Transport Reviews

ISSN: (Print) (Online) Journal homepage: www.tandfonline.com/journals/ttrv20

Aerial cable cars as a transit mode: a review of technological advances, service area characteristics, and societal impacts in Latin America and the Caribbean

Santiago Cardona-Urrea, Jaime Soza-Parra & Dick Ettema

To cite this article: Santiago Cardona-Urrea, Jaime Soza-Parra & Dick Ettema (2024) Aerial cable cars as a transit mode: a review of technological advances, service area characteristics, and societal impacts in Latin America and the Caribbean, Transport Reviews, 44:3, 684-708, DOI: 10.1080/01441647.2023.2294752

To link to this article: https://doi.org/10.1080/01441647.2023.2294752

TRANSPORT REVIEWS
2024, VOL. 44, NO. 3, 684–708
https://doi.org/10.1080/01441647.2023.2294752

Aerial cable cars as a transit mode: a review of technological advances, service area characteristics, and societal impacts in Latin America and the Caribbean

Santiago Cardona-Urrea [a,b], Jaime Soza-Parra [a] and Dick Ettema [a]

[a]Department of Human Geography and Spatial Planning, Utrecht University, Utrecht, The Netherlands; [b]Grupo de Investigación en Movilidad Sostenible (GIMS), Departamento de Ingeniería civil, Universidad Nacional de Colombia sede Manizales, Manizales, Colombia

ABSTRACT

The success of the first Metrocable line in Medellín (2004) as a feeder for the Metro system served as a turning point in considering the use of aerial cable cars (ACC) as a mode of public transport in urban settlements. In the following years, 33 ACC transit lines were inaugurated in Latin America and the Caribbean (LAC), the majority after 2010. This review has several aims: (i) to understand the differences in aerial cableway transit (ACT) technologies; (ii) to describe the characteristics of the ACC service area for the most critical case studies in LAC and identify their role in the public transport system; and (iii) to find the essential societal benefits presented by ACC. We will follow two complementary approaches. First, the review concentrates on the most recent technological advances. Second, 24 reports were obtained from scientific databases, complemented by another 18 found using the "snowball" method. Our findings show that detachable gondolas, called aerial cable cars in the transport literature, are the most used technology as a transit mode. Furthermore, the ACC initially served as a feeder mode, serving low-income communities on hillside terrains. However, some cases are restructuring the public transport system and building a comprehensive network utilising the ACC. The empirical evidence shows that complementary projects are essential to impact less-frequent ACC users and people in the neighbourhood. Moreover, travel time and cost reductions increase accessibility and reduce inequalities, especially in the service area. Participatory budgeting may also prompt community engagement with the project, especially among low-income residents. Considering integration between transport modes (and within transit modes) in the project's early stages will also increase ridership and users' accessibility. Future research should focus on the travel behaviour and societal impacts of ACC integrated into the structure of the public transport systems.

ARTICLE HISTORY
Received 10 August 2023
Accepted 7 December 2023

KEYWORDS
Aerial-cable cars; public transport; global south; societal impacts; transport innovations

CONTACT Santiago Cardona-Urrea s.cardonaurrea@uu.nl Department of Human Geography and Spatial Planning, Utrecht University, Princetonlaan 8A, 3584 CB, Utrecht, The Netherlands

1. Introduction

Public transport provision is essential to fulfil the population's accessibility needs, especially for those low-income people who face inequity and spatial segregation (Bocarejo & Oviedo, 2012). Cities with unique morphology characteristics, such as geographical constraints (e.g. hilly terrains or rivers) or consolidated urban settlements, have created a need for specialised transit modes like aerial cableway transit (ACT) technology to supply necessary public transport services (Alshalalfah et al., 2012; Brand & Dávila, 2011; Flesser & Friedrich, 2022; Vuchic, 2007). ACT technology uses a cable to suspend and propel cabins along a fixed route to move passengers automatically with electric power (Alshalalfah et al., 2012). Argel (Algeria) in 1956 and New York (US) in 1976 deployed aerial tramways (AT) for public transport (Alshalalfah et al., 2014; Canon Rubiano et al., 2020). Several other air-based technologies have been developed as well, including detachable gondolas (aerial cable cars-ACC) (Alshalalfah et al., 2012, 2013). Medellin's *Metrocable* in 2004 was the first implementation of ACC as a transit mode, producing a turning point for considering the technology suitable to fulfil transport needs in urban settlements and broadening the range of alternatives for decision-makers and travellers. *Metrocable* utilised a well-established technology commonly used to reach ski resorts (detachable gondolas) in mountainous regions or as a tourist attraction in global north countries (Alshalalfah et al., 2012; 2013; Brand & Dávila, 2011).

Most authors have agreed on the transport planning advantages of using ACT as a transit mode in urban settlements (Alshalalfah et al., 2012; Brand & Dávila, 2011; Flesser & Friedrich, 2022). Firstly, ACT could overpass areas of the city with topographic difficulties like hilly terrains or rivers where other transit modes cannot be implemented. Secondly, it is crucial to consider that only ACT stations and towers are constructed on the terrain. The rest of the system is aerial and can follow any direction but is always in a straight line between the stations. Thus, ACT disrupts neighbourhoods to a lesser extent compared to other transport infrastructure projects (e.g. building highways or dedicated bus lanes), especially in hilly terrain where space is limited. Thirdly, cheaper costs (up to 8 times cheaper compared with rail systems Alshalalfah et al. (2012)) and fast construction times make it an attractive option, especially among politicians with limited periods to show results to the community. Fourthly, ACT runs on electric power, reducing local air pollution and generating environmental and health benefits for residents.

Mostly technical and operational aspects of ACT have been reviewed in the literature, including technical advantages compared with other modes of transport, the frequency of implementations worldwide (Alshalalfah et al., 2012, 2014), and their costs, business, and operational models (Canon Rubiano et al., 2020). Tiessler et al. (2020) reviewed the existing ACT systems' planning, construction, operation aspects and case studies. They focus on the Emirates Air Line (London, UK) experience, transferring knowledge to German cases for future implementations. In another work, Flesser and Friedrich (2022) conducted a systematic literature review on urban aerial cable cars (ACC) as a sustainable transport mode, focusing on environmental, societal, economic, services and infrastructure aspects. The authors noted that most ACC systems today are concentrated in LAC, reaching 24.8% of the total ACC share worldwide, with 62% implemented as a transit mode (Flesser & Friedrich, 2022). For instance, LAC has constructed ACC in 12 cities and seven countries in the past two decades (Vergel-Tovar, 2022).

While previous reviews have addressed technological and financing characteristics (Alshalalfah et al., 2012; 2014; Canon Rubiano et al., 2020) and their implications for sustainability (Flesser & Friedrich, 2022), there is a lack of research into the societal impacts of ACC systems using empirical studies. Furthermore, the importance of including Spanish research databases and LAC cases specifically has been established (Flesser & Friedrich, 2022; Reichenbach & Puhe, 2022). Consequently, the following research questions have been raised for this literature review:

- Which ACT technologies have been developed, and which is the most commonly used transit mode in the LAC context?
- What are the socio-demographic, topographical, and daily mobility characteristics of ACC's service area, and what is the role that ACC plays in the public transport system?
- What are the societal impacts of using ACC as a transit mode, considering the empirical evidence in transportation research?

This literature review approaches these questions by focusing on the empirical evidence about LAC case studies. The reasoning for doing so is that ACT technology has been established as a niche transit mode there (Flesser & Friedrich, 2022; Vergel-Tovar, 2022), which has produced questions for policymakers about further investments in ACT systems as a transit mode. The article is structured as follows: Section 2 explains the methodology to retrieve the studies necessary to fulfil the study's aims. Section 3 reports the evolution of the ACT into a transit mode in urban settlements from a historical perspective. The most prominent technologies are also described by comparing their capacity and operational speed, establishing a coherent terminology for academics and practitioners. Section 4 reviews five relevant implementations of ACC in LAC, focusing on the service area's socio-demographic, topographical, and daily mobility characteristics, and their role in the public transport system. Section 5 reviews the empirical evidence, extracting the societal impacts of implementing the ACC. Finally, the conclusions sections include public policy recommendations and future research needs.

2. Methodology

The methodology of the literature review is twofold. First, section 3 started with the most recent literature review articles (Alshalalfah et al., 2012; 2014; Flesser and Friedrich 2022; Tiessler et al. 2020), complemented with manufacturers' technical reports to retrieve the most recent advances in the technology regarding transport capacity and operational speed. Secondly, Sections 4 and 5 are based on peer-reviewed articles, conference proceedings and book chapters published in English, Spanish, or Portuguese research databases (see Figure 1). Web of Science and Scopus as English databases and Redalyc and Scielo as Spanish and Portuguese databases were considered. Google Scholar was used to complement the search in both languages. The search was conducted in December 2022 and used the following keywords based on previous literature review articles on the topic (e.g. Flesser & Friedrich, 2022; Tiessler et al., 2020):

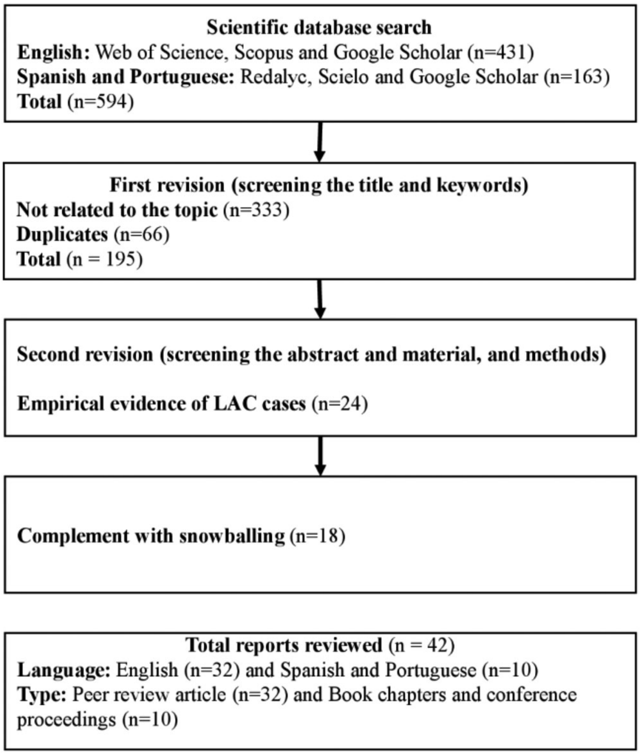

Figure 1. Methodology flow chart.

