ADVANCED CABLEWAYS POTENTIAL FOR TRANSFORMATIVE URBAN APPLICATIONS

By Jeral Poskey

INTRODUCTION

Cableways have been utilized around the world for centuries. They possess unique advantages over other conveyances, primarily because of their relatively simple infrastructure, and ability to be deployed over varying terrains. However, their application as urban transit systems, although growing in recent decades, has been limited. But even in these limited applications, cableways have often had transformative effects on the cities where they are located.

Emerging advances in cableway technologies create the potential for smart, autonomous cableways that introduce significant new capabilities. The benefits of advanced cableways could greatly expand the application of cableways as urban transit systems.

The Long, Distinguished History of Cableways and Ropeways

First, a brief history of cableways helps explain why urban cableway usage has been limited, and why they still hold tremendous potential. Cableways and ropeways have been utilized for centuries – they are one of the oldest forms of conveyance, predating nearly every transportation method outside of the wheel. Ancient drawings dating to 350 B.C. in China depict ropeways carrying people across rivers and gorges.

Photo credit: Brecht Bug, Roosevelt Island Cable Car Tram Terminal NYC, 2013. https://flic.kr/p/hxbuW9

Source: Elevator World & Endowment for the Preservation of Elevating History, www.elevatorworld.com

The long history of cableways and ropeways owes itself to their inherent simplicity: fundamentally, they require little more than stringing an elevated cable or rope with an attached basket for carrying materials or passengers. A series of wheels or pulleys then enables the rope or cable to be pulled. For hundreds of years, passenger ropeways were generally powered by the exertions of the riders who pulled the rope manually, although they could also be powered by animals, waterwheels and even clever uses of gravity. Gravity ropeways function without any external power, using ballast placed in downhill baskets to move the ropes pulling the uphill baskets. Gravity-powered passenger ropeways are still used in some developing countries such as Nepal, because of their simplicity, and even in the birthplace of the Industrial Revolution, there is still an industrial gravity ropeway in operation in Lancashire, England that conveys millions of pounds of shale from an upslope mine to the waiting village below.

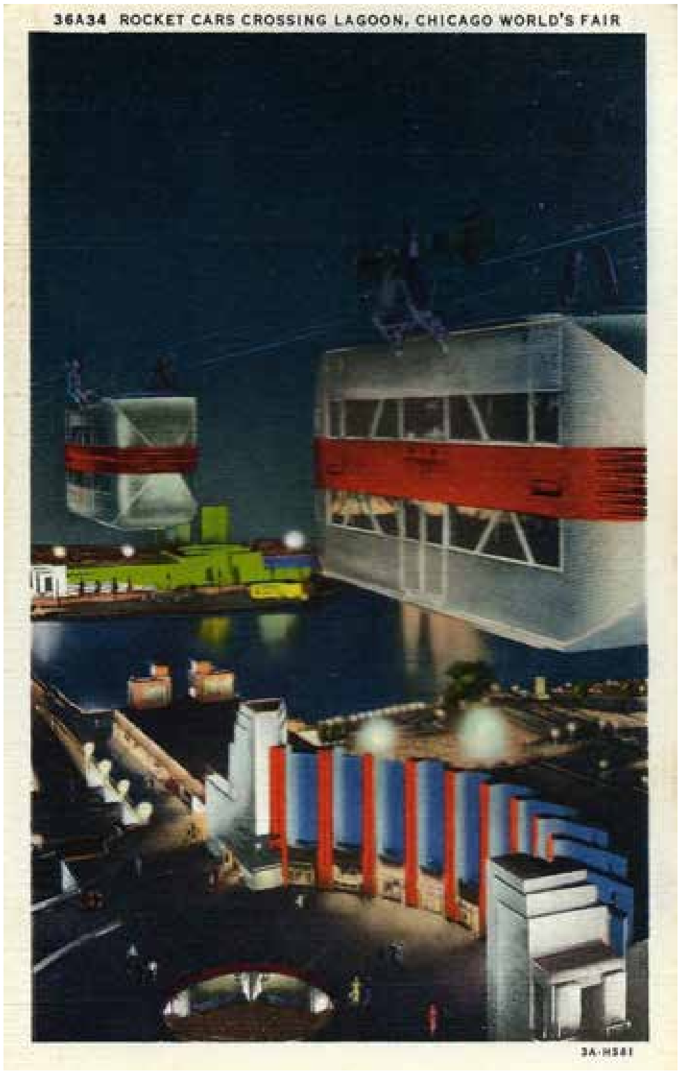
The first modern aerial cableway was built in Gdansk, Poland in 1644, utilizing multiple support posts that enabled a significantly longer system with several elevation changes (Gedanarium, 2020). By the late 19th century, steel cables had largely replaced ropes for safety and durability, with steam motors and, later, electric motors providing power. Cableways were primarily used at industrial sites in mountainous terrain, such as mines, to convey materials or a combination of materials and workers.

