WHITE PAPER: URBAN APPLICATION OF AERIAL CABLEWAY TECHNOLOGY

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EXECUTIVE SUMMARY

WSP USA is pleased to present the following white paper that summarizes the benefits and items for consideration of aerial cableway technology; outlines the project development process; and addresses advantages, costs and challenges associated with developing aerial cableway systems in urban environments.

Urban applications of aerial cableway technology have been successfully integrated into transit networks in numerous cities around the globe, including the Portland Aerial Tram (Portland, Oregon) and Roosevelt Island Tram (New York, NY). Interest in aerial cableway technology has grown considerably in the United States in recent years, and initial feasibility studies have been completed in several U.S. cities, including San Diego, CA; Washington DC; and Brooklyn, NY.

WSP is evaluating aerial cableway technology as an innovative first- and last-mile connection to regional transit in urban areas. Aerial cableway technology offers multiple benefits, including:

- relatively lower costs compared to other transportation modes,
- the ability to overcome significant changes in topography and other obstacles in natural and man-made environments,
- the ability to bypass congested roadways and transportation corridors,
- the ability to move high volumes of passengers: the equivalent of one city bus every minute,
- a streamlined design that fits into the urban environment,
- the potential to integrate transit-oriented development (TOD) near stations, and
- the ability to provide service between residential areas and key destinations.

Many of these benefits have been realized in existing systems in La Paz, Bolivia, and Medellin, Colombia. Specifically, Medellin's Line K transports more than 40,000 passengers per day between residential areas and the city center, reducing some commute times from more than an hour to approximately 10 minutes.

Aerial cableway systems can be integrated into urban environments seamlessly to offer an additional mobility option, increase transit ridership and reduce congestion. Potential urban applications include:

- **First- and Last-Mile Connections**: Aerial cableway systems can be used to provide connections between major regional rail and bus rapid transit (BRT) lines and key destinations located outside walking distance of stations and from high residential areas to regional rail/BRT lines.

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- **Alternative Mode to Address Physical Obstacles**: Aerial cableway systems can traverse challenging topography or other features, both natural or man-made, which make implementation of traditional transit applications, such a light rail, difficult or impractical.
- **Transit Extension or Connection**: Extending or connecting existing rail lines can be expensive, either due to topographic or other natural barriers, or simply due to the high cost of additional rail infrastructure. Aerial cableway technology can be used to extend or connect two or more existing transit lines in a cost-effective manner.
- **Airport Connector**: Aerial cableways can be used to connect airports with a regional transportation network.
- **Access to Peaks in Urban Areas**: Key regional destinations may be situated in hilly terrain where roadway access is limited. Aerial cableways can be used to connect these destinations to other modes of transportation.

INTRODUCTION

Internationally, extensive aerial cableway systems have evolved and carry large volumes of commuters as a viable alternative to traditional urban transit methods such as buses and rail. Large systems exist throughout South America, Asia and Europe, including the Singapore Cable Car expansion in 2015; Rio de Janeiro’s cableway launch in 2013; and the expansion of La Paz, Bolivia’s cableway system with six new urban lines. Many of these systems have one or more intermediate stations and provide service throughout dense, topographically challenging environments.

Examples from several South American cities, London and Singapore are presented below in Table 1.

