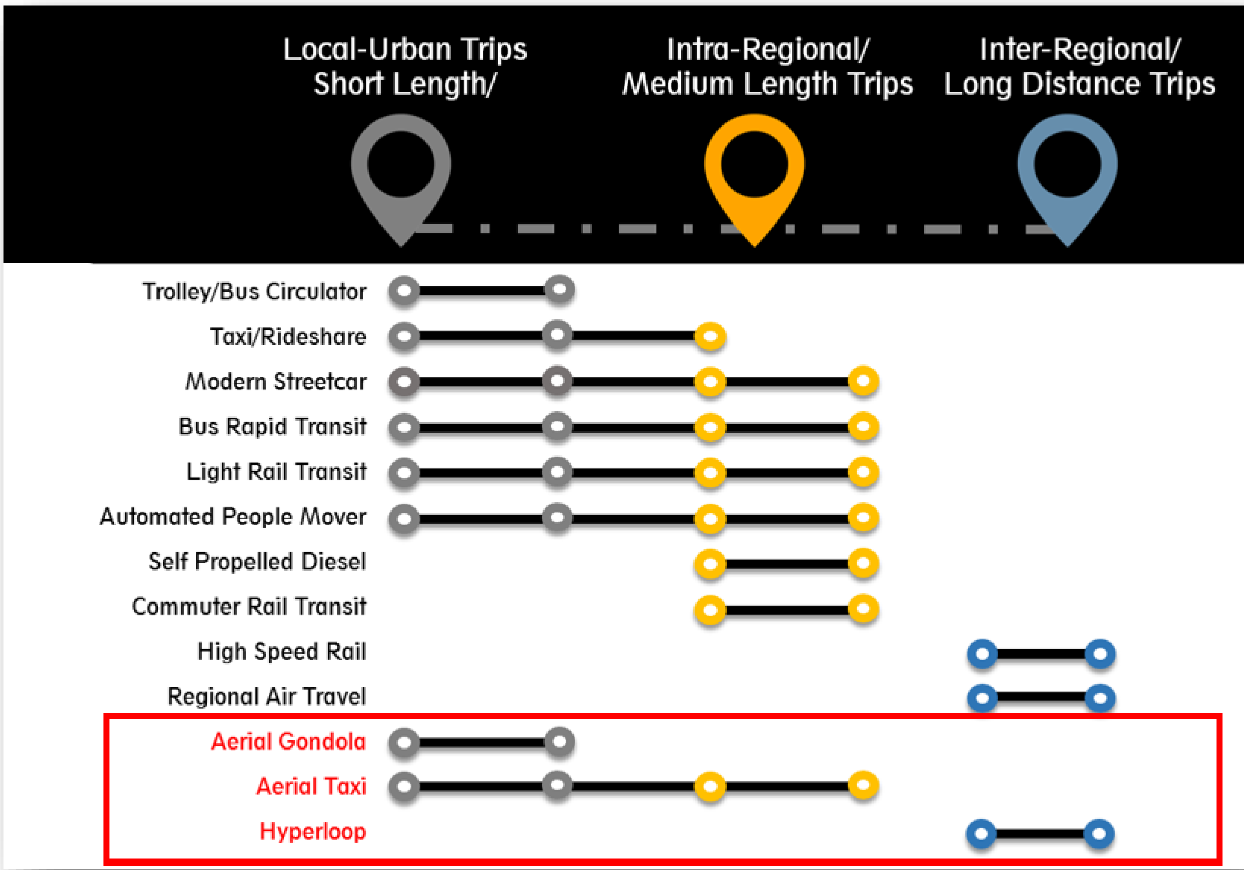


# 5 Opportunities and Next Steps

Aerial gondolas, air taxis and hyperloop are all in very different stages of development. However, there are significant opportunities to incorporate each of the technologies into local, regional and statewide planning efforts, based on the potential connections identified and their estimated timeframe for being operational. While the technical development continues for air taxis and hyperloop, collaboration and partnerships with regulatory authorities and private developers can create synergies that can continue to inform planning expectations, and potentially develop partnerships for future implementation.

Figure 36 provides comparative transit technologies to the modes provided within this report. The comparative transit markets outline where there are opportunities to consider one of the three technologies in the future when assessing potential transit options.