In 1893, the 2.3 kilometer Mount Parker Cable Car in Hong Kong was billed as "the only wire tramway erected exclusively for the carriage of individuals," hauling workers to and from the quarry, sparing them what would otherwise have been a 90-minute hike (WIkiwand, 2023). A year later, an aerial tramway began ferrying passengers across the Tennessee River in Knoxville, Tennessee (Allen, 2009). Much like industrial cableways, the first passenger tramways were largely used to span bodies of water or to conquer mountainous terrain.

Thus, it's not surprising that beginning with the Kohlerbahn in Austria in 1908, which introduced the first fully enclosed gondolas (Kolher-Bahn IT, 2008), cableways soon began dotting mountains and ski resorts across Europe, and eventually, around the world, creating the use case that many people now most commonly associate with cableways.

From Shale Rock and Skiers to Urban Settings

However, despite cableways' advantages of minimal infrastructure and associated low costs, their application in urban settings remained limited. While urban cableways began to appear within cities such as Grenoble, France; Cape Town, South Africa; and Rio de Janeiro, Brazil in the 1930s (Telepherique Grenoble Bastille, 2023), they were primarily novelties for tourism and sightseeing rather than serving as transit. In 1933, the "Rocket Cars" Sky Ride at the Chicago's World Fair carried more than 4.5 million passengers during the run of the event and was considered the architectural symbol and showpiece of the fair (Gondola Project, 2012). But despite discussion that it could be a model for future cableway applications in cities, it was dismantled following the conclusion of the fair, and thereafter, no similar urban cableways were built for decades.



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One of the first true commuter aerial gondola systems came in 1976 with the Roosevelt Island Tramway in New York City, which at the time provided the only direct transit connection from Roosevelt Island to Manhattan.

Finally, in the late 20th century and early 21st century, additional examples of cableways as a true form of urban transit began to emerge. The Portland Aerial Tram opened in 2006, connecting the Oregon Health & Science University's main campus atop Marquam Hill – the highest point in the city – with downtown Portland's South Waterfront district and its numerous transit hubs (Go By Tram, 2023). In 2022, Haifa, Israel inaugurated its Rakavlit gondola service which connects the HaMifratz Central Bus Station with the University of Haifa on Mount Caramel. The city's former mayor hailed its potential to relieve congestion, stating, "The cable car will take thousands of cars off the roads, and they will feel it on the municipal arteries in Haifa." (I24 News, 2022).

But the most extensive use of cableways as true commuter systems emerged across Central and South America. Unlike Portland and Haifa, which are point-to-point systems connecting only two stations each, several Central and South American cities have built systems with multiple lines functioning more like traditional streetcar, bus, light rail and subway systems. For example, Metrocable de Caracas in Venezuela, which began service in 2010, has 3 lines and 7 stations. La Paz's Mi Teleferico in Bolivia is one of the most extensive urban cableway systems in the world, with 10 different lines covering more than 25 stations. (Ed: See article in this issue).

Photo credit: Ben Bowes, Medellin Metrocable, 2008. [*https://flic.kr/p/5SPE1K*](https://flic.kr/p/5SPE1K)

Mi Teleferico Cableways Route Map*; Source: Mi Teleferico*

Medellin: The Transformative Power of Urban Cableways

Many of these Central and South American cableways have had profound transformative effects on their cities. The Metrocable system in Medellin, Colombia is widely credited with transforming the city from a blighted metropolis, best known by many people outside of Colombia as a notorious drug trafficking hub, into a more prosperous city that is now considered a cultural jewel of South America.

