



## DEVELOPMENT AND APPLICATION OF ROPEWAY SYSTEMS IN URBAN AREAS

Martin Starčević<sup>1</sup>, Mladen Nikšić<sup>1</sup>, Matea Mikulčić<sup>1</sup>, Mario Čičak<sup>2</sup>

<sup>1</sup> University of Zagreb, Faculty of Transport and Traffic Sciences, Croatia

<sup>2</sup> Zagreb Holding Ltd., Croatia

### Abstract

Urban transportation faces escalating challenges due to population growth, congestion, and environmental concerns. This prompted exploring innovative solutions to enhance mobility and mitigate negative impacts. For the most part, ropeway systems are not considered as usual transport means in urban areas. Gondola lifts and aerial tramways are essentially perceived as transport systems for skiers in winter resorts and to overcome topographical obstacles and barriers like mountains, gorges, and large water areas. Traditional transport modes cannot overcome these landscapes without significant financial costs and changes to the natural topography. However, ropeway systems can effectively be used in urban and sub-urban areas as complementary to central public transport systems or as a standalone means of transportation. Case studies from cities like Medellin, La Paz, Koblenz, and Toulouse demonstrate how ropeway systems can overcome transportation challenges and improve connectivity and mobility options for residents. However, it is essential to note that successful implementations may vary depending on cultural and local characteristics, necessitating careful consideration of the unique circumstances and challenges posed by each location.

*Keywords: ropeway systems, urban areas, public transport*

### 1 Introduction

Urban transportation systems face increasing challenges due to growing populations, congestion, and environmental concerns. In response, innovative solutions are being explored to enhance mobility while mitigating the negative impacts of traditional modes of transport. One such solution gaining attention is integrating ropeway systems into urban areas. Ropeway systems are a transportation technology for moving people in motor-less, engine-less cabins propelled by a steel cable [1]. Many ropeway transportation systems have been used all over Europe and the world in past decades as mass transportation modes in urban areas. Still, most of these solutions were built for recreational purposes in ski resorts and tourist attraction areas to transport skiers and tourists to a location inaccessible by other modes of transport [2, 3]. This paper explores the potential of ropeway systems in addressing urban transportation challenges, highlighting their benefits, applications, and considerations for successful integration. By examining case studies and emerging trends, one can better understand the role of ropeways in creating sustainable and efficient urban mobility solutions.

## 2 Classification of ropeway systems

The two main ropeway systems configurations include top-supported systems (in which cabins are supported from above) and bottom-supported systems (cabins are supported from below via tracks) [4]. Also, understanding the grip type for top-supported systems is crucial when assessing ropeway systems. The differentiation between detachable and non-detachable (fixed) grips is particularly significant, serving as a defining feature of the ropeway systems.

### 2.1 Top-supported ropeway systems

There are six major top-supported cable technologies (Table 1) in use today, and each offers its unique cost-performance package with varying speeds, capacities, and pricing.

**Table 1** Classification of top-supported cable technologies [4]

#	Cable technology	# of cables	Grip	Max. speed [km/h]	Max. capacity [pphd*]
1	Monocable detachable gondola (MDG)	1	Detachable	22	4.000
2	Bicable detachable gondola (BDG)	2	Detachable	22	4.000
3	Tricable detachable gondola (TDG)	3	Detachable	27+	6.000
4	Funitel	1 (dual loop)	Detachable	27	4.000-5.000
5	Aerial tram	3	Detachable	45	2.000
6	Pulsed gondola	1	Fixed	22	2.000

(\*) passenger per hour per direction

The monocable detachable grip gondola (MDG) is the most common aerial gondola technology available. It utilises one cable for both support and propulsion. In comparison, the bicable detachable grip gondola (BDG) has two cables, one cable for propulsion and other track cable for support. The TDG gondola is currently the fastest and highest-capacity gondola technology available. It has a detachable grip and three cables, two for support and one for propulsion. The funitel is a detachable grip system that looks like an aerial tram but acts like a gondola. The system utilises one dual-loop cable to carry short-armed cabins. The aerial tram is a large cabin with a fixed grip system consisting of one or two vehicles. The traditional aerial tram has two vehicles fixed to the same cable loop, shuttling back and forth in tandem. Pulsed gondolas are fixed grip systems that bind MDG/BDG style cabins together into so called pulses (as opposed to spacing them out along the cable) [4].

### 2.2 Bottom-supported ropeway systems

Bottom-supported ropeway systems are distinguished by their ground-level support structure and movement secured along rails with usually just one rope. Three major bottom-supported systems are used today: funiculars, mini-metros and inclined elevators (Table 2).