Table 1 Worldwide Aerial Cableway Systems

Location (date built)	System Length (mi)	# of Lines	# of Stations (system-wide)	Operational Capacity	Integrated with Transit Network?	Why technology was chosen?
La Paz, Bolivia "Mi Teleferico" Phase 1	18.7	9	27	3,000 pph	Yes	Overcome steep topography and traffic congestion, reduce pollution
Caracas, Venezuela "Metrocable de Caracas" Built 2007-2012	4.1	2	7	2,000 pph	Yes	Overcome steep topography and provide social services at stations
Medellin, Colombia "Metrocable Medellin" Built 2004-2010	5.8	3	9	3,000 pph	Yes	Overcome steep topography and connect barrios to rest of city
Rio de Janeiro, Brazil "Teleferico do Alemao" Built 2011	2.2	1	6	2,000 pph (approx.)	Yes	Build tourism, improve social conditions in the "favelas" (settlements of urban poor) on hillsides by connecting residents to rail network
London, United Kingdom "Emirates Air Line" Built 2012	0.7	1	2	2,500 pph	Yes	Connect exhibition areas for 2012 Olympic Games over the Thames River and to the subway system
Singapore "Singapore Cable Car" Built 1974, extended to Sentosa 2015	1.1	1	3	1,400 pph	No	Provide tourist attraction from Mount Faber, spanning Keppel Harbour and steep topography to Sentosa resort island

pph = persons per hour

Though aerial cableway systems have been used as a form of transportation for decades, they are seldom used in urban applications in the United States. This technology/mode has been used in limited markets, including ski areas and amusement parks. Recently, however, several cities throughout the country have shown interest in how the technology could be applied in their respective urban areas. This new consideration is being driven by the successes seen in Latin America and other parts of the world, and by an increased focus from many transit agencies to provide first- and last-mile solutions for improving access to regional transit lines.

In the United States, recent urban aerial cableway projects include:

- **Portland Aerial Tram**: Opened in 2006, this system provides service between Portland's South Waterfront district and the main Oregon Health & Science University campus.
- **Roosevelt Island Tram**: The first urban mass transport application of aerial tramways in the United States was completed in 1976 and was built to connect new low- and middle-income residential development on Roosevelt Island to Manhattan in New York City.

While aerial cableway technology has enjoyed a high level of success in other countries, an urban cableway system with intermediate stations in the United States has not yet been implemented. Both the Portland Aerial Tram and Roosevelt Island Tram are point-to-point systems with no intermediate stations.

SUMMARY OF BENEFITS AND ITEMS FOR CONSIDERATION

These systems offer an additional transit option to overcome obstacles in the built or natural environment, such as freeways, water bodies, or significant changes in topography (e.g., canyons and valleys), to improve "first-mile/last-mile" connections to major regional transit lines. Other potential benefits in urban aerial cableway systems include low capital cost, minimal footprint, low energy consumption and reduced emissions, and the ability to bypass congested roadways.

Aerial cableway systems offer several potential advantages over traditional modes of transit, including:

- **Cost**: Aerial cableway systems have a relatively small footprint and require minimal infrastructure to operate, and can be constructed for about $50 to $60 million per mile, depending on the number and complexity of system stations. Typically, annual operating and maintenance costs for aerial cableway systems are around $1 million per station.
- **Accessibility**: Level boarding allows for passengers of all ages and mobility levels to board and exit the cabins.
- **Versatility**: The technology can overcome obstacles in the built or natural environment, including railway lines, freeways, water bodies or significant changes in topography.
- **Energy Efficiency and Environmental Friendliness**: As an all-electric system, the aerial cableway uses less energy, and its greenhouse gas emissions are lower than other transit options.
- **Minimized Wait Times**: Cabins can arrive as frequently as every 12 seconds, sending passengers on their way more frequently than traditional modes of transit.
- **Congestion Bypass**: Travel times are not affected by congestion along arterial roadways or highways.
- **Smaller Footprint**: Impacts to existing infrastructure and environmental impacts can be minimized by the smaller system footprint.
- **Shorter Construction Duration**: Aerial cableway systems can be constructed in as little as 12-18 months, minimizing disruption and temporary construction impacts within urban environments.

- **Development Strategy**: Aerial cableway systems provide an opportunity to extend the reach of existing transit services to provide connections to new developments and minimize the increase in vehicular traffic on adjacent roadways. For example, the Portland Aerial Tram was constructed in conjunction with the South Waterfront Campus of Oregon Health & Science University (OHSU) to provide an alternative to accessing the main OHSU campus via automobile.