Metrocable enabled residents of some of the city's poorest favelas to connect with jobs in other parts of the city. Sergio Fajardo, the city's former mayor, described how "the barrios always had lots of energy but the energy was disconnected from the city" (Kimmelman, 2012).

The Medellin Metrocable system began operation in 2004, and has since expanded to now cover 19 stations stretching across 6 lines. The New York Times described how the cableways have encouraged business development, creating "a spine of commercial development" of restaurants, stores and schools paralleling the cableway lines in neighborhoods that previously were too dangerous even for the police to patrol (Kimmelman, 2012). The city also leveraged the cableways for cultural improvements, carefully planning construction of libraries, museums and other cultural sites near Metrocable stations, along with parks and open spaces for recreation (Lowenthal, 2010).

Similar effects have been realized as urban cableways continue to proliferate, particularly across the Americas. In May 2023, the Dominican Republic officially opened the second line of its Santo Domingo Cable Car system (Volario, 2023). A Dominican transit official said that the cableway helped residents to "prosper, transform and improve their lives, their quality of life,"(Quartucci, 2023) and plans are underway to expand the existing 4-station 4 kilometer system to 7 stations across 11 kilometers of cableways (Guzman, 2018).

Enabling and Enhancing Multimodal Systems

In addition to their benefits as standalone transit systems, Medellin, Santo Domingo and other cities are also leveraging their cableway systems as connectors and feeders for other transit, creating interconnected, versatile multimodal systems. It is relatively easy to lay out cableway systems so that they connect with other transit modes, and most of the previously mentioned urban cableways have done so.

Medellin's six Metrocable lines connect with the Medellin Metro light rail system and buses at its hub stations. Mexicable in Mexico City is intentionally designed so that each of its 14 cableway stations connect with one or more of the city's multiple bus services, or are connected to CENTRAM multimodal stations with Mexico City Metro, the world's tenth busiest metro transit system.

Similarly, the Roosevelt Island Tramway connects with eight New York City bus lines and is only one block from a major subway station with seven lines. The Portland Aerial Tram's South Waterfront station is at what is described as the most transportation-diverse intersection in the country, connecting with the main hub for the city's extensive streetcar system as well as light rail and bus lines. In addition to feeding mass transit, Portland demonstrates how cableways can also be an effective means of increasing use of other modes of non-car transportation by connecting its main station with several walking and bike paths. The tram's bike share station has the second-highest usage out of the city's 100 bike share stations (Go By Tram, 2023), a significant accomplishment in a city that is already ranked number one in the United States for bicycle ridership (Allegro, 2018). The tram is clearly facilitating bicycle usage in the community.

These systems have collectively shown that cableways can be effective transportation systems in urban settings. They are not only integral components of their respective cities' transit ecosystems, but are transforming urban landscapes both economically and socially. Similar to the success of the cableways in Medellin and other South American cities, the Portland Aerial Tram has been hailed as "one of the city's most transformational projects ever" for both improving mobility and spurring development along the city's South Waterfront (Gregg, 2017).

Limitations and Ingrained Use Cases

However, all of the urban commuter cableway systems mentioned previously are traditional gondola systems. They provide primarily point-to-point service. While some systems have built extended lines with multiple stations, this creates long total trip times because vehicles must slow down or stop at every mid-point station. And changing lines, for instance, between Medellin Metrocable's six different lines, requires disembarking and walking to a different platform, much like changing subway lines. This prevents creation of an expanded, integrated single cableway network.

In addition, like most other cableways, existing urban cableways are primarily deployed along hilly or mountainous terrain where other transit options are not feasible or effective. For example, the Medellin Metrocable was primarily built to reach favelas or neighborhoods that were largely inaccessible by conventional transit such as buses because of steep, mountainous terrain.

A contributing factor to urban gondolas being primarily located in challenging topography is likely ingrained thinking resulting from cableways' centuries-long association with ski resorts; mountainous tourist attractions such as Palm Springs, California; and industrial mining applications in hilly terrain. This history of the predominant uses for cableways creates an association with these "default" use cases and may be hindering envisioning usage within flat, crowded urban landscapes.

Cableways in non-mountainous locations are often simple two-station systems to span a body of water, such as Roosevelt Island or the IFS Cloud Cable Car in London.