- Scopus query: TITLE-ABS-KEY ((aerial AND cableway* AND transit) OR (aerial AND ropeway* AND transit) OR (cable AND propelled AND transit) OR ((urban OR (transit OR (public AND transit) OR (public AND transport*) OR (transit AND mode))) AND (cableway OR (cable AND car) OR gondola OR ropeway)))
- Scielo query: *transporte público* AND (*cable aéreo* OR *teleférico* OR *telecabina*)

A total of 593 reports (431 in English and 163 in Spanish and Portuguese) were obtained. The title and keywords were screened, finding 333 unrelated to the research topic and 66 duplicates. The abstract, materials, and methods of the rest of the reports were reviewed, classifying those related to ACC case studies in LAC that encompassed empirical evidence about the implementation. Studies related to hypothetical projects were not considered. Twenty-four research documents fit the abovementioned criteria, complemented by 18 from the snowball method (32 in English, 6 in Spanish, and 4 in Portuguese). The reports focused on the case studies of Bogotá, Medellín, and Manizales (Colombia), Rio de Janeiro (Brazil), and La Paz (Bolivia) (see Appendix 1 for a complete list of the reports). Despite the concentration of the studies in those cases, results can be extrapolated to other cities in LAC because of social, cultural, and economic similarities among countries. The main findings were related to social urbanism and community engagement, mobility, accessibility, social inclusion, and tourism.

3. The evolution of the aerial cableway into a transit mode

This section focuses on the evolution of the ACT into a transit mode in urban settlements. First, the ACT technology is described considering the operational characteristics: capacity and speed. Second, a brief historical perspective of the ACT as a transit mode is presented.

3.1. The technology behind ACT

ACT systems are composed of cabins, stations, towers (or pylons), the cable (or rope) as the heart of the system, and the evacuations and rescue system (Alshalalfah et al., 2012, 2013). The literature recognises two prominent ACT technologies for urban areas (Tiessler et al., 2020): Aerial tramways (AT) and Detachable Gondolas (DG). DG is distinguished by the number of cables: Monocable (MDG), Bicable (BDG), and Tricable (TDG). In transport literature, DG is traditionally referred to as "aerial cable cars" (ACC) (Alshalalfah et al., 2012, 2013; Brand & Dávila, 2011; Flesser & Friedrich, 2022). The main differences between these technologies are the cabin and line capacity and the operational speeds (see Figure 2).

AT comprises two parallel cabins simultaneously transporting passengers in opposite directions (Alshalalfah et al., 2012). The renovation of the New York AT in 2010 allowed the generation of separate cables to carry the two cabins, called Dual Haul Aerial Tramway (DHAT), allowing greater flexibility to respond to passenger demand (Alshalalfah et al., 2012, 2013). The AT cabin capacity could vary from 4 to 230 people with a maximum

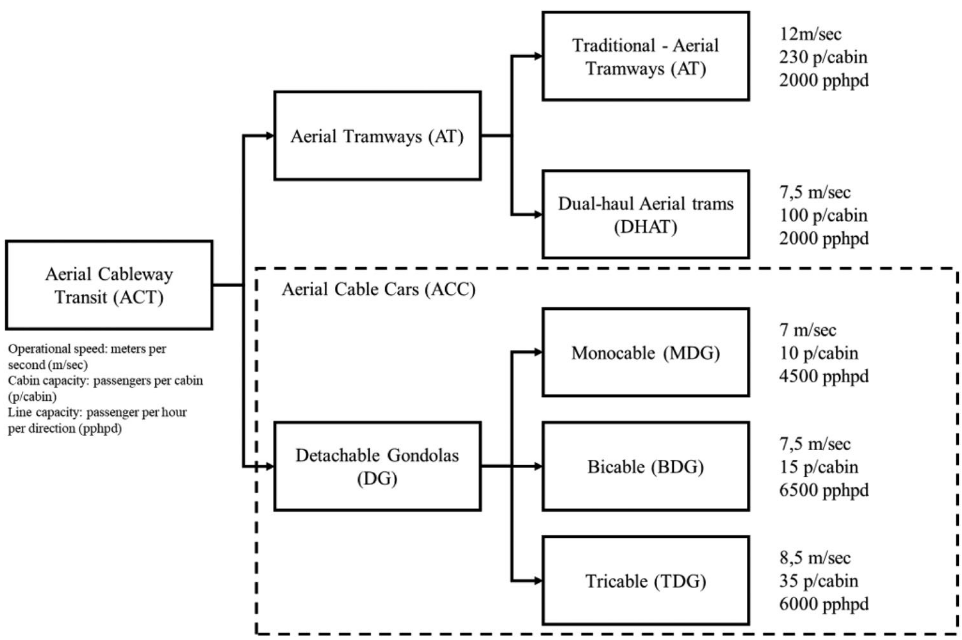

Figure 2. Aerial Cableway Transit categories and their maximum operation speed, cabin, and line capacity. Source: Own elaboration considering data reported by Alshalalfah et al. (2012) and technology brochures from ACT manufacturers.

speed of 12 meters per second (m/s), reaching a line capacity of up to 2000 passengers per hour per direction (pphpd) (Alshalalfah et al., 2012, 2013; Leitner, n.d.-a).

On the other hand, Monocable (MDG), Bicable (BDG), and Tricable (TDG). Detachable Gondolas cabins transport up to 10, 15, and 35 people per cabin with operational speeds of between 6 and 8.5 m/s (Alshalalfah et al., 2012, 2013) (see Figure 2). Since cabins can follow each other at shorter distances than aerial tramways, MDG line capacity reaches up to 4500 passengers per hour per direction (pphpd) (Canon Rubiano et al., 2020; Leitner, n.d.-c) while theoretical capacities of BDG and TDG reach up to 6500 and 6000 pphpd (Leitner, n.d.-d); however, in practice TDG systems work with lower capacities, as they are installed in the global north such as Germany and France serving medium and small-sized cities (Canon Rubiano et al., 2020). Higher line operational capacity makes DG more suitable as a transit mode since travellers prefer higher frequencies, perceiving the waiting and transfer times to be longer than transport times, especially in the global south with less operational reliability (Fan et al., 2016; Heinrichs & Bernet, 2014; Tirachini et al., 2022). However, integrating ACT into other transit systems like trains, metro, trams, or buses with lower frequencies, lower reliability, and larger capacity is challenging with regard to designing comfortable transfers that avoid crowding and waiting times (Reichenbach & Puhe, 2022; Težak et al., 2016).

DG technology has been continually developed over the past decade. At the beginning of 2010, BDG had better wind stability and operational speeds than MDG without the costs of TDG (Alshalalfah et al., 2012, 2013); however, advances in MDG safety technology, maintaining their lower construction costs and increasing their capacity, relegated the BDG option in comparison to MDG. Recently, manufacturers have developed a BDG technology that surpasses the line and cabin capacity of MDG and TDG, establishing it as an interesting option for systems with high potential passenger demand (Leitner, n.d.-b).

DG is currently preferred as a transit mode over AT, considering the systems operating worldwide. On the other hand, most of the DG deployed are MDG (45 urban lines worldwide, of which 73.3% are in LAC). Implementation costs could vary considering the context, topographic characteristics, and street layout. Findings suggest that costs per kilometre are highly variable, e.g. costs for MDG projects in Colombia vary from 13 million (*Miocable*–Cali) to 106 million (*Metrocable*-Medellín). Besides, there is no strong evidence regarding which technology presents the lowest overall costs. Previous reviews remarked that MDG is affordable; nevertheless, the evidence shows that the most expensive projects per kilometre are MDG: Metrocable (Medellín) and the Emirates Air Line (London). Despite the costs, MDG is the primary ACT technology implemented among global south countries, e.g. in LAC and Northern Africa (Alshalalfah et al., 2012; Canon Rubiano et al., 2020; Flesser & Friedrich, 2022; Vergel-Tovar, 2022). For a more detailed summary of ACC capital costs, business models, and operational characteristics, please check Canon Rubiano et al. (2020).

3.2. ACT as a transit mode

The use of the ACT to move passengers and goods goes back two centuries, specifically in America and Asia (Alshalalfah et al., 2014; Taylor, 1938). This section presents some of the most relevant historical examples of ACT. In Manizales (Colombia), ACT systems connected people and goods during the first part of the twentieth century, including the world's most extensive ACC line: 72 km between Manizales and Mariquita, which was inaugurated in 1922 and closed operations in 1961 to prioritise investment in roads (Escobar et al., 2015; Pérez Angel, 1997). During the second half of the century, ACT was more frequently associated with ski resorts and tourist attractions in the global north, like Europe and North America, which stimulated the development of their technology in terms of passenger capacity, comfort, and safety (Alshalalfah et al., 2012; Brand & Dávila, 2011; Garsous et al., 2019; Sarmiento et al., 2020).

In the second part of the twentieth century, the first AT line in Argel (Algeria) was inaugurated in 1956, with three more lines constructed between 1984 and 1987. Their success boosted renovations in the first decade of the 2000s and the construction of two ACC lines in 2014 and 2019 (Canon Rubiano et al., 2020). In 1976, an AT system was deployed in New York (US) as a temporary transit solution while New York's subway expansion was finished in 1989 (Alshalalfah et al., 2012). After that, the Roosevelt Island Aerial Tramway gained enough popularity to continue as a tourist attraction. The system was renovated in 2010, implementing a DHAT that increased its wind stability and flexibility to adapt to passenger demand (Alshalalfah et al., 2012).

The first ACT system using MDG technology as a transit mode was inaugurated in 2004 in Medellín (Colombia). The *Metrocable Line K* connects inaccessible and low-income informal neighbourhoods located on mountains with steeper terrain to relevant destinations in the *Aburra* Valley and the Metro system (Brand & Dávila, 2011). Today, Colombia has ten lines deployed in five different cities (see Figure 3), making the country the leader in ACC implementation as a transit mode worldwide. Since 2014, the world's most extensive and densest ACC network has been built in La Paz and El Alto (Bolivia), designed to connect inhabitants living at different altitudes, especially between and within the two city centres (Garsous et al., 2019; Koch, 2013). The *Mi Teleférico* ACC network now includes ten lines, 30.5 kilometres and 36 stations. Recently, the second line of *Cable bus* in México City was recorded in the Guinness Book of Records as the longest ACC line with 10.55 km (El Financiero, 2021). México City has three more ACC lines integrated into their public transport systems; the most recent was inaugurated in 2023 (Mexicable, 2023) and another is scheduled to be inaugurated at the end of 2023 (Gómez, 2023).