*Figure 36: Comparative Transit Markets*




Based on the compilation of research, the following timeframes were developed to illustrate the years when technology advancement is anticipated.


*Image Source: Leitner-ropeways.com*


*Image Source: EmbraerX eVTOL concept*

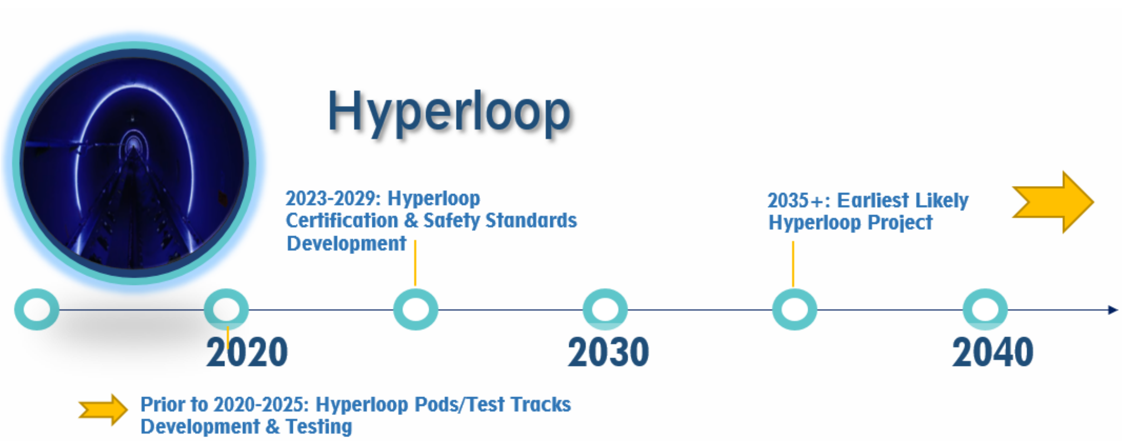



*Image Source: Virgin Hyperloop One*

As indicated, the opportunities and potential next steps differ between each of the technologies due to their different stages of technical and regulatory development. Based on the regional mission of TBARTA and the direction set forth within *Envision 2030*, specific TBARTA recommendations are provided for each of the technologies that align with TBARTA's current goals, capabilities, and operational intent.

For each technology, "Other Opportunities" have also been identified. These offer a menu of options that have been identified as potential next steps for any communities interested in evaluating, demonstrating or applying any of the innovative technologies from this report in the future. They represent common best practices, as well as areas where established coordination or evaluation processes could enable the development of technologies or make a locale, region or state more prepared and/or attractive as these technologies consider pilots, demonstrations, or amenable locations to launch services. These serve as a reference guide, and could be conducted in coordination with TBARTA, or be utilized by local or state partners interested in furthering the development of any of the technologies.

## 5.1 Aerial Gondolas

### TBARTA Recommendations

Of the three modes examined in this study, urban aerial gondolas have the greatest potential for near-term implementation since they already exist and operate throughout the world. This study identified potential connections for aerial gondolas within the TBARTA service area. If there is Board interest in pursuing implementation of an urban aerial gondola project, a logical next step would be for TBARTA to see whether there is any municipal interest in a specific connection or corridor. If so, it could be studied in greater detail and added to TBARTA's Regional Transit Vision Map. Given that the Board recently adopted the Status Quo option in the Envision 2030 Regional Transit Development Plan, additional funding (federal, state, and local) would have to be identified in order to implement any urban aerial gondola project.

### Other Opportunities

Urban aerial gondolas have various applications that extend beyond regional service. For example, they could also provide a connection to local transit service. The following list of suggestions outlines some opportunities where TBARTA could partner with local communities, and/or where communities could explore applications of CPT technology themselves.

***Partner and Collaborate***

Due to the novelty of CPT technologies being used as a transit application in Florida, there is not necessarily the comfort level or experience in incorporating them into existing transit systems, as there is with other transit technologies. Partnerships, collaboration and outreach will be necessary to raise the awareness of CPT capabilities and opportunities. Some early partnership opportunities include:

- **Begin Early Public Engagement with Local Communities (Local/Regional/State):** Public perception and acceptance has been identified as one of the major obstacles to implementing CPT systems. Potential concerns range from privacy, impacts to viewsheds, and skepticism on usefulness of the technology.