It's worth noting the Roosevelt Island Tramway was only intended to serve as an interim transit solution because of lengthy delays in opening the Roosevelt Island Subway Station. But because of its popularity, the tramway remains in operation today, carrying more than two million passengers each year (Roosevelt Island Operating Corporation, 2023). Similarly, London's IFS Cloud Cable Car was originally proposed as an alternative to a proposed Thames Gateway Bridge and now carries more than 1.5 million passengers a year owing to both commuters as well as tourists and social media influencers who enjoy the spectacular views (BBC, 2023).

Other flat terrain passenger cableways are the familiar "sky ride" type of conveyances found at amusement parks and theme parks, such as state fairs and the Skyliner at Disney World in Orlando, Florida.

Regardless of the setting, the sensation of quietly soaring above the ground can, in many senses, make the journey immensely enjoyable, providing a very positive and popular user experience. At the same time, despite the success of urban cableways, existing applications overlook the potential for far broader applications of cableways in urban settings that could take advantage of cableways' favorable properties including minimal infrastructure, high sustainability, and low costs. In addition, cableways themselves are in many ways largely unchanged since they were first mechanized in the late 1800s. The integration of modern 21st century technology has the potential to greatly expand the utility and applications of cableways, while retaining their inherent advantages.

Photo credit: Jpellgen, Skyliner, Disney's Pop CenturyOrlando, Florida, 2020. https://flic.kr/p/2jJUVu9

Project Swyft

Overcoming these limited notions of use cases for where cableways can and should be utilized poses challenges.

While the author was a project executive for transportation in Google's real estate division, Google was continually looking for more efficient and sustainable ways to move its employees – both across corporate campuses as well as into surrounding communities. The goal was to enable employees to easily connect with housing, retail, entertainment and recreation, as well as connect with mass transit such as subways and commuter rail for those who needed to commute longer distances.

Project Swyft was created to identify suitable transportation modes that combined low cost, high capacity, and high sustainability, while also minimizing the land needed for transportation infrastructure. The project team examined virtually every mode of transportation – on the ground, in the air, in a tunnel – whether autonomous or otherwise. After thorough analysis, the team came to the realization that no mobility solution, whether currently available or even on the drawing board, could meet our objectives, particularly costs for both construction and operation.

In evaluating and re-evaluating potential options, the team was continually drawn back towards cableways, primarily because of their aforementioned inherent advantages, including minimal infrastructure, high sustainability and low costs. However, we also kept running up against cableways' limitations, including:

- Relatively low passenger throughput compared with other mass transit modes.
- Generally limited to point-to-point travel – otherwise, multi-station lines produced slow average speeds and long trip times.
- Inability to negotiate complicated turns. (This limitation can be partially addressed through the use of mid-point stations. However, the turning radius that can be achieved is limited and mid-point stations add substantial cost.)

We subsequently discovered that emerging cableway technologies were being developed that could potentially address these limitations while retaining cableways' inherent advantages.

1. Electric Self-Propulsion

Current cableways are generally vehicles affixed to cables that are pulled by bullwheels located at end-point and mid-point stations driven by large motors. The cables then pull all attached vehicles simultaneously. However, recent significant advances in electric vehicle (EV) automotive technology may be highly applicable to cableways. These include:

- Small, lightweight powerful electric motors
- High-capacity batteries
- Fast charging and wireless induction charging

These enable creation of advanced cableways where every vehicle travels independently along fixed cables. This can be accomplished by each vehicle containing a battery and electric motor. Instead of a grip module that affixes traditional gondolas to moving cables, the vehicle is suspended from a bogie or trolley containing a motive power unit that propels the vehicle along a fixed cable.

2. Cable-to-Rail Interface

As discussed previously, traditional cableways utilizing moving cables are unable to negotiate complicated turns. In addition, while grips can disengage a vehicle from a moving cable, they are unable to transition the vehicle to a different cable line. However, having a vehicle that self-propels along a fixed cable and then can transition to a cable-to-rail interface leading the vehicle from the cable on to a rail guideway greatly increases its capabilities.

- Rail guideways enable complicated turns – intersections can become omni-directional with little or no limitation.
- Vehicles can switch between different cable lines.
- Vehicles can be merged on to cable lines, merging at cruising speed into existing traffic flows.

An additional advantage is that this technology enables stations to be located offline. Vehicles approaching their destination station can transition from the mainline cable on to a rail guideway that then directs the vehicle into the station. At the station, it can be brought to a full stop for passenger disembarkation and embarkation of new passengers.