After Medellin's *Metrocable Line K* inauguration in 2004, 33 ACC lines were inaugurated in seven LAC cities; 90.9% of them after 2010 (Canon Rubiano et al., 2020; Vergel-Tovar, 2022). Six more lines are currently under construction. Those have given momentum to the technology, becoming an established alternative transit mode (Flesser & Friedrich, 2022; Reichenbach & Puhe, 2022). ACC has been increasingly considered as an urban mobility solution for practitioners, transport authorities, and operators due to these specific transport planning advantages over other transit modes. It is time to review ACC transit implementations in LAC to reap insights about the societal impacts of ACC systems to inform policymakers when deciding about upcoming ACC projects (Vergel-Tovar, 2022).

4. Understanding aerial cable cars in LAC

This section will concentrate on two ACC typologies emerging from empirical studies of LAC cases: (i) Medellín, Bogotá, and Rio de Janeiro, and (ii) La Paz and Manizales. A

Figure 3. Aerial Cable-Cars lines deployed in LAC cities. Own elaboration.

description of the socio-demographic, daily mobility and topographic characteristics of the ACC's service area is presented to understand which population segments are served and the ACC's role in the public transport system.

4.1. The ACC to reduce spatial inequity: Medellín, Bogotá and Rio de Janeiro

The ACC service areas in Bogotá, Medellín, and Rio de Janeiro share certain similarities. The ACC works as a feeder serving low-income neighbourhoods located in hillside terrain in the city's peripheries or spatially disadvantaged areas. These neighbourhoods have an inadequate provision of essential services, including public transport, road infrastructure, water, and sewerage (Duarte Santos & Soares Gonçalves, 2017; Heinrichs & Bernet, 2014; Sarmiento et al., 2020). Some relevant examples include *Comunas 1* and *2* in Medellín (2004) (Brand & Dávila, 2011), *Ciudad Bolivar* in Bogotá (2018) (Sarmiento et al., 2020) or the favelas of *Complexo do Alemao* (2011) and *Providencia* (2014) in Rio de Janeiro (Duarte Santos & Soares Gonçalves, 2017). In addition, ACC systems in these cities reach neighbourhoods with a more structured urban shape but with topographical constraints. For instance, the following ACC lines inaugurated in Medellín (e.g. *Line J's* 2008) mainly influenced social housing projects (Coupé & Cardona, 2013; Goodship, 2015).

However, the success of ACC differs between Bogotá and Rio de Janeiro (Freire-Medeiros et al., 2020). The ACC in Brazil were constructed as a part of an ambitious government investment project in the favelas (Duarte Santos & Soares Gonçalves, 2017). The idea came from politicians who visited Medellín's case, using the most significant part of the budget to build the ACC. However, the favelas' inhabitants preferred to attend to other priorities in their neighbourhoods, such as sewerage or water provision (Braga, 2017; Duarte Santos & Soares Gonçalves, 2017). Furthermore, the idea was to use the ACC with a mixed purpose, especially in *Complexo do Alemao*, attracting tourists while offering residents transport for free (Freire-Medeiros et al., 2020; Freire-Medeiros & Name, 2015). Rio de Janeiro's ACC closed operations in 2016, and efforts to open again have not been made (Cavalcanti & Campos, 2022). On the contrary, the ACC in *Ciudad Bolivar* (*Transmicable*) was an ambition following many years of community struggle for a transit mode that could be implemented in their steeper terrain, complemented with social urbanism investment in the neighbourhood (Guevara-Aladino et al., 2022; Sarmiento et al., 2020). Ciudad Bolivar's *Transmicable* currently transports 27,000 inhabitants daily (Guzmán, Arellana et al., 2023), while the last ridership reports in *Complexo do Alemao* were below 11,000 passengers daily (Duarte Santos & Soares Gonçalves, 2017).

The ACC lines in all three cities are fully integrated as a feeder of the public transport system (Garnica Quiroga, 2020; Morales-Betancourt et al., 2023; Okami et al., 2022). Residents can use the system paying only one ticket or a differential fare. After their success with *Line K* in 2004, Medellín built four more ACC transit lines, integrating with Metro, Bus Rapid Transit (BRT), Tram, and traditional buses (see Figure 4). Meanwhile, Bogotá's ACC (see Figure 4) is connected, and fare integrated with the BRT system of the city (*Transmilenio)* (Guzman et al., 2022; Guzman, Arellana et al., 2023). On the other hand, during Rio de Janeiro's ACC operation, it was free of charge for residents in the favelas. It is physically integrated into the train network, Light Rail Transit (LRT) and BRT system, paying only the fare to enter the other transit modes in contrast the tourists must pay the complete fare (Duarte Santos & Soares Gonçalves, 2017).

Before implementing the ACC lines in Medellin and Bogotá, BRT bus feeders and traditional buses or paratransit supplied the public transport in the neighbourhoods of both cities without integration with the city's public transport system. Consequently,

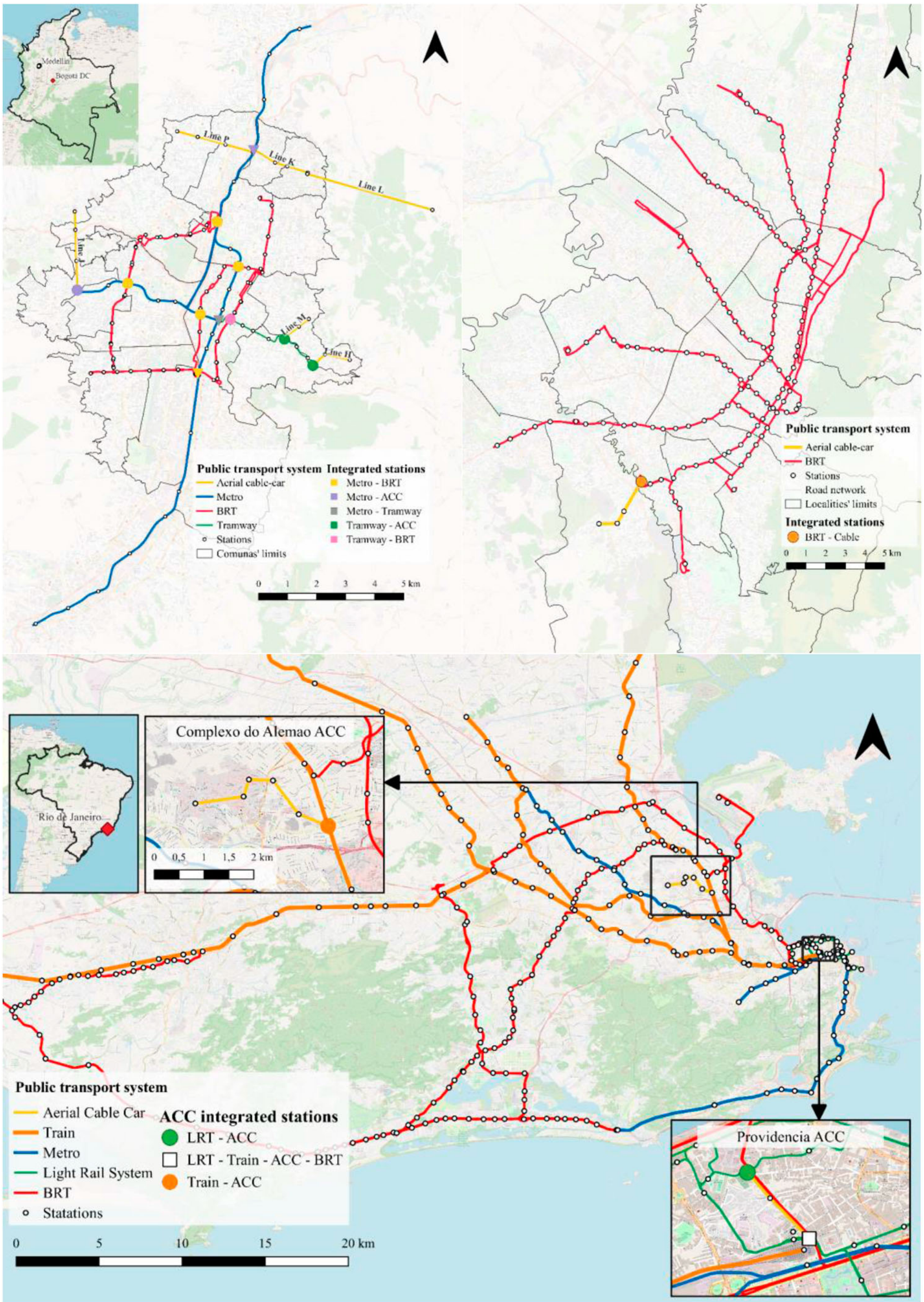

Figure 4. Medellín's (top-left), Bogotá's (top-right) and Rio de Janeiro's (bottom) public transport system. Circles represent integrations with two, triangles with three, and squares with four transit modes. Own elaboration with open data gathered from Medellín's, Bogotá's, Rio de Janeiro's government, and Openstreetmaps.

travellers pay multiple fares, increasing their transport budget and travel time to reach the essential parts of the city, especially the city centre, where most of the employment is (Bocarejo et al., 2014; Brand & Dávila, 2011; Garnica Quiroga, 2020; Guzman et al., 2022). In Bogotá, the paratransit system, provided by private cars with limited capacity, was not affected by the ACC line but expanded to rural areas of the neighbourhood to connect travellers to the ACC stations (Villar-Uribe, 2021). In Rio de Janeiro's case, the daily mobility of *Complexo do Alemao* and *Providencia* inhabitants before the ACC introduction were by foot or using paratransit services. Pedestrian connections were through steep stairs and narrow alleys. Paratransit modes comprised vans, kombis, and moto-taxis (Espósito Galarce & da Silva, 2016; Freire-Medeiros & Name, 2017; Gonçalves & Bandeira, 2017). Despite higher costs and uncertainty, those paratransit systems offer greater flexibility and coverage than the ACC, since the ACC service is fixed to specific stations and covers specific areas. For instance, most of the residents in *Complexo do Alemao* complained about the location of the stations on the hilltop of the favelas because they must climb the mountain if they wanted to use the system, despite its free cost (Duarte Santos & Soares Gonçalves, 2017). Moreover, the ACC did not allow the transport of bulk cargo inside the cabins, a disadvantage when favela residents go for groceries outside the neighbourhood due to a lack of access to food (Braga, 2017; Worms & Sluyter, 2018).

The daily mobility of most of the dwellers in the service area of ACC lines in Medellin, Bogota, and Rio de Janeiro is within their neighbourhood; therefore, the frequent ACC users are workers and students (Agudelo V. et al., 2013; Brand & Dávila, 2011; Coupé, 2013; Duarte Santos & Soares Gonçalves, 2017; Gonçalves & Bandeira, 2017; Guzman et al., 2022). For them, the fare integration of the public transport system increases their accessibility to opportunities and zones they can reach with lower costs and travel time (Bocarejo et al., 2014).