- **Determine if additional regulation is required:** Though there is no Tram Safety Board in the State of Florida, it may be prudent to begin conversations on the viability or necessity of standardizing CPT operations in a public transit context.
    - **Establish Stakeholder Working Group**
        - Additional coordination is needed, possibly thorough a stakeholder working group, to identify the roles and responsibilities of stakeholders at the state, regional, and local level in terms of regulation, funding, and operations.

***Plan and Evaluate***

CPT technology can be incorporated into planning evaluations as an option for public consideration and technical analysis. This can be done in local and regional feasibility studies, as well as identifying opportunities early in long range planning efforts. Potential ways to integrate CPT technology includes:

- **Transportation Planning Integration (Local/Regional/State):** Given the existence of CPT technologies, there are opportunities for planners to incorporate CPT technologies into planning efforts now, particularly in Long Range Transportation Plans (LRTPs).
    - Identify how CPT technologies can integrate with local and regional transit and transportation plans.
    - Identify if and how CPT could serve as a cost-effective alternative to building ground-based transportation.
- **Undertake a Feasibility Study:** Any analysis on CPT technologies in terms of their feasibility would follow the well-established process undertaken by other public transit projects. A potential corridor for analysis would need to be identified by project stakeholders to determine project feasibility.
    - **Determine Organizational Capacity:** Potential owners and operators should asses their agencies capacity to operate a CPT system. It may be necessary, or preferred, to contract for daily operations support with a manufacturer.
    - **Determine Partnership Opportunities:** Many recent CPT systems have been developed through a partnership of private and public sector interest. Based on project location there is the possibility to garner multiple funding streams through a partnership.
    - **Coordinate Transit Connectivity and Fare System:** Determining appropriate connections to the wider transit network is paramount. Logical connections to a CPT project should be established. Additionally, determining the collection of fares is important. A CPT system can be seamlessly integrated to established fare systems.

## 5.2 Air Taxis

### TBARTA Recommendations

As shown earlier in the timeline above, 2025 is the anticipated timeframe for demonstration projects of air taxis with pilots on board. Between now and then, air taxi developers will continue to work on flight testing and aircraft certification, and testing specific use cases for air taxi mobility. Given that air taxis have adopted the business model of TNCs, it is unclear how much of a direct role TBARTA, or any public transit agency, would have in future air taxi operations. That being said, there are still opportunities that TBARTA could pursue to help facilitate the development of air taxi service in the Tampa Bay region.

First and foremost, TBARTA could invite air taxi developers to come present on their aircraft's capabilities and the status of their testing. The forum could be a Board meeting or expanded to a larger industry summit. This would put the Tampa Bay region on the radar of air taxi developers. Based on what is learned from this engagement, a next step could be for TBARTA to investigate the possibility of having an air taxi developer(s) conduct test flights in the Tampa Bay region. This would naturally require coordination with the Tampa International Airport.

Another opportunity would be for TBARTA to collaborate with NASA on its work with local communities to model vertiport locations. During the study, TBARTA staff had informal phone calls with NASA modelers, and they expressed interest in partnering with TBARTA to identify potential vertiport locations in the region. Pursuing a partnership with NASA could raise the profile of the Tampa Bay area, attract potential demonstrations and pilot projects, and serve as a planning tool for local and regional transportation plans.

## Other Opportunities

Over the next several years, there will be significant coordination with developers, government bodies, and the public to identify acceptable vehicle and operating requirements. Both public and private stakeholders will likely lead initiatives throughout the country to implement pilot projects and demonstrations to prove the technology and determine issues and opportunities. There are also critical land use and zoning considerations that local communities can begin to look at now to encourage the development of UAM in a safe and equitable manner, while protecting communities from potential nuisances. While transportation planning continues to address the local, regional and statewide needs, there are opportunities to integrate the infrastructure requirements that will enable the technology in the future.

The following outlines additional opportunities and considerations for local, regional and state agencies to take part in the early activities that will shape the development and advancement of UAM.