In addition, this enables all trips to be nonstop from origin-to-destination. Vehicles move off the mainline cable when approaching their destination station. All other vehicles that are on-cable and headed to destinations that are further downline remain on-cable, bypassing the intermediate station entirely. This enables vehicles to avoid all intermediate stops, dramatically reducing total trip times and making for a significantly improved user experience.

Rendering of autonomous gondolas bypassing intermediate stations. Stations are offline enabling on-demand service. Source: Swyft Cities

3. Line Switching & Merging

Cableways could add these line switching capabilities through either off-vehicle or on-vehicle switching mechanisms.

- Off-vehicle switching can utilize physical switches within rail guideways atop support posts to direct vehicles on to the appropriate line, akin to railroad track switches.
- On-vehicle switching can utilize each vehicle's bogie mechanism for both motive power as well as switching engagement between cables.
- Line switching can enable a cableway line to be connected with other cableway lines creating expanded, seamless networks.

An additional advantage of networking is that each additional station would exponentially increase the number of origin-destination routings, dramatically expanding the utility of the network for its riders.

4. Autonomous Control System Software

Taking full advantage of capabilities such as offline stations and merging vehicles requires another component being rapidly advanced through the automotive industry – autonomous guidance software. However, the requirements would be vastly different from the highly complex sensor-based systems that road-based autonomous vehicles (AVs) use to handle tasks such as navigating streets and complicated intersections, interfacing with other traffic, negotiating stop lights and stop signs, and avoiding obstacles such as pedestrians and bicycles. Advanced cableway guidance software would be more akin to dispatching and trip navigation software used by ride-hailing services. It would take user inputs such as origin point and destination point. It would then locate and assign a vehicle. Ideally, the advanced cableway vehicle would already be waiting and available for the passenger(s) at the origin point.

Upon embarkation and departure from a station, the control system software would select optimum routing, avoiding congestion, breakdowns and other line service interruptions. Such software would also require additional backend layers for traffic management to maintain optimum flows and throughput, manage line capacity, and reposition empty vehicles to locations where it anticipates demand. Importantly, the software would allow seamless merging of departing vehicles into the traffic flow without any disruption or slowing of mainline traffic.

Advanced control system software can also enable very low headway or time-distance spacing between vehicles. This aspect is critical to enabling much higher passenger throughput than conventional gondola systems. Vehicles could be spaced closely together, maximizing capacity and throughput for every line.

During the course of Project Swyft, a clear picture began to emerge of how these advanced technologies could transform cableways into a much more effective system for urban applications. Higher speeds, low headways, and shorter total trip times would result in high passenger throughput as well as an improved user experience. Routes would not have to be linear, but could be laid out along nearly any configuration with turns easily incorporated at any given location along the line where needed.

Project Swyft Small-Scale Proof-of-Concept Demonstrating Self-Propulsion Bogies, Cable-Rail Interfaces, Offline Stations. Source: Swyft Cities

In addition, systems could be constructed as true networks rather than linear point-to-point systems. This means that travel could be nonstop between any two points across the entire network, regardless of the total number of nodes.

Table 1 – Capacity By Transportation Mode

	Typical Capacities (pphpd)	Maximum Peak Capacities (pphpd)
Conventional Gondolas	2,000	6,000
Autonomous Gondolas	2,000-3,000	10,000
LRT	10,000-15,000	20,000
BRT	10,000-12,000	36,000*
Subway	20,000-50,000	80,000

pphpd: passengers per hour per direction

Sources: Transportation Research Board, Gondola Project, Swyft Cities, ITDP and

https://railsystem.net/category/transit-systems/

* Only if Bogotá-type passing lanes, sub-stops, and express services are introduced;
source: https://brtguide.itdp.org/branch/master/guide/why-brt/performance.

Potential Second- and Third-Order Effects of Urban Cableways

These advanced cableway technologies could provide benefits beyond the direct and immediate benefits afforded to riders of speed and convenience. Broader urban application of next-generation cableways hold the potential to be transformative for cities. They could potentially address two major issues currently impacting urban life in many cities.

1. The Need for Multimodal Transit Feeder Systems

As previously mentioned, cableways can be effective feeder systems for mass transit, helping address ridership issues.