4.2. The ACC to structure public transport: La Paz and Manizales

The steeper topography and the city size were crucial considerations in La Paz (Bolivia) (*Mi Teleférico*) and Manizales (Colombia) (*Cable Aéreo*) to structure their public transport system around ACC (see Figure 5). They installed the ACC between their city centres first, expanding the network around those high-demand lines, e.g. connecting with their neighbouring towns: El Alto (Bolivia) and Villamaría (Colombia) (Escobar et al., 2015; Garsous et al., 2019). La Paz developed a Master Plan in 2012, which included the construction of an ACC network composed of 11 lines and 39 stations (see Figure 5) to supply part of the daily mobility of 1.7 million trips by their inhabitants (Garsous et al., 2019; Koch, 2013; Martinez et al., 2018). Before the ACC network operated by *Mi Teleférico* company, paratransit modes (Minibus, Micros, and Trufis) supplied the inhabitants' public transport needs (see Garsous et al. (2019) page. 175 for a complete description of the transit modes). Today, these services compete with *Mi Teleférico* because the Master Plan did not consider their integration with the ACC network. Their flexibility and lower fares are attractive to a massive segment of travellers, e.g. Garsous et al. (2019) reported that 57% of dwellers used Minibus, 5% used Micros, and 5% used Trufis, compared with 2% using the ACC network. The results are consistent with those of Martinez et al. (2018), where *Mi Teleférico* in the first phase represents 3.78% of the modal share in La Paz. *Mi*

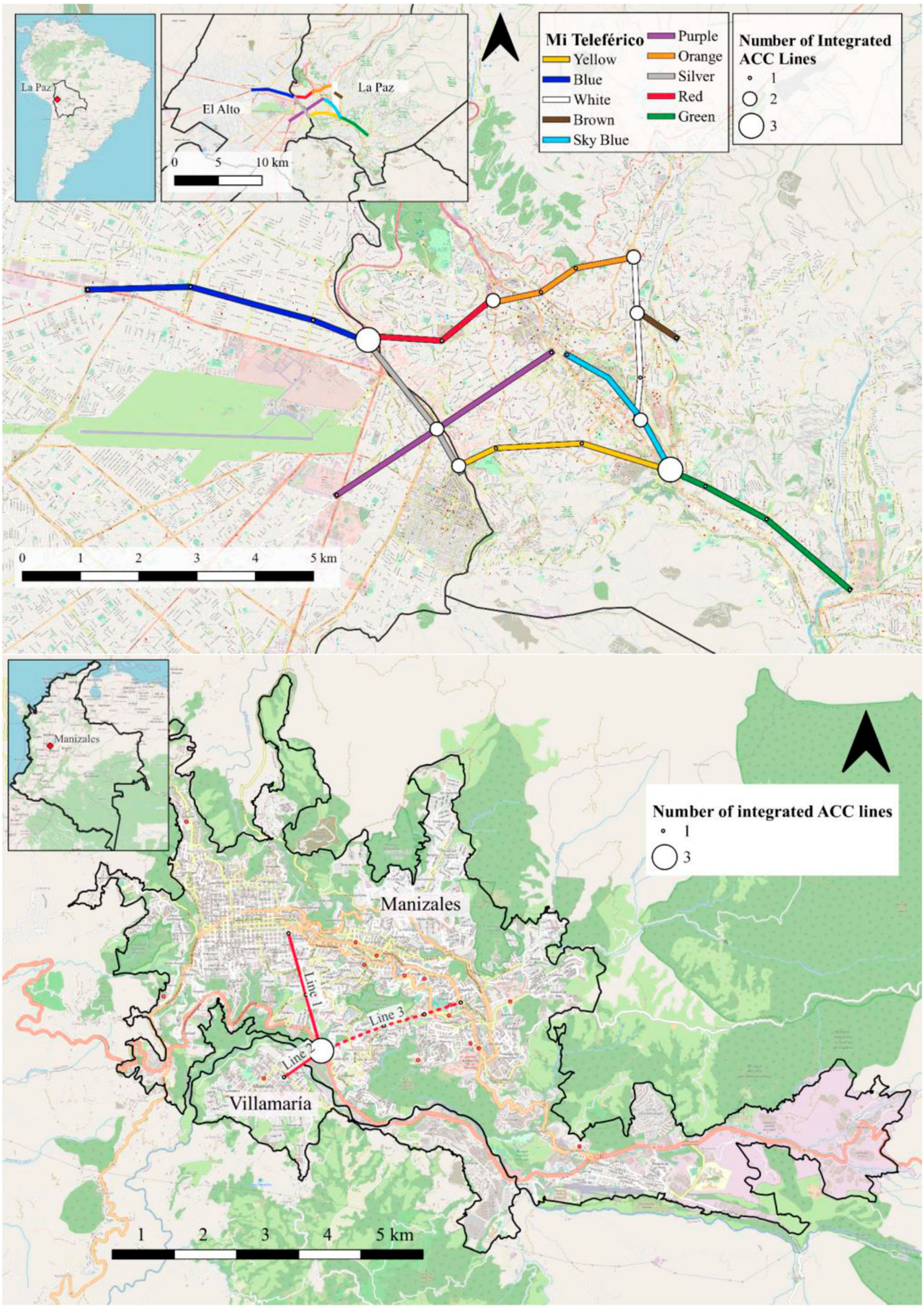

Figure 5. La Paz (above) and Manizales (below) aerial cable-car system. Own elaboration with open data gathered from La Paz's and Manizales' government's websites and Openstreetmaps.

Teleférico shows that the frequent users have higher incomes and levels of education (Martinez et al., 2018). These reports considered data from 2015, when only the first phase of *Mi Teleférico,* composed of Lines Red, Green, and Yellow, operated without physical integration. Moreover, before the Covid-19 pandemic, the system reported 96 million journeys (approximately 250,000 per day) in 2019, with ten ACC lines working (the Golden line is still in the planning phase) (Mi Teleférico, 2022). Before *Mi Teleférico* construction, some authors like Koch (2013) questioned their implementation because the ACC lines would not fulfil the necessities of travel demand as other transit modes (such as BRT) would. Furthermore, fully integrating all the transit modes would be necessary to reach the public transport system's equity, efficiency, and sustainability objectives in La Paz (Koch, 2013).

The country's budget support allows La Paz to develop the ACC network faster than Manizales. The government's effort in the medium-sized city of Manizales enabled the inauguration of two lines in 2009 and 2013 (one more is under construction). Their service area covers the city centres of Manizales and Villamaría and middle-income neighbourhoods in the southwest hillsides of Manizales (Escobar et al., 2015; Escobar & Garcia, 2011). Two additional lines are necessary to complete the ACC network defined in the mobility plans (Escobar et al., 2015, 2022). Similar to La Paz, competition with traditional buses has been a constant challenge in their operation because integration (physical or fare) was not considered in the ACC planning, resulting in low passenger demand and underuse (Escobar et al., 2015). The rest of the public transport needs are supplied by vehicles with 15–40 passengers, operated by private companies and covering almost all of the city with 71 bus routes (Rodas-Zuleta et al., 2022). The traditional buses are paid by cash, and the bus stops are flexible, offering users a high degree of accessibility compared to the ACC network.

5. Societal impacts

Most of the empirical studies concentrated on the cases of Medellín, Rio de Janeiro, and Bogotá, where the ACC was designed as a feeder of the public transport system. On the other hand, case studies such as La Paz and Manizales, where the ACC is the city's public transport structure, have not been extensively investigated. This section discusses the societal impacts of both ACC types discussed above in more detail. Results were grouped into categories of social urbanism and community engagement, mobility, accessibility and social inclusion, tourism, and politics and governance. Other societal impacts, such as environmental and health outcomes and impact on violence and crimes, have received less attention among scholars, and we lack evidence to report such outcomes.

5.1. Mobility, accessibility, and social inclusion

Travel time and cost reductions are the benefits most directly perceived by the population and researched by scholars after ACCs implementations (Bocarejo et al., 2014; Brand & Dávila, 2011; Escobar et al., 2015; Escobar & Garcia, 2011; Garnica Quiroga, 2020; Garsous et al., 2019; Guevara-Aladino et al., 2022; Heinrichs & Bernet, 2014; Martinez et al., 2018; Matsuyuki et al., 2020). *Metrocable Line K* users reported reductions of 45 min using the ACC to connect with the Metro system (although the increase in waiting times because of long queues during rush hours could affect the overall reduction) (Brand & Dávila, 2011; Heinrichs & Bernet, 2014). At the same time, reductions of 20% (22 min) in commuting travel times for residents of Ciudad Bolivar, Bogotá, around the area of influence of *Transmicable* were measured (Guevara-Aladino et al., 2022). The average commute time in Bogotá is 52 min; nevertheless, vulnerable and low-income communities located in the peripheries of the city experience higher commuting times (Garnica Quiroga, 2020; Guevara-Aladino et al., 2022), a pattern frequently repeated in other LAC cities.

On the other hand, research on travel time impacts at the city level has distinct results. For instance, a significant impact on commuting time was found in the first phase of *Mi Teleférico* in La Paz, with a reduction of 22% in travel times (Garsous et al., 2019). They compare single-mode trips made in the ACC network against other transit modes (e.g. minibuses) and private vehicles (e.g. cars and motorcycles). Moreover, Martinez et al. (2018) found reductions of 70 min in commute times for *Mi Teleférico* frequent users. The time was reallocated to education and recreational activities. Meanwhile, reductions in travel time of 7.7% were observed in Medellín (Bocarejo et al., 2014) and 3.4% in Manizales (Escobar et al., 2015; Escobar & Garcia, 2011) at the city level.

Travel cost reductions are mainly related to fare integration with the public transport system, especially in those cases where the ACC works as a feeder (Bocarejo et al., 2014; Coupé, 2013; Guzman et al., 2022; Heinrichs & Bernet, 2014). However, travel times and cost benefits are limited because not all the residents are frequent users of the ACC, and most people's daily mobility is within the neighbourhood (Cavalcanti & Campos, 2022; Heinrichs & Bernet, 2014).

The empirical evidence has shown increased accessibility, social inclusion, and quality of life. The ACC has boosted the change of vocational jobs (Matsuyuki et al., 2020) and doubled the accessibility to employment in the surroundings of the first *Metrocable* line (Bocarejo et al., 2014). Moreover, according to Cordoba et al. (2014), *Metrocable* increased the average number of trips per day among the area of influence (an average of 2 trips per person per day), decreasing the risk of social exclusion. Remarkably, the introduction of ACC also led to an increase in the use of public transport, especially among low-income residents and women (Milan & Creutzig, 2017).