Additional items to be considered when evaluating aerial cableway systems include:

- Transit operators need to develop operations and maintenance (O&M) expertise with a new technology, though this can potentially be contracted out.
- Depending on the specific aerial cableway technology used, the system may more sensitive to inclement weather, as high winds and electrical storms may require a temporary shutdown.
- Traditional system evacuation procedures have been developed for resort-based aerial cableway systems, while urban-based evacuation procedures are in the process of being developed.
- Insurance premiums are typically higher than for traditional transit modes due to the high elevation of operations and newer technology application.
- Air rights need to be secured to build and operate aerial cableway systems, which can be challenging in urban environments.

Though challenges with implementing aerial cableway systems do exist, the benefits of the technology have the potential to outweigh any limitations and provide an overall mobility enhancement in urban areas.

TECHNOLOGY OVERVIEW

This section provides a summary of system specifications. Details for each component are discussed below.

STATIONS

Aerial cableway stations are the most complex components within aerial cableway systems, and as a result are usually the most expensive as well. Stations not only allow for passengers to board and alight a system, but they also contain key components that power a system. Aerial cableway systems can include some or all of the following station types:

- **Drive Station**: Usually located at one end of a system, the drive station houses the system motor and other key components used to power the system. Drive stations can often include more space for cabin storage and maintenance. Specific storage requirements vary based on ridership demands. Cabin storage areas can be located either adjacent to the station platform or placed under a station, depending on constraints at the station site.
- **Return Station**: Located on the opposite end of a system from a drive station, return stations include necessary mechanical components required to return cabins back to the drive station. Return stations have the same electromechanical components as a drive station, but do not include components to power the system.
- **Intermediate Station**: Located at one or more points between the two end points of a system, intermediate stations provide additional opportunities for passengers to board and alight a system. Intermediate stations can also be constructed in a manner that allows for the system to turn at key locations. Cabin storage and maintenance facilities can also be included within intermediate stations.

Aerial cableway stations vary in size depending on passenger throughput and location within the system. Typically, station footprints range from 50 feet by 70 feet for a return station, to 50 feet by 180 feet for an intermediate station. Station widths can increase if an end station is elevated to provide vertical access features like elevators and stairs.

TOWERS

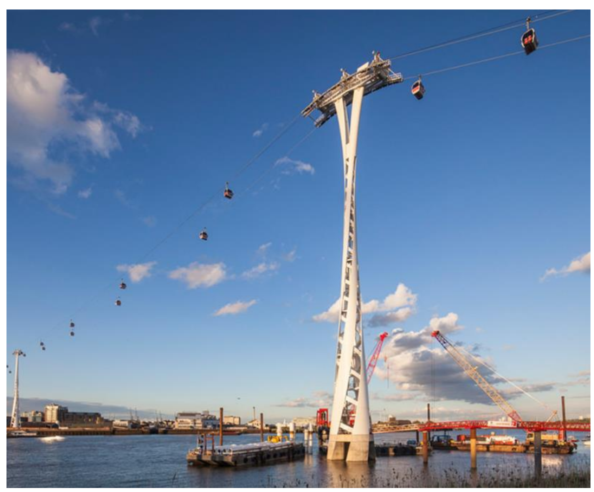
Between stations, aerial cableway systems are supported by several vertical towers. Towers are typically spaced between 300 and 400 feet apart, depending on characteristics in the built environment, and the distance between towers can vary.

The height of the aerial cableway towers is dependent on the following:

- **Minimum Vertical Clearance**: Depending on the environment below the system, the height of towers vary to ensure minimum vertical clearance thresholds are met.
- **Tower Spacing**: In general, the greater the horizontal distance between towers, the higher the towers themselves need to be.
- **Cable Sag**: The cable guideway itself experiences sag between towers due to downward gravitational forces on the cable and individual cabins. The cable guideway sags 3.5 percent of the horizontal distance between the towers. This sag needs to be taken into consideration when determining the size of towers.