***Partner and Collaborate***

- **Partner and Coordinate with NASA and FAA Activities (Local/Regional/State)**: NASA is looking for opportunities to work with local communities who are interested in partnering with them to define the systems-level requirements and regulatory framework for implementation.
    - **Begin Early Public Engagement with Local Communities (Local/Regional/State):** Public perception and acceptance has been identified as one of the major obstacles to implementing a UAM system. Potential concerns will range from safety, noise, equity, to viewshed/flight path. Partnerships with federal regulatory bodies will help to inform the regulatory and development process.
- **Partner and Coordinate with Aircraft Developers (Local/Regional/State):** Transportation planners have a unique opportunity to work alongside aircraft developers/manufacturers during the nascent stage of vehicle development to influence vehicle design, based on the anticipated impact of UAM vehicles on ground-transportation planning environments.
    - Provide developers support in testing technology and establishing pilot projects and/or demonstrations.
    - Collaborate on specific use cases that can solve real world problems that could relate to operational issues or concerns for the UAM industry, or problems that the UAM is

actively trying to solve. Some may include, but not be limited to: operational function, community engagement, noise, maintenance and landing infrastructure, and air traffic management.
    - Work with private sector partners, public sector partners, and federal regulators to establish plans for demonstrations or pilot projects aimed at developing public trust and confidence in a new mode of transit.
- **Establish a Stakeholder Working Group (Local/Regional/State)**: A Stakeholder Working Group could help to establish consistent standards and operating procedures, including local, regional and state agencies (with engagement of federal agencies where appropriate).
    - A stakeholder working group can determine go/no-go criteria for UAM industry participation. Early engagement offers a chance to play a foundational role in the development of vehicles, business models, routes, and mission types that will be implemented by the private sector. Considerations might include:
        - Expectations or potential requirements for modal equity
        - Whether there should be regulatory control of where vehicles fly, and the vehicle characteristics permitted in different areas of the city
        - Determine if there is interest to attract business, or simply "stay out of the way"
    - In addition to aviation stakeholders, other key public-sector entities include:
        - Development services
        - Public safety/emergency responders
        - Public works/utility providers
        - Where appropriate, elected officials and/or their staffers
        - NASA and/or FAA (FAA may be dealt with most easily by partnering with a local airport, who is well versed in the unique culture and expectations of the FAA)
        - Nearby or adjacent cities with which the community has significant connectivity
    - Outreach to the state legislature or other such bodies which commission funding for advanced transportation technology initiatives or aviation initiatives.
        - State economic development entities
        - State transportation commissions
        - State department of transportations (including the division of aviation/aeronautics)
- **Coordinate with Airports (Local/Regional/State)**: Airports already have close coordination with FAA and are already well-versed in commercial aviation. They will be a critical partner, leader and resource in planning for and establishing UAM.
- **Host UAM Summits** (Regional/State): A statewide UAM industry summit could provide a collaborative environment to understand the operational and regulatory considerations impacting UAM, while highlighting the assets of the region and state for potential demonstrations and pilot projects. The City of Orlando is also considering the potential for UAM to solve transportation challenges. Bringing regions together throughout the state could create larger synergies to attract more pilot projects and demonstrations.

***Plan and Evaluate***

- **Identify Early Land Use/Zoning Issues and Opportunities (Local):** Land use and zoning will play an important role in ensuring UAM remains a mobility opportunity without becoming a public nuisance. Local communities can study potential land use and zoning issues related to vertiport placements, operations, and take-off and landing areas.

- Consider infrastructure provisioning for electric charging systems
- Identify opportunities for fleet storage and servicing
- Initiate a comprehensive policy development process that provides guidance on local-level challenges like:
  - Land-use and zoning
  - Noise and vehicle classifications
  - Fleet management and vehicle storage
  - Considerations for local-level registration requirements (vehicle vs. operator)
  - Route planning and management
  - Integration with other transportation innovation initiatives, such as connected and autonomous vehicle technology, data specification requirements