Different results have been reported regarding access to the ACC stations, especially between Medellín and Rio de Janeiro. In Medellín, the ACC stations are located on the hillside, while in Rio de Janeiro, they were placed on the hilltop of the favelas, making access difficult (Duarte Santos & Soares Gonçalves, 2017). For example, during Rio de Janeiro's ACC operation, the influenced area reached only 10 min of walking around the stations (Braga, 2017; Gonçalves & Bandeira, 2017). Most residents preferred other modes of transport, especially paratransit services, because the location of ACC stations is unattractive. On the other hand, *Metrocable* users are willing to walk more (up to 1 h) because of the integration with the Metro system and the travel cost savings (Agudelo V. et al., 2013).

The residents in *Metrocable* area of influence report that modal choice was driven by the transport budget and travel time; however, safety in the surroundings of the stations is also essential, especially when crime and violence are frequent (Agudelo V. et al., 2013; Sarmiento Ordosgostia et al., 2013), something prevalent in neighbourhoods where the ACC used to be deployed (Brand & Dávila, 2011; Freire-Medeiros et al., 2020). For instance, women perceived the buses to be safer because the walking distance to the bus stop is lower than ACC station, i.e. they spend less time exposed to violence and crime in the neighbourhood (Agudelo V. et al., 2013; Sarmiento Ordosgostia et al., 2013). On the contrary, the *Transmicable* case showed that in-vehicle security perception for women ACC users is high (Guzman et al., 2022), i.e. they feel more secure than expected inside the ACC cabins. Differences in safety perception among case studies can be related to the context and methods applied. In addition, the increase in gender-based violence inside public transport vehicles, particularly buses, has been recently studied in LAC (Quiñones, 2020; Rodas-Zuleta et al., 2022). Nevertheless, no reports about those situations considering ACC were found. Furthermore, Guzmán, Cantillo-García et al. (2023) found an increase in social capital with the inauguration and use of Transmicable, i.e. this was an essential variable in the modal choice.

The long-term impact of *Line K* in Medellín on travel behaviour reveals that traditional buses remain the predominant transport mode in the neighbourhoods. At the same time, the ACC is primarily used to access the Metro system (Okami et al., 2022). Okami et al. (2022) found an increase in the use of private modes, particularly among young males who commute more frequently using motorcycles. Additionally, the ACC had a minor effect on the modal shift from private vehicles in La Paz, as a higher percentage of ACC users previously used other transit modes (Martinez et al., 2018).

Findings show that Manizales' ACC ridership is below the forecast passenger demand. It reduces users' travel and waiting times; nevertheless, the system has failed to attract more ridership, causing economic problems for the operator (Escobar et al., 2015). On the other hand, disruptions in the ACC operation have been reported during heavy storms or maintenance periods in Medellín (Agudelo V. et al., 2013; Coupé, 2013; Matsuyuki et al., 2020). For example, heavy storms could cause unexpected disruption in the ACC operation, forcing the users to take other transit modes or to wait in the cabins while the operation continues (Agudelo V. et al., 2013). However, no statistical differences in the travel times were found between the ACC and alternative transit modes (e.g. buses) during maintenance periods in Medellín, showing excellent planning to tackle the disruptions (Matsuyuki et al., 2020).

Finally, the paratransit options in the neighbourhoods were not affected by the ACC implementations, and they continue to be an essential part of daily mobility because of their flexibility and low costs (Braga, 2017; Capillé & Reiss, 2019; Duarte Santos & Soares Gonçalves, 2017; Villar-Uribe, 2021). Paratransit routes expanded to work as a feeder of the ACC in Bogota (Villar-Uribe, 2021). Meanwhile, some people in Rio de Janeiro perceived that integrating paratransit services and the ACC could increase coverage and accessibility (Braga, 2017; Duarte Santos & Soares Gonçalves, 2017).

5.2. Social urbanism and community engagement

Social urbanism is an urban planning initiative related to investing in high-impact and quality projects in zones with historical government deficits, e.g. informal neighbourhoods (Brand, 2010). Coined during Fajardo's administration in Medellín (2004–2007), it is related to projects (Brand & Dávila, 2011), such as the improvement of public spaces and housing, creation of education and cultural facilities, provision of water and sewerage, increase of green space and parks, among others (Brand, 2010; Brand & Dávila, 2011). The ACC has commonly been the start of solid investment in social urbanism in several cities in LAC (e.g. Medellín, Bogotá, and Rio de Janeiro) (Duarte Santos & Soares Gonçalves, 2017; Espósito Galarce & da Silva, 2016; Galvin & Maassen, 2020; Guevara-Aladino et al., 2022). Usually, social urbanism projects impact less frequent ACC users in the neighbourhood (Brand & Dávila, 2011, 2013; Coupé, 2013; Guevara-Aladino et al., 2022). For instance, women frequently use the Employment and Entrepreneurship Support Centre (CEDEZO) or the España Library Park (closed since 2015 due to reparations) in Medellín, two of the most important complementary projects around *Metrocable* (Matsuyuki et al., 2020). Moreover, increased physical activity, mental health and well-being were observed with the renovation of public parks in the surrounding areas of *Transmicable* in Bogotá (Guevara-Aladino et al., 2022).

The cases of Medellín and Bogotá have also shown high levels of community engagement through participatory budgeting, giving the inhabitants the power to decide how to allocate investments in their neighbourhood, usually for small projects, but not involved in crucial decisions such us the ACC itself (Galvin & Maassen, 2020; Guevara-Aladino et al., 2022). A general increase in the sense of pride, satisfaction with their neighbourhood, and the perception of neighbourhood visibility regarding the rest of the city have been observed, which is even higher among frequent ACC users (Brand & Dávila, 2011, 2013; Coupé, 2013; Guevara-Aladino et al., 2022; Matsuyuki et al., 2020). For example, travel and life satisfaction increases in Ciudad Bolivar with the inauguration of *Transmicable* (Guzmán, Arellana et al., 2023). Similarly, Milan and Creutzig (2017) found that the quality of life around the *Metrocable* service areas has also improved, considering socio-economic well-being, public infrastructure, and social capital indicators. Conversely, lower levels of community engagement were found in the second *Metrocable* line in Medellín (*Line J*) because complementary projects and neighbourhoods dynamics were not adequately connected (Brand & Dávila, 2011, 2013; Coupé & Cardona, 2013; Milan & Creutzig, 2017). No research was found regarding the recent Medellín ACC's lines (*Line H*, *Line M* and *Line P*).

The case of Rio de Janeiro's ACC was characterised by a lack of complementary projects and community engagement (Braga, 2017; Duarte Santos & Soares Gonçalves, 2017; Espósito Galarce, 2020; Espósito Galarce & da Silva, 2016; Freire-Medeiros et al., 2020; Freire-Medeiros & Name, 2015, 2017), and a profound disconnection between residents' needs and government objectives (Cavalcanti & Campos, 2022; Worms & Sluyter, 2018). For example, nearly 50% of the budget allocated to investment in the favelas was used to build the ACC; however, residents would prefer those investments in other areas such as water, sewerage, sidewalks, and roads (Duarte Santos & Soares Gonçalves, 2017; Worms & Sluyter, 2018). On the contrary, between six and seven times Medellín's ACC cost was invested through participatory budgeting in complementary projects in the next four years after the inauguration of the first line (Brand & Dávila, 2011, 2013).

Around ACC's towers and stations in Medellín and Rio de Janeiro there is evidence of the appropriation of residual spaces (Agudelo V. et al., 2013; Coupé & Cardona, 2013; Espósito Galarce, 2020; Espósito Galarce & da Silva, 2016; Freire-Medeiros & Name, 2015; Goodship, 2015). Residual spaces are open spaces in urban contexts that urban designers often overlook. The rise in pedestrian flow around the ACC stations has led to an increase in the presence of informal street sellers and formal businesses such as shops, bars, and restaurants (Agudelo V. et al., 2013; Braga, 2017; Coupé & Cardona, 2013; Freire-Medeiros & Name, 2015; Goodship, 2015; 2016). However, the disconnect in planning processes between residents and the government has generated disputes around the residual spaces created by the ACC in *Complexo do Alemao*. For example, the residents installed a ping pong table, and some businesses flourished around it.

Nevertheless, the government replaced this space with an outdoor gym that is rarely used (Espósito Galarce, 2020; Espósito Galarce & da Silva, 2016).

5.3. Tourism

The ACC as a transit mode is linked with tourism because it offers a panoramic view of the city and the service area (Freire-Medeiros & Name, 2015). The first Metrocable line attracted a high flow of tourists, even though its primary objective was to supply daily mobility for residents (Jurado & Mesa-Arango, 2019). However, the quality of service for commutes has been reduced because of long queues due to the high demand (Jurado & Mesa-Arango, 2019). However, few tourists venture to the other lines, which indicates that tourism-related effects are usually concentrated in certain areas and lines. On the other hand, Rio de Janeiro's ACC was designed for mixed use as both a transport facility for favelas residents and as a city tourist attraction (Freire-Medeiros & Name, 2015). The ACC was the opportunity for politicians to sell the favela landscape as a tourist destination, taking advantage of the view from the sky (Duarte Santos & Soares Gonçalves, 2017; Freire-Medeiros et al., 2020; Freire-Medeiros & Name, 2015, 2017; Worms & Sluyter, 2018). The residents adapt to the flow of tourists, creating positive relationships between them and the ACC, e.g. visit guide tours through *Complexo do Alemao* ACC were offered and stands selling drinks and snacks were located outside the stations (Espósito Galarce & da Silva, 2016; Freire-Medeiros & Name, 2015). However, the ACC in Rio de Janeiro failed in their objectives. Despite being free, the favela's residents did not use the ACC, and the tourist flow did not cover operational costs (Cavalcanti & Campos, 2022). Consequently, both systems (*Complexo do Alemo* and *Providencia*) closed operations in 2016 (Cavalcanti & Campos, 2022; Duarte Santos & Soares Gonçalves, 2017; Espósito Galarce, 2020).

5.4. Politics and governance

Political decisions have played a pivotal role in implementing ACC projects in LAC. For instance, the first *Metrocable* line (Colombia) was a local effort, primarily because the national government chose not to support it due to concerns about project uncertainty (Brand & Dávila, 2011). After its success, the national government developed public policies to support and promote similar projects in other cities, including Manizales, Cali, Pereira, Bogotá, and additional lines in Medellín. Meanwhile, Rio de Janeiro's politicians implemented the ACC (2010) without considering proper technical support, i.e. inhabitant's necessities were left aside (Cavalcanti & Campos, 2022; Duarte Santos & Soares Gonçalves, 2017). They concentrated more on the prestige and tourist flow brought by important events such as the Olympic Games (2016) and the FIFA World Cup (2014), leaving aside the social impacts on the community (Cavalcanti & Campos, 2022; Freire-Medeiros et al., 2020; Freire-Medeiros & Name, 2015). In contrast, the La Paz ACC network (2014) had the total support of the national government, creating an ambitious plan to connect the city through this technology (Garsous et al., 2019; Koch, 2013; Martinez et al., 2018). Nevertheless, frictions between the national and local governments were reported due to different visions of mobility in the long run for La Paz (Koch, 2013).