Towers are usually t-shaped, lattice, or cantilever. T-shaped towers are most commonly used, though other tower types may be necessary due to tower heights, constraints within a built/natural environment, or architectural preferences.

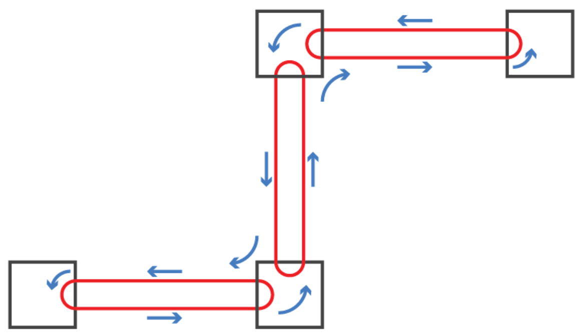
Typical cantilever tower (Source: Google)



T-shaped tower with architectural treatment (Source: popupcity.net)

Aerial cableway systems are sometimes required to turn corners due to constraints in the natural or built environment. This can be achieved with either turning towers, or more commonly, turning terminals. At turning terminals, passenger cabins slow down to a speed of approximately 300 feet per minute to transfer from one cable loop to another and change course.

Turn towers require the same electromechanical components as an intermediate station, but do not require the same ancillary components, such as elevators and ticketing machines, that are required at stations where passengers board and alight.



Typical Multi-Loop Configuration

Passenger Cabins

Passenger cabin sizes vary depending on which type of aerial cableway technology is used. Cabins can be modified to include features designed to enhance the overall passenger experience, such as enhanced ventilation, air conditioning and internet access (Wi-Fi). Cabins could also be fitted with bicycle racks on their exteriors, making them a more attractive option for cyclists and to provide a first- and last-mile option. Cabins can also be equipped with on-board one-or two-way communication systems that could be used to communicate with passengers in the event of an emergency or for security reasons. Cabins provide level boarding to meet Americans with Disabilities (ADA) requirements and to enable boarding and alighting for passengers with mobility devices.

Cables

Aerial cableway systems operate using woven steel cables that operate in loops. There are two types of cable: propulsion and track. A propulsion cable is used to propel and guide cabins throughout a system, whereas track cables remain stationary and provide support.

Grips

Passenger cabins are connected to the cable by a grip. There are two types of grips: detachable and fixed. Upon entering a station, cabins with detachable grips will detach themselves from the cable and move through the station using a conveyor system. This enables cabins to slow to a speed that allows for passengers to board and alight the system without disrupting cabins that are traveling between stations. This feature can significantly increase the capacity of a system, and allows for systems to include intermediate stations or turn terminals.

Fixed grips are permanently attached to the cable. Due to this, the entire system must be slowed and/or stopped when a cabin arrives at a station. Intermediate stations and turn towers are not typically feasible in fixed-grip systems.

Urban aerial cableway systems generally use one of three key system technologies: aerial tramway, mono-cable detachable gondola (MDG) and tri-cable detachable gondola (3S).

Key characteristics of each type of cableway are highlighted in Table 2.

Table 2. Summary of Common Aerial Cableway Technologies

Characteristic	Aerial Tramway	Mono-cable Detachable Gondola (MDG)	Tri-cable Detachable Gondola (3S)
Description	Aerial tram systems usually include one or two cabins fixed to the same cable loop and oscillate back and forth.	The most commonly used type of aerial cableway technology, the MDG uses one cable to both support and guide cabins through the system.	The 3S is faster, has a higher per-cabin capacity and can operate in higher wind speeds than the MDG. It is also one of the most expensive types of aerial cableway technology.
System Capacity (pphpd)	2,000	4,000	6,000+
Cabin Capacity	250	15	38
Maximum Operating Speed (kilometers/hour)	45 (~28 mph)	25 (~16 mph)	30 (~19 mph)
Access Speed (for boarding and alighting)	N/A	60 feet per minute	60 feet per minute
Maximum Wind Speed During Operation (kilometers/hour)	80 (~50 mph)	70 (~43 mph)	100 (~62 mph)

pphpd: passengers per hour, per direction
Data source: Doppelmayr

FUNDING STRATEGIES AND OPTIONS

As with all urban transportation projects, a combination of creative leveraging from multiple funding sources would most likely be required to fund capital and operating costs. These include federal, state, local and even private sources that may be necessary to fund the development of a system.