**Table 2** Classification of bottom-supported cable technologies [5]

#	Cable technology	Track layout	Max. speed [km/h]	Max. capacity [pphpd*]
1	Funiculars	Variable slopes	50	8.000
2	Inclined elevators	Straight line	15	1.000
3	Mini-metro (APM)	Variable slopes	55	10.000

(\*) passenger per hour per direction

Funiculars are inclined railway systems consisting of two cars connected by a cable and counterbalancing each other. They operate on a steep incline, typically on a mountainside or hill, and use a combination of gravity and a propulsion system to move between two stations [6]. Inclined elevators are vertical transportation systems designed to traverse steep inclines or changes. In this case cars operate independently rather than in interconnected pairs, such as in funiculars and in a straight line without changing direction. Mini-Metros are a rail-based, fully automated means of transport. As funiculars or inclined elevators, they cover short routes with bends and considerable differences in altitude, rolling on steel wheels, pneumatic tyres, or gliding on air cushions. They are usually used in airports, providing effective connections between terminals [7].

### 2.3 Grip types for ropeway systems

Ropeway systems utilise different types of grips to secure cabins or gondolas to the haul rope. Two major types of grips include fixed grip and detachable grip. Fixed or non-detachable grips (Fig. 1) remain permanently attached to the haul rope and do not disengage at stations along the ropeway route. Instead, cabins are loaded and unloaded while the ropeway is in motion, typically using platforms or loading areas alongside the track. As such, when cabins arrive at a station, the entire line must also slow and stop to enable passengers to board and disembark. Since the flow of cabins or line speed is disrupted, this feature severely reduces capacities and speeds but can reduce maintenance requirements and operational complexities. This type of grip is usually utilised in ski chair lifts and pulsed gondolas [4].



**Figure 1** Fixed grips on a chairlift and pulsed gondola [8, 9]

A detachable grip (Fig. 2) enables a cabin to separate itself from the cable when it enters a station. This feature reduces a speed of cabin via a conveyor system upon arrival at a station. Also, it offers flexibility in cabin loading and unloading, as cabins can be stopped and detached individually at stations without affecting the operation of other cabins on the ropeway. As a result, this feature dramatically increases a capacity and speed of the cable line. Detachable grips also enable intermediary and angle stations [4].



Figure 2 detachable grips on a chairlift and bicable gondola [10, 11]

### 3 Implementation of ropeway systems in urban areas

Transportation organisations have significantly changed in recent years, especially in urban areas. These changes encompass a broad spectrum of innovations, from technological advancements (like battery-electric vehicles) to novel organisational strategies (like car-sharing) and community-based initiatives (like free bike sharing). Even within the traditional realm of public transport, new methods are being explored to enhance efficiency and economic viability while also striving to boost public transport usage and decrease environmental impact of the transportation sector using established technology known from the mountains to deliver public transport in urban areas. Generally seen as environmentally friendly with a small ecological footprint, the potential of urban ropeways has not yet been demonstrated in Germany. Applying the ‘multi-level perspective’ established in transition research, we analyse challenges in the diffusion process. Results are based on 14 interviews with transport planning experts, ropeway manufacturers and actors from cities with urban ropeway projects. The following major obstacles are identified: (1[12]. Ropeway systems are widely regarded as environmentally friendly modes of transportation thanks to minimal noise and significant emissions reduction due to utilisation of electric power in station motors, with the potential of renewable energy sources. Additionally, due to their flexibility and low space requirements, they are easily integrated into spatially limited surroundings. Beside transport and environmental, there are also other beneficial aspects of their application like social, economic, and marketing.

Urban ropeways have limitations that make them unsuitable for every transportation need. They offer direct, point-to-point connections but have limited capacity for intermediate stops, restricting their ability to serve entire areas. Route alignment poses a challenge, as sharp curves are costly to engineer. Construction costs of a specific urban ropeway depend not only on characteristics of the carrying and traction ropes and parameters of intermediate tower structures, but also the specific location of the line with associated restrictions and the ground in the interval between the terminal stations [13]. However, if looking to circumvent typical urban obstacles like buildings, rivers or roads, the investment costs of other conventional urban transport alternatives are then much higher (Table 3), and it takes more time to finish implementation. Consequently, urban ropeways are best utilised as part of a broader public transport system, such as spanning topographical obstacles, connecting high-demand destinations to existing transit networks, filling gaps in public transportation, or alleviating congestion on overloaded routes. Also, the increase in their capacity has a minimal effect on the operational cost of the system unlike trams and buses [14].