5.5. Crime, health, and housing

Regarding crime and violence, a positive impact in Medellín was found, in the neighbourhoods where the ACC was built. For instance, there is a decrease in the homicide rate and residents' reports of violence, especially near the stations (Cerdá et al., 2012; Matsuyuki et al., 2020). Furthermore, the role of ACC as a mechanism of presence and control of the state has also been pointed out due to an increase of people observing the neighbourhoods' dynamics from the sky (Capillé & Reiss, 2019; Coupé, 2013; Freire-Medeiros et al., 2020).

Impacts on the health regarding physical activity and environment, and the housing market and rent have been scarcely studied. The *Transmicable* ACC registered the lowest exposure to pollutants during travel compared to BRT feeders, traditional buses, paratransit services and walking (Morales-Betancourt et al., 2023). Nevertheless, residents do not experience the air quality benefits after the ACC implementation despite high expectations before the construction (Guzman et al., 2022). In addition, the project help to maintain a high level of physical activity in the neighbourhood through transport-related walking trips (Baldovino-Chiquillo et al., 2023).

Finally, no relation has been found in the housing prices and rental market with the deployment of the ACC in Medellín, despite the transactions increasing after implementing the first line (Bocarejo et al., 2014; Coupé, 2013). However, changes in the land use near the stations (e.g. the flourishing of businesses, shops, bars, etc.) and neighbourhood dynamics (changes in the rental market, increase of touristic flow) suggest effects of gentrification in the long term that should be studied. For example, Posada and García-Suaza (2022) found a decrease in informal housing with the construction of *Metrocable Line H* (Medellín) increased by the proximity to the ACC's stations; however, the authors remarked that several mechanisms could influence this causal relationship, e.g. the increase of accessibility to the labour market and housing rents.

6. Conclusions

The Aerial Cableway Transit (ACT) technology in urban environments is divided in two: Aerial Tramways (AT) and Detachable Gondolas (DG) (Aerial Cable Cars-ACC in transport literature). The first has a maximum capacity of 2000 pphpd, while DG could reach up to 6500 pphpd. Monocable Detachable Gondolas (MDG) are the most adopted technology in LAC as a transport mode. Other DG technologies, such as Tricable or Bicable, have been implemented in global north countries. The main differences are the cabin and line capacity and the construction costs. Our review has not found Aerial Tramway (AT) deployments as a transit mode over the past decade.

The topographical difficulties and spatial inequity patterns in many LAC cities have led to the more rapid adoption of ACC in this context, especially since 2010, when more than 90% of the lines were built. Our review identifies two main roles of ACC in LAC cities in relation to the service area's sociodemographic, topographic, and mobility characteristics. First, the ACC reached low-income and vulnerable neighbourhoods placed in hilly terrain and the peripheries of the cities. The ACC works as a feeder of broader transport systems, increasing the accessibility and social inclusion of these zones. Second, the ACC has been planned as the structure of the public transport system, reaching multiple zones of the city (especially the most attractive zones, e.g. the centre) due to a steeper topography throughout the built environment. In both cases, the limited capacity of the technology could be a burden in relation to an increase in passenger demand or the expansion of the ACC network.

The ACC implementations have a deep connection with social inclusion. The empirical evidence shows how complementary projects and social urbanism were essential to impact vulnerable communities comprehensively. Furthermore, travel time and cost reductions were the most crucial mobility outcome. Politics and governance have been crucial in adopting this transit mode in LAC cities. Initially, the local authorities took most of the effort and risks. At the same time, the national government started to be more involved as the success and societal benefits of the first lines were discovered. The empirical evidence found allowed us to identify future research directions and recommendations for policymakers which will be described next.

6.1. Future research needs

While significant empirical research has shed light on the impacts of aerial cable cars (ACC) as a transport mode, there remains a need for further investigation into several key areas. Specifically, research should delve into the effects of ACC on gentrification, road safety, or air pollution. Notably, transport equity from an accessibility perspective has only been examined in the case of Medellín by Bocarejo et al. (2014). Future research should build upon this line, employing innovative calculations that move beyond aggregated measures to individual measures (Vecchio et al., 2020). Researchers can analyse the effects in greater detail by utilising accessibility-activity models and incorporating individual characteristics from household travel surveys and built environment variables from secondary sources (Luz et al., 2022; Vecchio et al., 2020).

Moreover, to enhance our understanding of travel behaviour about ACC, there is a need for further exploration of user profiles and the modal shift between different transport modes. Existing studies have highlighted the influence of factors such as violence and crime, social capital, satisfaction with the neighbourhood, and other latent variables in the modal choice of ACC, particularly in transport-disadvantaged communities (Agudelo V. et al., 2013; Guzman, Cantillo-García, et al., 2023; Guzman, Arellana et al., 2023; Sarmiento Ordosgostia et al., 2013). It is essential to identify additional latent variables that influence the use of ACC in these communities.

Additionally, while traditional buses, paratransit, motorcycles, and walking play significant roles in daily mobility, ACC primarily attracts workers and students. Further research is needed to understand why people prefer other transport modes, especially when making the modal shift from private vehicles to ACC to enhance sustainable mobility (Okami et al., 2022). Multimodality is another crucial aspect that warrants investigation, particularly regarding the modal choice for first and last-mile trips to access the ACC. Furthermore, examining the combination of ACC with micromobility options, such as transporting bicycles and scooters inside the cabins, presents potential for enhancing the overall transportation experience.

Finally, research around case studies should consider three unexplored dimensions. First, most of the studies found involved cities where ACC operates as a feeder of the public transport system, while there is scarce analysis when it is the system's backbone. Second, the city's size has implications for the transport system due to differences in the service area and travel behaviour; exploring medium-sized cities should be a priority. Thirdly, the impact of ACC in other contexts in LAC (e.g. México, Ecuador, Venezuela, or Dominican Republic), Northern Africa (e.g. Algeria) and Europe (e.g. France, Germany, or the UK) must be studied. Differences between global south and north countries' case studies would be relevant to analyse.

6.2. Policy recommendations

ACCs can help reduce spatial inequity and social exclusion in transport-disadvantaged communities (Posada & García-Suaza, 2022). Complementary projects are crucial and participatory budgeting has shown promising results in increasing community engagement with the ACC, which is critical for the success of the transport project. The implementation of ACC's should be complemented with other transit modes to ensure accessibility due to a limitation in transport capacity and flexibility. Moreover, the political role should be guided by technical decisions, prioritising the societal impacts.

The integration of the ACC into the public transport system should follow: (i) physical and fare integration with other transit modes, preventing competition among transit modes potentially increasing the ACC's ridership; (ii) Paratransit services should be considered as stakeholders, especially to complement the first and last mile part of the journey (Villar-Uribe, 2021), (iii) Bikes and micro-mobility vehicles should be allowed to transport inside ACC cabins (see examples of Manizales, Bogotá, and La Paz) without additional costs to other passengers. This will prompt multimodal trips and increase the ACC's service area. Additionally, fare policies must be considered with the integration, especially among usual travellers and vulnerable groups.

Furthermore, the built environment around the stations and towers must prompt active mobility (walking and cycling) as the first and last-mile mode of transport. The project should include construction and optimisation of sidewalks and bike paths and improving lighting to raise security. This objective is challenging to achieve in zones with rugged topography; outdoor electric stairways (Medellín or Rio de Janeiro) are good examples of complementary infrastructures that could increase the local accessibility of the community (Naef, 2018).

Finally, the ACC systems will always have the potential to attract a significant flow of tourists because of their privileged view of the city. Nevertheless, these benefits could be concentrated in specific spots, like in the first *Metrocable* line in Medellín. Transport planners and decision-makers should communicate this potential to the residents with the positive and negative effects. Including tourism stakeholders in the design phase could help to achieve these goals.

Acknowledgements

The authors would like to acknowledge the comments of Orlando Sabogal-Cardona in the early drafts of the manuscript.

Disclosure statement

No potential conflict of interest was reported by the author(s).

Funding

This work was supported by the Ministerio de Ciencia, Tecnología e Innovación of Colombia under Grant 906, of which Santiago Cardona Urrea is a recipient.

ORCID

Santiago Cardona-Urrea http://orcid.org/0000-0002-5032-3145
Jaime Soza-Parra http://orcid.org/0000-0003-1530-0439
Dick Ettema http://orcid.org/0000-0001-8404-5510

References

Agudelo V., L., Mejía, G. Á., Sarmiento Ordosgostia, I., & Córdoba, M. J. (2013). Users'daily experience of aerial cable-cars. In J. D. Dávila (Ed.), *Urban, mobility & poverty: Lessons from Medellín and Soacha, Colombia* (pp. 104–113). Development Planning Unit, UCL & Faculty of Architecture, Universidad Nacional de Colombia (Medellín campus).

Alshalalfah, B., Shalaby, A., & Dale, S. (2014). Experiences with aerial ropeway transportation systems in the urban environment. *Journal of Urban Planning and Development*, *140*(1), 04013001. https://doi.org/10.1061/(ASCE)UP.1943-5444.0000158

Alshalalfah, B., Shalaby, A., Dale, S., & Othman, F. M. Y. (2012). Aerial ropeway transportation systems in the urban environment: State of the art. *Journal of Transportation Engineering*, *138*(3), 253–262. https://doi.org/10.1061/(ASCE)TE.1943-5436.0000330

Alshalalfah, B., Shalaby, A., Dale, S., & Othman, F. M. Y. (2013). Improvements and innovations in aerial ropeway transportation technologies: Observations from recent implementations. *Journal of Transportation Engineering*, *139*(8), 814–821. https://doi.org/10.1061/(ASCE)TE.1943-5436.0000548

Baldovino-Chiquillo, L., Sarmiento, O. L., O'Donovan, G., Wilches-Mogollon, M. A., Aguilar, A. F., Alberto Florez-Pregonero, A., Martínez, P. A., Arellana, J., Guzmán, L. A., Yamada, G., Rodriguez, D. A., & Diez-Roux, A. V. (2023). Effects of an urban cable car intervention on physical activity: The TrUST natural experiment in Bogotá, Colombia. *The Lancet Global Health*, *11*(8), e1290–e1300. https://doi.org/10.1016/S2214-109X(23)00274-7

Bocarejo, J. P., & Oviedo, D. R. (2012). Transport accessibility and social inequities: A tool for identification of mobility needs and evaluation of transport investments. *Journal of Transport Geography*, *24*, 142–154. https://doi.org/10.1016/j.jtrangeo.2011.12.004

Bocarejo, J. P., Portilla, I. J., Velásquez, J. M., Cruz, M. N., Peña, A., & Oviedo, D. R. (2014). An innovative transit system and its impact on low income users: The case of the Metrocable in Medellín. *Journal of Transport Geography*, *39*, 49–61. https://doi.org/10.1016/j.jtrangeo.2014.06.018

Braga, P. C. (2017). Rethinking the Providence Hill cable car: Transit, equity, and urban design in Rio de Janeiro. *Journal of Urbanism: International Research on Placemaking and Urban Sustainability*, *10*(3), 310–317. https://doi.org/10.1080/17549175.2016.1254673

Brand, P. (2010). El urbanismo social de Medellín, Colombia. *Arquitectura: Revista Del Colegio Oficial de Arquitectos de Madrid (COAM)*, *359*, 99–103.