- **Develop UAM Integration Plan Guidance (Local/Regional/State)**: While air taxis and UAM are still under development, there are significant opportunities for locals, regions and states to take part in testing and define how UAM can integrate into the existing transportation infrastructure and support the needs of transportation more broadly.
- **Develop Vertiport Standards and Requirements (Local/Regional)**: Local communities and/or regional agencies can evaluate a few key considerations related to vertiport development: (1) system requirements, (2) procedural requirements, and (3) design requirements.
  - ***System requirements*** would be derived from system demand patterns and UAM ConOps that would indicate key requirements such as proper vertiport placement and other considerations which could affect the efficiency of the system.
  - ***Procedural requirements*** would encompass the operations in and around vertiports, and would include items such as approach and landing procedures, takeoff and departure procedures, taxiing procedures, charging procedures, snow and ice removal procedures, safety procedures, and emergency procedures.
  - ***Design requirements*** would encompass the end-to-end passenger experience and key needs to support infrastructure functionality, and would include passenger management, arrivals and departures, aircraft parking, fire suppression and mitigation, flight aids, and vehicle support.
- **Coordinate Building Code Standards (Local/Regional):** Coordination with local jurisdictions can help to set standards early for potential vertiports, vertihubs and vertistops. Standards can include electrification, landing pad infrastructure, visitor access expectations and accommodations, fare payment, and guidelines for each class of infrastructure.
- **Transportation Planning Integration (Local/Regional/State):** Given the anticipated timeline of UAM, there are incremental phases of operation that planners can incorporate into planning efforts now, particularly in LRTPs.
  - Identify how UAM can integrate with local and regional transit and transportation plans.
  - Identify if and how UAM could serve as a cost-effective alternative to building ground-based transportation in a number of scenarios, such as:
    - Instances where latent demand is being serviced by unnecessarily lengthy car trips when ground-based transit service (bus, rail, paratransit) is cost-prohibitive per mile for the level of demand it would service

        - Instances where there is an explicit goal to attract new business opportunities/jobs/economic development in transportation innovation
        - Instances where there are specific sustainability goals that need to be met
        - Communities that have a relatively high level of executive and business travelers using helicopter services
    - Integration with **mobility hubs** and **intermodal center** designs and development. As studies and conceptual development progresses, plans can incorporate vertiport infrastructure, or at a minimum, not preclude the future placement of landing pad and electrification infrastructure.
    - **Initiate Early Public Involvement:** During local and regional long range transportation efforts, engaging the public early about UAM can prepare the public and gain insights on areas of importance to the community.
- **Operational Capacity Assessment (Local/Regional/State):** UAM will come with new roles in local, regional and state governments to incorporate UAM into transportation planning, and support necessary licenses and certifications for piloted systems. An Organizational Capacity Assessment can identify the strengths and weaknesses of agency preparedness to handle the demands of managing and coordinating with a new mobility sector.
    - Identify the resources for overseeing or liaising with the UAM industry. Since there is no new revenue at this stage, a key consideration is how to resource the uptick in requests for meetings, coordination, and eventually demonstration by private companies and federal authorities like FAA and NASA. Some strategies for this include:
        - Incorporating UAM into a transportation innovation fellowship-type position
        - Requesting executive resources to support the initiative
        - Requesting political resources to support the initiative, for example through a local or state entity's economic development and commerce agencies

***Engage***

- **Community Engagement**: The local and regional organizations will be critical to engaging the community, whether to answer questions or gather feedback on community concerns. Engagement should start early and continue during studies, pilots, demonstrations, and through any implementation. As a new mode of transportation, the public acceptance will be necessary for UAM to become a new mobility option.
    - Listen to community impacts and coordinate with UAM sector to mitigate as necessary

## 5.3 Hyperloop

### TBARTA Recommendations

Hyperloop is still in the early stages of development. There is still much work left to be done in the area of testing and certification. Similar to air taxi, there are regulatory gaps at the federal level that need to be filled. As shown earlier in the timeline above, 2035 is the earliest anticipated date that one will see a hyperloop project.

Because hyperloop is anticipated to serve long distance trips between cities in the 200- to 500-mile range, any future hyperloop corridor will require coordination at the state level. The FDOT could play an important role as a discussion facilitator similar to the role it played as a discussion facilitator on the topic of automated vehicles.

The first recommendation is that this Final Report along with the four Tech Memos be shared with the Central Office of FDOT to share the information from this study for future use.