**Table 3** Maximum capacity of different types of urban transport [14, 15]

#	Type of transport	Max. capacity [persons/hour]	Investment costs [\$ million/kilometre]
1	Single traffic lane for passenger cars	9.000*	
2	Buses within mixed traffic	1.250	0.5-0.6
3	Bus lanes	10.000	
4	Bus rapid transit	9.000-35.000	5-40
5	Light rail on streets (tram)	11.800	5-10
6	Light rail	19.000	10-50
7	Metro	36.000	40-100
8	Heavy rail	49.000	50-120

(\*). 2.250 passenger cars per hour, 4 persons per vehicle

Of course, these limitations can vary depending on cultural and local characteristics. The most obvious example is Medellin, Columbia, with its first urban ropeway system in South America. Medellin is the second largest metropolitan area in Columbia, with a population of 2.57 million inhabitants. The aerial Medellín Metrocable ropeway system (Fig. 3) is an innovative public sector project that connects informal low-income neighbourhoods in steep and inaccessible areas (comunas) to the rest of the city. It was the first system in the world dedicated to public transport, with a fixed service schedule. Since starting operations in 2004, it has carried 30.000 people daily. It is operationally integrated into the rest of Medellín’s mass transit system (SITVA), which includes the overground Metro, bus rapid transit system (BRT) and a tramway line [16].



**Figure 3** Metrocable Medellin gondola [16]

Another example is the capital city of Bolivia, La Paz, which is situated in a canyon on the edge of the Andean highlands, approximately 3.650 meters above sea level. The metropolitan area has a population of roughly 1.8 million inhabitants, and just over half live in El Alto at 4.100 meters above sea level. The daily commute from El Alto to La Paz and back involves navigating the single highway connecting the two cities or braving the narrow side streets that zigzag the steep mountainous terrain separating the two cities. In 2014, the Mi Teleférico (MT) mass-transit aerial cable car system opened, ferrying passengers from El Alto to the downtown and back in 10 minutes from end-to-end stations, compared to over an hour before (Fig. 4). Before the construction of the cable car, travel between La Paz and El Alto had to be done only by heavily crowded buses and minibuses which had to go through winding streets, reducing road safety, and were usually stuck in traffic [17].



Figure 4 Mi Teleferico gondola, La Paz, Bolivia [18]

Similar systems are implemented in Caracas. All these examples represent significant improvements in the accessibility of existing ‘comunas’ or ‘favelas’. Although, previously underserved by public transport, they provide a more efficient alternative to the former queues of buses stuck in traffic. These initiatives have effectively addressed longstanding transportation challenges in these communities, offering residents better connectivity and mobility options [12].

However, it is essential to note that the contexts in which these improvements occurred may differ substantially from those of European cities. Factors such as the existing public transport infrastructure and the overall transport planning strategies vary significantly between regions and countries. Therefore, while these successes offer valuable insights and potential solutions, direct comparisons with European cities must be made cautiously, considering unique circumstances and challenges of each location.

One of the examples in Europe is Seilbahn Koblenz (Fig. 5), which was opened in 2010 in the city of Koblenz in Germany. The system is unique because it is the first to use three-wire cables (3S) systems in urban environments. This relatively new system has the highest capacity of all other gondola systems, reaching up to 7.000pphp (reduced in Koblenz to 3.800 for touristic reasons), Also it has the largest cabins for up to 35 passengers. Another significant thing about this system is short construction period of 13 months. The cableway was initially built to link the historical Bundesgartenschau festival area to downtown Koblenz [14].



Figure 5 Seilbahn Koblenz gondola [19]

The city of Toulouse opened in 2022 the longest ropeway system in France, called “Téléo” (Fig. 6). This gondola system has been constructed as a space-saving 3S, three kilometres long. More than 8.000 passengers aboard the cabins of the Téléo tri-cable ropeway every day. The system is fully integrated into the public transport network as part of the Toulouse Agglomération’s transport network. It crosses the river Garrone and connects three major transport hubs in the metropolis during 10 minutes of journey. These are the “Oncopole” university institute for cancer research, “Rangueil” hospital, and “Paul Sabatier University” with its 30.000 students [20, 21].

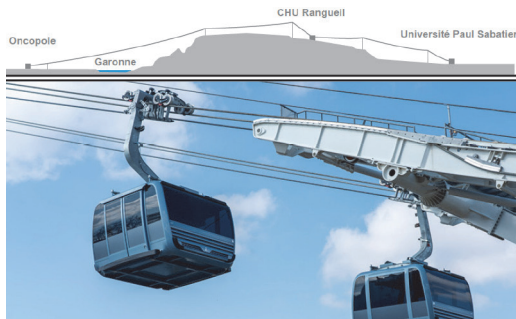


Figure 6 “Téléo” Toulouse gondola [20]

## 4 Conclusion

As the public shifts towards embracing self-driven cars and e-mobility, many researchers and media outlets claim these trends as revolutionary, positioning them as future transportation systems. However, ropeway systems are reshaping our perception of urban transportation. Despite their modest pace of adoption, these environmentally friendly modes of transport are gaining traction and making significant inroads in cities across the developing world and Europe, poised to transform the urban landscape in the coming years.