Finding and securing funding for any public transit project is a competitive process at all levels of government. There are several potential funding sources, ranging from local improvements districts and public-private partnerships (P3s), to federal, state and local transit improvement programs. The innovative nature and cost-effectiveness of aerial cableway technology makes it a strong candidate for a variety of funding programs, and competitive for transit-project funding opportunities and investments.

The following provides an overview of potential funding mechanisms. The strategies noted below are not exhaustive; a more detailed review of potential funding options could be undertaken both during a feasibility study or in subsequent phases of the project development process.

UNIQUE FUNDING SOURCES

Public-Private Partnership Opportunities

An aerial cableway system could be a candidate for a P3. Through P3, a private entity would invest its own money through borrowing or equity and assume much of the risk association with construction of the system. This approach has been used in the United States for several large-scale transportation projects, which typically require a multi-billion-dollar investment from a private entity. The relatively low capital investment required for an aerial cableway system in comparison to these projects could be appealing to private entities.

P3 opportunities for aerial cableway systems should be explored based on the following:

- International experience shows a broad level of private investment in this technology.
- Ridership projections are robust.
- Major activity centers can be served.
- Joint development opportunities may exist within proposed station areas.
- The Design-Build-Operate-Maintain project delivery method is common for this type of technology, especially with the limited amount of expertise for the O&M. (Although, over time, the resources can be built up by an agency operator.)

Commercial Sponsorship and Advertisement Revenue

An aerial cableway system could secure funding from commercial sponsorship and/or advertisement revenue, including the following:

- System Naming Rights: An aerial system could secure sponsorship and naming rights, similar to the agreement in place with Emirates Airlines and the London Underground in London, United Kingdom.
- Station Naming Rights: Naming rights could be sold for each station location.

TRADITIONAL FUNDING SOURCES

A wide range of more traditional public funding and financing options are also available to help cover the cost of aerial cableway systems. This section outlines these options.

Federal Grants and Financing

At least four sources of federal grant funding are available for projects of this type: Section 5309 Capital Investment Grants (CIG), Section 5307 formula funds, Better Utilizing Investments to Leverage Development (BUILD) grants, and Title 23 Flexible Funding. Federal loans are also available through the Transportation Infrastructure Finance and Innovation Act (TIFIA) program. Wherever federal funding or financing are used, both program-specific and cross-cutting federal grant requirements apply, which can add to the time and cost of project delivery.

Section 5309 Capital Investment Grants

The Federal Transit Administration (FTA)'s CIG program offers discretionary funding for fixed guideway transit projects and other eligible investments. The Fixing America's Surface Transportation Act (FAST Act) authorized $2.3 billion per year for the program through FY2020.

If the total capital cost of an aerial cableway system is less than $300 million, the system could be eligible for $100 million within the Small Starts category of the CIG program. If the cost exceeds $300 million, the project could receive funding within the New Starts category. Small Starts funding is capped at $100 million, whereas New Starts funding can be provided up to 50 percent of the total capital cost.

Both New Starts and Small Starts have unique sets of procedures, FTA approval steps, and project evaluation criteria.

Figure 1 illustrates the process for each program.

Challenges and issues associated with New Starts and Small Starts funding include:

- CIG funds are awarded on a discretionary basis. There is no certainty of receiving a grant until the grant is awarded; all pre-grant steps are carried out "at risk."
- At minimum, the project would need to receive a "medium" rating on FTA's project justification and local financial commitment criteria. The justification criteria are mobility improvements, environmental benefits, congestion relief, land use, economic development and cost-effectiveness. At this stage of project planning, it is unclear how well the project would rate on these criteria.