Currently, in the United States, mass transit ridership is extremely low. A study by the U.S. Census Bureau found that even pre-pandemic in 2019, only five percent of all U.S. workers used mass transit to commute to work. And most of that was concentrated in just a few cities. New York City alone accounted for forty percent of total mass transit commuters. The top seven cities made up fully seventy percent (U.S. Census Bureau, 2021).

While subways, elevated rail and light rail provide efficient means of moving high volumes of people, they require high population densities to be effective. One major reason is that subway and light rail systems are often limited by their catchment – the area around stations from which they draw riders. A study of the Bergen-Hudson light rail in New Jersey by Rutgers University found that the majority of riders lived within a half-mile of a station – roughly the distance a person can comfortably walk in 10 minutes or less (Carnegie, 2021).

Levels of density in the catchment area play a critical role in transit ridership. A study by the University of California Transportation Center and the University of California, Berkeley Center for Future Urban Transport, found that every additional 100 residents within a quarter mile of a station resulted in 34 additional transit trips per weekday, and every additional 100 jobs correlated to 69 additional trips (Guera, 2012).

But a half-mile radius covers a total land area of barely 500 acres, making it difficult for such a limited area to contain a sufficient number of residents and workers. In addition, distance is not the only factor. Transit stops are often not accessible on foot in every direction – potential barriers are numerous: rail tracks, multilane freeways, and areas without good sidewalk infrastructure.

Advanced urban cableways have the potential to expand the catchment area for each rail or subway transit station by creating a feeder system that expands the pool of potential riders to a broader surrounding area beyond the normal half-mile walking radius.

2. Cableways as an Effective Means to Achieve Ideal Urban Density

Another aspect of urban density is that advanced cableways could help neighborhoods achieve better density. We know the kinds of neighborhoods where many people want to live: medium-density, mixed-use, highly walkable districts that are sometimes termed "The 15-Minute City." In such districts, housing, offices, retail, entertainment, recreation, education, medical care are all within close proximity of each other and easily accessible. The Congress for New Urbanism (CNU) defines the concept of the 15-Minute City as "a mixed-use, walkable metropolis where you don't need a car to meet your daily needs." (Steuteville, 2021).

Transportation plays a key role in either enabling or hindering ideal density. First, a city's transportation ecosystem plays a large role in shaping its density levels. Unfortunately, the current situation is that many cities, particularly in the United States, have density that is far from ideal, owing to car-centric urban planning. In car-centric districts, infrastructure to support car usage takes up large amounts of street-level land: streets, curbing, and perhaps most importantly, parking. It's estimated that twenty percent of all land in U.S. city centers is devoted solely to parking (Parking Reform Network, 2023). In Los Angeles County alone, there are an estimated 18.6 million parking spots, which collectively take up more than 200 square miles of land (Phillips, 2016). This ground-level infrastructure severely limits the ability to achieve ideal density mixed-use developments. It not only uses land that could otherwise be re-purposed for non-transportation needs, but pushes destinations further apart from each other – whether housing, retail, offices, entertainment, etc.

This, in turn, results in even more ground-level infrastructure being built to move people from place to place, whether by car, bus, shuttles, rail, etc., creating an self-perpetuating expanding spiral of sprawl.

It's important to note that such infrastructure is also highly carbon-intensive, representing millions of tons of embodied carbon, primarily in the form of materials such as concrete, asphalt, steel, etc., contributing to poor environmental sustainability.

Existing transit options are mixed in their ability to encourage ideal density development. Light rail and elevated trains can facilitate efficient movements of large numbers of people, however, average construction costs are approximately $85 million per mile (Institution for Transportation Development Policy, 2023). Below-ground transit costs can often be prohibitively expensive. The recent Second Avenue Subway extension in New York City cost a staggering $2.5 billion per mile to build (Woodhouse, 2023). The proposed BART San Jose extension is projected to cost $1.5 billion per mile (Kamisher, 2022). It's noteworthy that a recent analysis found that U.S. rail transit projects cost an average of fifty percent more on a per-mile basis than in Europe and Canada (Obando, 2021).

Micro-mobility, such as bicycles and e-scooters – whether owned or shared – can in some instances provide effective ground-level transportation. Their relatively small footprint and infrastructure can reduce street congestion by replacing car and bus traffic. However, they have limitations such as generally single-rider use, limited space for packages or personal belongings, generally limited to able-bodied riders, and weather limitations.