Though ropeway systems may evoke images of alpine and ski resorts, their role has evolved considerably. Because of distinct national and social characteristics of South America, ropeway systems have evolved into fully integrated public transport modes, unlike in Europe. There they typically serve as complementary options to existing public transport or cater primarily to tourism needs. Additionally, advancements in ropeway technology, such as improved cabin designs, faster speeds, and increased capacity, enhance their viability as viable urban transportation solutions. Moreover, in conditions of greater competitiveness of transport modes, the issue of meeting expectations and motivating users is important to prevail in their preferences towards long-term sustainable public transport. It remains to detect and address potential obstacles to their wider applicability in European conditions so that can reach full potential here as well.

## References

- [1] Gondola project, <https://www.gondolaproject.com/learn-the-basics-what-is-cable-propelled-transit/>
- [2] Marocchi, A.: A new approach to the Urban Transportation by cable , a sort of Copernican revolution, 11<sup>th</sup> International OITAF Congress, Bozen, Italy, 6-9 June 2017.
- [3] Nikšić, M., Gašparović, S.: Geographic and Traffic Aspects of Possibilities for Implementing Ropeway Systems in Passenger Transport, *Promet – Traffic&Transportation*, 22 (2010) 5, pp. 389–398
- [4] Dale, S., Chu, N., Imhauser T.: *Cable Car Confidential - The Essential Guide to Cable Cars, Urban Gondolas & Cable Propelled Transit*, Toronto, Canada: Creative Urban Projects Inc, 2013.
- [5] POMA, <https://www.poma.net/en/product-range/funicular-railway/>
- [6] Hofmann, G.: *Advanced Funicular Technology* OITAF San Francisco, 2000, <https://repository.mines.edu/handle/11124/70549>
- [7] Leitner, <https://www.leitner.com/en/products/ropeway-systems/detail/minimetror/>
- [8] Leitner fixed-grip chairlift, <https://www.leitner.com/en/products/ropeway-systems/detail/fixe-grip-chairlifts/>

- [9] Grenoble Pulsed gondola, <https://www.ledauphine.com/transport/2022/01/03/isere-grenoble-le-telepherique-de-la-bastille-a-l-arret-pour-un-mois>
- [10] Detachable chairlift, <https://www.flickr.com/photos/kalung1/16373440014>
- [11] Detachable gondola, Beijing, <https://www.beijing-visitor.com/china-city-guides/hong-kong-attractions/big-buddha>
- [12] Reichenbach, M., Puhe, M.: Flying high in urban ropeways? A socio-technical analysis of drivers and obstacles for urban ropeway systems in Germany Transportation Research Part D: Transport and Environment, 61 (2018), pp. 339–55, DOI: 10.1016/j.trd.2017.07.019
- [13] Korotkiy, A., Lagerev, A., Meskhi, B., Lagerev, I., Panfilov, A.: The development of transport infrastructure of large cities and territories on the basis of technology of passenger ropeways. Rostov on Don, Russia: Don State Technical University, 2017.
- [14] El-Jouzou H.: A Comparative Study of Aerial Ropeway Transit (ART) Systems, Frankfurt University of Applied Sciences, 2016.
- [15] Težak, S., Sever, D., Lep, M.: Increasing the capacities of cable cars for use in public transport, J Public Transp, 19 (2016) 1, pp. 1–16
- [16] Wallace, B.: An innovative, inclusive and green transit system, Oxfam GB Oxfam Int, 7 (2021), pp. 1–22
- [17] Martínez, S., Sánchez, R., Yañez-Pagans, P.: Getting a Lift: The Impact of Aerial Cable Cars in La Paz Bolivia, study proposal Washington DC, USA, 2018.
- [18] Mi Teleferico, La Paz, <https://www.lapazlife.com/the-worlds-highest-cable-car-ride/>
- [19] Seilbahn Koblenz, <https://www.seilbahn-koblenz.de/homepage.html>
- [20] Teleo cable car, Toulouse, [https://www.teleo-tisseo.fr/tour-d-horizon?locale=en\\_US](https://www.teleo-tisseo.fr/tour-d-horizon?locale=en_US)
- [21] Teleo, Toulouse, <https://www.poma.net/en/work/teleo/>