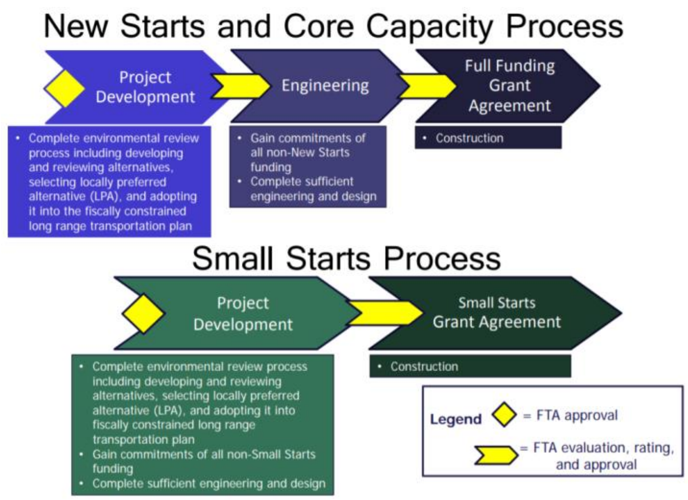


Figure 1. New Starts and Small Starts Processes

<u>BUILD Transportation Discretionary Grants</u>

Formerly known as the Transportation Investment Generating Economic Recovery (TIGER) grant program, the BUILD Discretionary Grant program provides funding for road, rail, transit and port projects that promise to achieve national objectives. The program is administered by the U.S. Department of Transportation (USDOT) using an annual solicitation for project applications. The program is competitive, and USDOT uses a rigorous merit-based process to select projects. In the latest round of selections, USDOT selected 41 recipients to receive a total of $500 million (average grant size was approximately $12 million). Congress has appropriated $1.5 billion for FY2018 grants.

The eligibility requirements of BUILD allow project sponsors at the state and local levels to obtain funding for multi-modal, multi-jurisdictional projects that are more difficult to support through traditional USDOT programs. BUILD can provide capital funding directly to any public entity, including municipalities, counties, port authorities, tribal governments, metropolitan planning organizations (MPOs), or others, in contrast to traditional federal programs, which provide funding to specific groups of applicants (mostly state DOTs and transit agencies). USDOT tends to favor applicants that exceed eligibility criteria and demonstrate significant non-federal commitment.

PROJECT OPERATIONAL OPTIONS

At project completion, there are several methods by which an aerial cableway project could be turned over for O&M. The following examples include:

- **MPO/Transit Operator**: An aerial cableway system could be 100 percent implemented by the MPO and delivered to a local transit operator for O&M. The project would become a part of the overall transit system. The transit operator would collect the fare and hold the revenue risk.
- **Public-Private Partnership**: In this scenario, the system would be completed, turned over to San Diego Metropolitan Transit System, and then be operated under contract by a private vendor for a select period. A local transit operator would collect the fare and hold the revenue risk.
- **Private Owner/Operator**: The entire project would be franchised out to a private entity for both construction and operations. The private entity could collect the revenues and hold the revenue risk. Alternatively, a local transit operator could collect the fare revenue and hold the revenue risk and then pay the private entity an "availability payment." An availability payment is a type of performance-based payment method paid to the private entity based on the availability of the system in operation.

As with the design and delivery phases, options regarding operations should be explored further in the feasibility study.

PROJECT DEVELOPMENT

A feasibility study is a logical first step to address the opportunities and challenges associated with the feasibility of an aerial cableway project at a high level. If a feasibility study finds that implementing a system could be beneficial, then the next step would be to conduct a more thorough planning assessment or alternatives analysis. Afterward, a system would need to pass through environmental clearance. The level of environmental clearance would be determined by both the system location and the funding source(s).

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