A second recommendation would be for the creation of a Hyperloop Steering Committee led by FDOT with representation from public agencies such as MPOs, Regional Planning councils (RPCs), transit agencies, cities, and counties. One of the purposes of the committee could be to make sure that information about hyperloop is being shared on a state-wide basis. For example, the proposed hyperloop route from Miami to Orlando was selected in 2017 by Hyperloop One as one of ten global winners in their Hyperloop One Challenge. Initiatives and information like this could be coordinated and shared on a statewide level. A statewide Hyperloop Steering Committee could help to facilitate the dissemination of information and incorporate regional stakeholders in the planning process.

A third recommendation would be for FDOT to include discussion about hyperloop in its next update of the Florida Transportation Plan. The Innovative Transit Technology Study looked at possible hyperloop connections in the state. The Florida Transportation Plan could look at corridors and connections in greater detail, incorporating the necessary stakeholders.

## Other Opportunities

At this time, technical operational characteristics are based on technical assumptions, and real-world testing will be needed to prove the safety and functionality of the technology.[37] Hyperloop companies have generated excitement and interest in the technology.

The following outlines additional opportunities for communities to take part in the early activities that will shape the development and advancement of hyperloop.

***Partner and Collaborate***

- **Develop a High Speed Transport Steering Committee**: As discussed previously, a steering committee comprised of the state DOT and jurisdictional representatives can provide strategic direction and momentum to carry out a statewide feasibility assessment. This steering committee can identify specific laws, agreements and regulations necessary for moving a joint project forward. A steering committee could also commission studies to evaluate innovative funding and financing strategies. Statewide resources would need to be identified to support the committee and planning efforts. Additionally, hyperloop could be evaluated against the operational characteristics of other existing technologies to consider various alternative potential and impacts.
    - A steering committee may consider **incorporating a representative from neighboring states** to understand the impacts of various alignments and connections as they integrate into the Southeast U.S. network.

- **Statewide Advisory Group**: An advisory group including stakeholders from major regional destinations throughout Florida would provide greater collaboration. An advisory group can inform the collaborative process with input from public, private and non-profit sectors. The advisory group should include professionals in passenger transportation, as well as freight logistics.
- **Partner with Developers**: Throughout the U.S., VHO and HTT have partnered with communities to provide operational assessments, analysis and data. Forging a partnership early, and incorporating into the statewide planning process will provide the state and region with continued updates, resources and an understanding of continued development trends and needs.

***Plan and Evaluate***

- **Incorporate hyperloop and high speed transport into state planning**: Given hyperloop's operational characteristics, connectivity will need to be evaluated on a statewide basis, or in partnership with other regions to identify potential route alignments. A feasibility study and business case analysis would provide a basis for understanding the benefits and economic opportunities of alignment alternatives. This process should incorporate the ports and airports given the importance of economic connectivity for passenger and/or freight operations.
- **Regional Planning Coordination**: As initiatives advance, regional and local plans should take part in identifying terminus locations that provide regional connectivity. While hyperloop is not interoperable with other modes, a supporting regional and local network will be necessary for a successful high speed connection. Planning efforts can identify the level of supporting service that will be necessary for a high speed connection to understand the level of investment and resources needed to make high speed transport a reality.
- **Conduct a Statewide Feasibility Study**: Without showing preference to a specific technology, a steering committee and statewide advisory group can spearhead a high speed feasibility study to evaluate potential alignments. While high speed rail studies have been conducted in the past, hyperloop presents opportunities and impacts that should be considered with new fixed-guideway infrastructure. Additional consideration should be given to tube infrastructure grade elements to better understand the cost considerations and impacts.
- **Research Center:** Utilizing academic and research resources that exist in the state will foster an environment of engagement and learning as new innovative modes work through development, research and use case analysis. Engagement with the Center for Urban Transportation Research (CUTR) in Tampa Bay could be opportunity for the Tampa Bay region to be on the forefront of research and analysis.
- The greatest opportunity for local government to shape the future of hyperloop technology is through **local and regional master plans, zoning and land use ordinances**. Local jurisdictions can incorporate mechanisms to enhance public transportation and allow for emerging transportation technology. Designated TOD districts or overlays could be utilized in addition to tax incentives for business and housing adjacent to existing or proposed transportation hubs.

***Engage***

- **Engage the Public**: As a new mode of transport, extensive public engagement will be needed to understand concerns and priorities, and to educate about the technology. Similar to UAM, as a new mode of transport, public acceptance will be critical to move forward.