Cableways, with their minimal ground-level footprint, can be an effective way to move people both within and between urban districts. They not only move traffic off of street-level but also reduce the need for infrastructure for roads, curbs and parking, freeing land for more productive uses, such as housing, office, retail, entertainment, etc.

In addition to enabling those uses of land, creation of more open, green spaces also contributes to a higher quality of urban life.

The Santo Domingo cableway in the Dominican Republic is credited with enabling the creation of nearly 20,000 square meters of new public spaces (Quartucci, 2023). And creation of more open spaces is beneficial to economic activity as well. A study by the New York City Department of Transportation found that converting parking lots and curb spaces into parks, public seating or walking areas dramatically increased sales volumes for retail businesses in surrounding areas (NYC DOT, 2012).

But having effective mobility options is key to enabling ideal densities by providing convenient ways to move around the neighborhood. As Smart Growth America noted in a 2013 report: "people want to live in vibrant, mixed-use communities that provide a variety of mobility options" (Smart Growth America, 2023). In addition to being able to move around within the neighborhood, access to quality transit is a key component of a 15-minute city, enabling people to also travel longer distances when needed. As the Congress for New Urbanism notes, "Transit service is one of the human needs that should be fulfilled in the 15-minute city." (Steuteville, 2021).

Advanced Cableways Fit a More Comprehensive & Holistic Approach to Urban Design

The successes seen in urban areas as diverse as Portland, Medellin and New York City were all achieved using traditional cableway systems that in many ways are not fundamentally different from the earliest mechanized cableways. Application of advanced technologies that capitalize on cableways' relatively simple infrastructure but greatly expand their capabilities could open new possibilities for highly efficient, flexible transportation systems that can easily adapt to a much wider variety of urban locations and real estate development plans.

Going back to the success of its Metrocable system, Medellin city planner Federico Restrepo notes the importance of viewing transportation not simply as a means of moving people from Point A to Point B. From its inception, the Medellin cableway was viewed as a key urban planning component that could positively impact all aspects of the city's economy and social life. "We took a view that everything is interconnected — education, culture, libraries, safety, public spaces." (Kimmelman, 2021).

Far too often, transportation, real estate development and economic planning are conducted in silos rather than in concert. A 2013 Victoria Transport Policy Institute report strongly advocated for coordinated policies that simultaneously produce "transport and land use management reforms that improve transportation options, reduce automobile dependency and create more accessible land use." (Litman, 2003).

As we discovered during our research work for Google's Project Swyft, cableways possess several key advantages over other transportation modes, but also some important limitations. Advanced cableways with greater capabilities and technologies that remove those limitations would bring numerous advantages in helping urban planners meet their ambitious goals.

CONCLUSION

Cableways and ropeways have some of the longest histories among conveyances, largely because of their inherent advantages, including minimal infrastructure, minimal ground-level footprint, low energy consumption and high sustainability, and low build and operating costs compared with other transit modes.

Current uses of passenger cableways are still predominantly in mountainous or hilly terrain such as ski resorts, and at tourism, sightseeing and recreation sites. Urban deployments for transit use, while relatively few, have proven their effectiveness. In the course of moving residents for commuting, as well as improving access to retail activity, recreation, open spaces, and other public transit, they have been shown to generate significant second- and third-order effects of increasing economic activity and generally improving quality of life for residents. However, these current urban cableways are based on traditional cableway designs, leaving them with significant limitations in their capabilities hindering trip times, capacity and networking.

Advanced technologies, many developed for electric vehicles (EVs) and autonomous automotive vehicles (AVs) such as electric self-propulsion, autonomous guidance, and app-based dispatching, as well as cableway hardware developments, such as cable-to-rail interfaces, line switching and turning, raise the potential for advanced cableways that could greatly expand capabilities.

Project Swyft at Google established a model for advanced cableways that combine these innovations, which has since been spun off as a separate company. The first pilot systems are currently being planned in New Zealand and the Dallas-Fort Metroplex. Successful piloting of these systems could demonstrate their effectiveness and establish certification processes. This, in turn, could greatly expand applications for cableways, particularly in urban settings, where potentially a wide swath of cities worldwide could realize the benefits from next-generation cableway systems.

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