Brand, P., & Dávila, J. D. (2011). Mobility innovation at the urban margins: Medellín's Metrocables. *City*, *15*(6), 647–661. https://doi.org/10.1080/13604813.2011.609007

Brand, P., & Dávila, J. D. (2013). Metrocables and "social urbanism": Two complementary strategies. In J. D. Dávila (Ed.), *Urban, mobility & poverty: Lessons from Medellín and Soacha, Colombia* (pp. 46–54). Development Planning Unit, UCL & Faculty of Architecture, Universidad Nacional de Colombia (Medellín campus).

Canon Rubiano, L., Portabales Gonzalez, I., Flor, L., Duarte, D., & Sierra Valdivieso, L. (2020). *Urban aerial cable cars as mass transit systems : Case studies, technical specifications, and business models (English)*. World Bank Group. http://documents.worldbank.org/curated/en/

140251611326011996/Urban-Aerial-Cable-Cars-as-Mass-Transit-Systems-Case-Studies-Technical-Specifications-and-Business-Models

Capillé, C., & Reiss, C. (2019). Formas de mobilidade, visibilidade e poder em Medellín: Metrocable e Parques-Biblioteca. *Bitácora Urbano Territorial*, *29*(3), 79–90. https://doi.org/10.15446/bitacora.v29n3.67844

Cavalcanti, M., & Campos, M. (2022). A fantástica obra da Paz: O teleférico do alemão e a produção de infraestrutura Urbana no Rio de janeiro. *Dados*, *65*(2), 1–32. https://doi.org/10.1590/dados.2022.65.2.259

Cerdá, M., Morenoff, J. D., Hansen, B. B., Tessari Hicks, K. J., Duque, L. F., Restrepo, A., & Diez-Roux, A. V. (2012). Reducing violence by transforming neighborhoods: A natural experiment in Medellin, colombia. *American Journal of Epidemiology*, *175*(10), 1045–1053. https://doi.org/10.1093/aje/kwr428

Cordoba, D. Z., Stanley, J., & Stanley, J. (2014). Reducing social exclusion in highly disadvantaged districts in Medellín, Colombia, through the provision of a cable-car. *Social Inclusion*, *2*(4), 1–13. https://doi.org/10.17645/si.v2i4.127

Coupé, F. (2013). The metrocables: Risk, poverty, and inclusion. In J. D. Dávila (Ed.), *Urban, mobility & poverty: Lessons from Medellín and Soacha, Colombia* (pp. 68–80). Development Planning Unit, UCL & Faculty of Architecture, Universidad Nacional de Colombia (Medellín campus).

Coupé, F., & Cardona, J. G. (2013). Impact of the metrocables on the local economy. In J. D. Dávila (Ed.), *Urban, mobility & poverty: Lessons from Medellín and Soacha, Colombia* (pp. 89–103). Development Planning Unit, UCL & Faculty of Architecture, Universidad Nacional de Colombia (Medellín campus).

Duarte Santos, L. B., & Soares Gonçalves, R. (2017). A questão da mobilidade nos projetos de urbanização: o teleférico como modal de transporte nas favelas. *Escenarios: Empresa y Territorio*, *6*(8), 15–34. http://esumer.edu.co/revistas/index.php/escenarios/article/view/41

El Financiero. (2021, August 27). *Cablebús de la CDMX logra Récord Guinness*. El Financiero; El Financiero. https://www.elfinanciero.com.mx/cdmx/2021/08/26/cablebus-de-la-cdmx-logra-record-guiness/

Escobar, D. A., & Garcia, F. J. (2011). Impacto de un sistema de transporte tipo Cable sobre la movilidad Urbana, Caso Manizales (Colombia). *Avances Investigación En Ingeniería*, *8*(1), 92–98. https://revistas.unilibre.edu.co/index.php/avances/article/view/2609

Escobar, D. A., Sarache, W., & Jiménez-Riaño, E. (2022). The impact of a new aerial cable-car project on accessibility and CO2 emissions considering socioeconomic stratum. A case study in Colombia. *Journal of Cleaner Production*, *340*(1), 130802. https://doi.org/10.1016/j.jclepro.2022.130802

Escobar, D. A., Tapasco, O., & Giraldo, J. (2015). Medición de Desempeño del Sistema de Transporte Cable Aéreo de la Ciudad de Manizales en Colombia, usando Tres Enfoques: Analítico, Simulado y de Accesibilidad Urbana. *Información Tecnológica*, *26*(6), 199–210. https://doi.org/10.4067/S0718-07642015000600020

Espósito Galarce, F. (2020). Espacios residuales entre la arquitectura y la infraestructura. El teleférico del Complexo do Alemão. *Bitácora Urbano Territorial*, *30*(3), 277–290. https://doi.org/10.15446/bitacora.v30n3.86950

Espósito Galarce, F., & da Silva, R. C. M. (2016). Apropiación, uso y abandono de los espacios residuales provocados por el teleférico del Complexo do Alemão, Río de Janeiro. *Arquitetura Revista*, *12*(1), 11–23. https://doi.org/10.4013/arq.2016.121.02

Fan, Y., Guthrie, A., & Levinson, D. (2016). Waiting time perceptions at transit stops and stations: Effects of basic amenities, gender, and security. *Transportation Research Part A: Policy and Practice*, *88*, 251–264. https://doi.org/10.1016/j.tra.2016.04.012

Flesser, M., & Friedrich, B. (2022). Are we taking off? A critical review of urban aerial cable cars as an integrated part of sustainable transport. *Sustainability*, *14*(20), 13560. https://doi.org/10.3390/su142013560

Freire-Medeiros, B., de Mattos Rocha, L. I. A., Farias, J., & Name, L. (2020). Of cable-cars and helicopters: Mobility regimes and the politics of visibility in the favelas of Rio de Janeiro. *Visual Studies*, *35*(5), 478–488. https://doi.org/10.1080/1472586X.2020.1840099

Freire-Medeiros, B., & Name, L. (2015). "Peace, love, and fun" an aerial cable car and the traveling favela. In J. Cidell & D. Prytherch (Eds.), *Transport, mobility, and the production of urban space* (pp. 263–278). Routledge Taylor and Francis Group.

Freire-Medeiros, B., & Name, L. (2017). Does the future of the favela fit in an aerial cable car? Examining tourism mobilities and urban inequalities through a decolonial lens. *Canadian Journal of Latin American and Caribbean Studies / Revue Canadienne des études Latino-Américaines et Caraïbes*, *42*(1), 1–16. https://doi.org/10.1080/08263663.2017.1281944

Galvin, M., & Maassen, A. (2020). Connecting formal and informal spaces: A long-term and multi-level view of Medellín's Metrocable. *Urban Transformations*, *2*(1). https://doi.org/10.1186/s42854-020-00008-8

Garnica Quiroga, V. (2020). El impacto y la percepción de los usuarios acerca del servicio del TransMicable en Bogotá D.C., como modo de última y primera milla. *Territorios*, *44*, 1–14. https://doi.org/10.12804/revistas.urosario.edu.co/territorios/a.8456

Garsous, G., Suárez-Alemán, A., & Serebrisky, T. (2019). Cable cars in urban transport: Travel time savings from La Paz-El Alto (Bolivia). *Transport Policy*, *75*, 171–182. https://doi.org/10.1016/j.tranpol.2017.05.005

Gómez, A. (2023, February 9). *En noviembre, lista la Línea 3 del Cablebús*. Contralínea. https://contralinea.com.mx/interno/semana/en-noviembre-lista-la-linea-3-del-cablebus/

Gonçalves, C., & Bandeira, R. (2017). Transporte público em favelas: Análise da percepção da acessibilidade ao teleférico do Alemão. *Transportes*, *25*(2), 15. https://doi.org/10.14295/transportes.v25i2.1280

Goodship, P. (2015). The impact of an urban cable-car transport system on the spatial configuration of an informal settlement. *The Case of Medellin. SSS 2015 - 10th International Space Syntax Symposium*, 1–17.

Goodship, P. (2016). Understanding the role of spatial connectivity in integrating informal settlements, through the case of Medellin's urban cable-cars. *Proceedings of the International Conference on Education and Research in Computer Aided Architectural Design in Europe*, *2*, 79–88. https://doi.org/10.52842/conf.ecaade.2016.2.079

Guevara-Aladino, P., Baldovino-Chiquillo, L., Rubio, M. A., Slesinski, C., Levy, P., Flórez, D., Flórez, S., & Sarmiento, O. L. (2022). Winds of change: The case of TransMiCable, a community-engaged transport intervention improving equity and health in Bogotá, Colombia. *Cities & Health*, 7, 32–40. https://doi.org/10.1080/23748834.2022.2038981

Guzman, L. A., Arellana, J., Oviedo, D., Castaño, D., & Sarmiento, O. L. (2023). Lifting urban mobility for the poor: Cable-cars, travel satisfaction and subjective well-being. *Transportation Research Part D: Transport and Environment*, *119*(12), 103765. https://doi.org/10.1016/j.trd.2023.103765

Guzman, L. A., Cantillo-Garcia, V. A., Arellana, J., & Sarmiento, O. L. (2022). User expectations and perceptions towards new public transport infrastructure: Evaluating a cable car in Bogotá. *Transportation*, *50*(3), 751–771. https://doi.org/10.1007/s11116-021-10260-x

Guzman, L. A., Cantillo-Garcia, V. A., Arellana, J., & Sarmiento, O. L. (2023). Evaluating the effects of social capital on travel behavior: Modeling the choice of an innovative transport mode. *Travel Behaviour and Society*, *33*(3), 100612. https://doi.org/10.1016/j.tbs.2023.100612

Heinrichs, D., & Bernet, J. S. (2014). Public transport and accessibility in informal settlements: Aerial cable cars in Medellín, Colombia. *Transportation Research Procedia*, *4*, 55–67. https://doi.org/10.1016/j.trpro.2014.11.005

Jurado, D., & Mesa-Arango, R. (2019). *Effect of queues, time perception, and user behavior on the selection of urban aerial ropeway transit – metrocable Medellín*. Paper 19-03730, 98th Annual Meeting of the Transportation Research Board, 2019. http://dx.doi.org/10.2139/ssrn.4238047.

Koch, F. (2013). La Paz - El Alto: The old dream of an aerial cable-car. In J. D. Dávila (Ed.), *Urban, mobility & poverty: Lessons from Medellín and Soacha, Colombia* (pp. 183–190). Development Planning Unit, UCL & Faculty of Architecture, Universidad Nacional de Colombia (Medellín campus).

Leitner. (n.d.-a). *Aerial tramways*. Retrieved March 23, 2023, from https://www.leitner.com/en/products/ropeway-systems/detail/aerial-tramways/

Leitner. (n.d.-b). *Bicable gondola lifts*. Retrieved March 23, 2023, from https://www.leitner.com/en/products/ropeway-systems/detail/bicable-gondola-lifts/

Leitner. (n.d.-c). *Detachable gondola lifts*. Retrieved March 23, 2023, from https://www.leitner.com/en/products/ropeway-systems/detail/detachable-gondola-lifts/

Leitner. (n.d.-d). *Tricable gondola lifts*. Retrieved March 23, 2023, from https://www.leitner.com/en/products/ropeway-systems/detail/tricable-gondola-lifts/

Luz, G., Barboza, M. H. C., Portugal, L., Giannotti, M., & van Wee, B. (2022). Does better accessibility help to reduce social exclusion? Evidence from the city of São Paulo, Brazil. *Transportation Research Part A: Policy and Practice*, *166*(11), 186–217. https://doi.org/10.1016/j.tra.2022.10.005

Martinez, S., Sanchez, R., & Yañez-Pagans, P. (2018). *Getting a Lift: The Impact of Aerial Cable Cars in La Paz, Bolivia*. Interamerican Development Bank Working Paper IDB-WP-009 56. https://publications.iadb.org/publications/english/viewer/2018DEC11_Getting_a_Lift.pdf

Matsuyuki, M., Okami, S., Nakamura, F., & Sarmiento-Ordosgoitia, I. (2020). Impact of aerial cable car in low-income area in Medellín, Colombia. *Transportation Research Procedia*, *48*, 3264–3282. https://doi.org/10.1016/j.trpro.2020.08.150

Mexicable. (2023). *Mexicable 2, Línea Verde*. Mexicable. https://www.mexicable.com/#/lineaVerde/inicio

Milan, B. F., & Creutzig, F. (2017). Lifting peripheral fortunes: Upgrading transit improves spatial, income and gender equity in Medellin. *Cities*, *70*(7), 122–134. https://doi.org/10.1016/j.cities.2017.07.019

Mi Teleférico. (2022). *Indicadores de gestión e impacto*. https://www.miteleferico.bo/institucion/informacion-estadistica

Morales-Betancourt, R., Wilches-mogollon, M. A., Sarmiento, O. L., Mendez, D., Angulo, D., Filigrana, P., Arellana, J., Guzman, L. A., Garzon, G., Gouveia, N., Levy, P., & Diez-roux, A. V. (2023). Commuter's personal exposure to air pollutants after the implementation of a cable car for public transport: Results of the natural experiment TrUST. *Science of the Total Environment*, *865*(12), 160880. https://doi.org/10.1016/j.scitotenv.2022.160880

Naef, P. (2018). Touring the 'comuna': Memory and transformation in Medellin, Colombia. *Journal of Tourism and Cultural Change*, *16*(2), 173–190. https://doi.org/10.1080/14766825.2016.1246555

Okami, S., Matsuyuki, M., Sarmiento-Ordosgoitia, I., & Nakamura, F. (2022). Residents' travel behavior in a low-income settlement with aerial cable cars in Medellin, Colombia. *Case Studies on Transport Policy*, *10*(2), 1332–1342. https://doi.org/10.1016/j.cstp.2022.04.016

Pérez Angel, G. (1997). *Colgados de las nubes: historia de los cables aéreos en Colombia*. Fondo Cultural Cafetero, Bancafé.

Posada, H. M., & García-Suaza, A. (2022). Transit infrastructure and informal housing: Assessing an expansion of Medellín's Metrocable system. *Transport Policy*, *128*(8), 209–228. https://doi.org/10.1016/j.tranpol.2022.09.011

Quiñones, L. M. (2020). Sexual harassment in public transport in Bogotá. *Transportation Research Part A: Policy and Practice*, *139*(6), 54–69. https://doi.org/10.1016/j.tra.2020.06.018

Reichenbach, M., & Puhe, M. (2022). Struggling with inertia: Regime barriers opposing planning and implementation of urban ropeways. *Journal of Urban Mobility*, *2*(5), 100023. https://doi.org/10.1016/j.urbmob.2022.100023

Rodas-Zuleta, M. del M., Cardona, S., & Escobar, D. A. (2022). Gender-based violence and Women's mobility, findings from a medium-sized Colombian city: A quantitative approach. *Journal of Transport & Health*, *25*(4), 101376. https://doi.org/10.1016/j.jth.2022.101376

Sarmiento, O. L., Higuera-Mendieta, D., Wilches-Mogollon, M. A., Guzman, L. A., Rodríguez, D. A., Morales, R., Méndez, D., Bedoya, C., Linares-Vásquez, M., Arévalo, M. I., Martínez-Herrera, E., Montes, F., Meisel, J. D., Useche, A. F., García, E., Triana, C. A., Medaglia, A. L., Hessel, P., Arellana, J., … Diez Roux, A. V. (2020). Urban transformations and health: Methods for TrUST—a natural experiment evaluating the impacts of a mass transit cable Car in bogotá, Colombia. *Frontiers in Public Health*, *8*(8). https://doi.org/10.3389/fpubh.2020.00064

Sarmiento Ordosgostia, I., Córdoba M. J., Mejía G. Á., & Agudelo V. L. (2013). Metrocables and travel patterns in Medellín: The inclusion of latent variables in transport models. In J. D. Dávila (Ed.), *Urban, mobility & poverty: Lessons from Medellín and Soacha, Colombia* (pp. 81–88). Development Planning Unit, UCL & Faculty of Architecture, Universidad Nacional de Colombia (Medellín campus).

Taylor, C. L. (1938). Aerial ropeway transport. *Proceedings of the Institution of Mechanical Engineers*, *139*(1), 525–529. https://doi.org/10.1243/PIME_PROC_1938_139_018_02
Težak, S., Sever, D., & Lep, M. (2016). Increasing the capacities of cable cars for use in public transport. *Journal of Public Transportation*, *19*(1), 1–16. https://doi.org/10.5038/2375-0901.19.1.1
Tiessler, M., Ricci, G. L., & Bogenberger, K. (2020). Urban cableway systems: State-of-art and analysis of the Emirates Air Line, London. *2020 IEEE 23rd International Conference on Intelligent Transportation Systems, ITSC 2020*, 1–8. https://doi.org/10.1109/ITSC45102.2020.9294324
Tirachini, A., Godachevich, J., Cats, O., Muñoz, J. C., & Soza-Parra, J. (2022). Headway variability in public transport: A review of metrics, determinants, effects for quality of service and control strategies. *Transport Reviews*, *42*(3), 337–361. https://doi.org/10.1080/01441647.2021.1977415
Vecchio, G., Tiznado-aitken, I., & Hurtubia, R. (2020). Transport and equity in Latin America: A critical review of socially oriented accessibility assessments. *Transport Reviews*, *40*(3), 354–381. https://doi.org/10.1080/01441647.2020.1711828
Vergel-Tovar, C. E. (2022). Sustainable transit and land use in Latin America and the Caribbean: A review of recent developments and research findings. In *Advances in transport policy and planning* (1st ed., Vol. 9). Elsevier. https://doi.org/10.1016/bs.atpp.2021.05.001
Villar-Uribe, J. R. (2021). Modernización del transporte público en la periferia Urbana: ¿el fin del transporte informal? Caso de estudio: sistema de cable aéreo Transmicable en la localidad de Ciudad Bolívar, Bogotá - Colombia. *Urbe. Revista Brasileira de Gestão Urbana*, *13*, e20190367. https://doi.org/10.1590/2175-3369.013.e20190367
Vuchic, V. R. (2007). *Urban transit systems and technology*. John Wiley & Sons. https://doi.org/10.1080/01944360801940623
Worms, J. L., & Sluyter, A. (2018). Conceived versus lived social spaces and the transformation of the Morro da Providência Favela of Rio de Janeiro since 2008. *The Latin Americanist*, *62*(4), 545–567. doi:10.1353/tla.2018.a712988

Appendix 1. Articles reviewed

	Main Methodology		
Case Study	Quantitative	Qualitative	Mixed
Medellín (Colombia)	Cerdá et al. (2012), Sarmiento Ordosgostia et al. (2013), Bocarejo et al. (2014), Cordoba et al. (2014), Goodship (2015, 2016), Jurado and Mesa-Arango (2019). Matsuyuki et al. (2020), Okami et al. (2022), Posada and García-Suaza (2022)	Brand (2010), Brand and Dávila (2013), Coupé (2013), Agudelo V. et al. (2013), Milan and Creutzig (2017), Capillé and Reiss (2019), Galvin and Maassen (2020)	Brand and Dávila (2011), Coupé and Cardona (2013), Heinrichs and Bernet (2014)
Bogotá (Colombia)	Garnica Quiroga (2020), Guzman et al. (2022), Guzman, Arellana, et al. (2023), Morales-Betancourt et al. (2023), Guzman, Cantillo-Garcia, et al. (2023), Baldovino-Chiquillo et al. (2023)	Guevara-Aladino et al. (2022)	Villar-Uribe (2021)
Manizales (Colombia)	Escobar et al. (2015), Escobar and Garcia (2011)		
Rio de Janeiro (Brazil)		Espósito Galarce and da Silva (2016), Espósito Galarce (2020), Freire-Medeiros and Name (2015, 2017), Gonçalves and Bandeira (2017), Worms and Sluyter (2018), Freire-Medeiros et al. (2020), Cavalcanti and Campos (2022)	Duarte Santos and Soares Gonçalves (2017), Braga (2017)
La Paz (Bolivia)	Garsous et al. (2019), Martinez et al. (2018)		