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World Transport Policy and Practice

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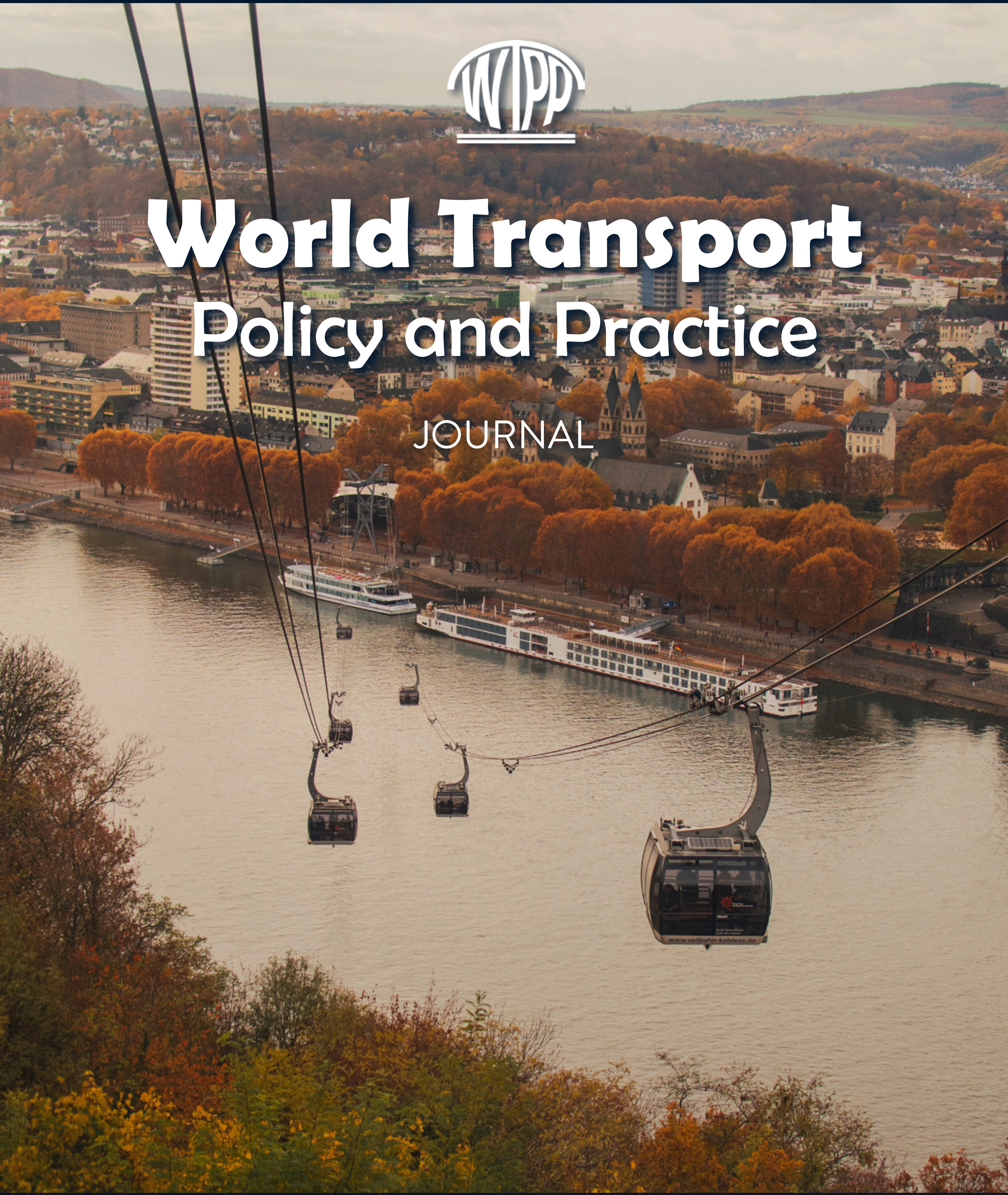

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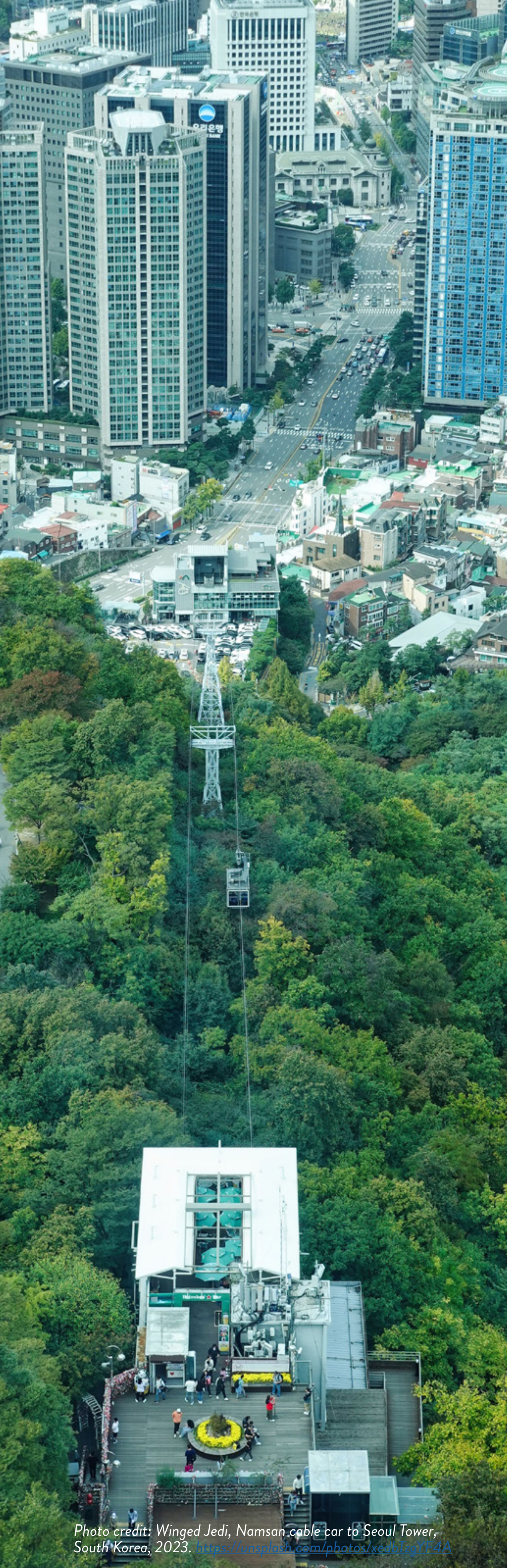

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WORLD TRANSPORT Policy and Practice JOURNAL

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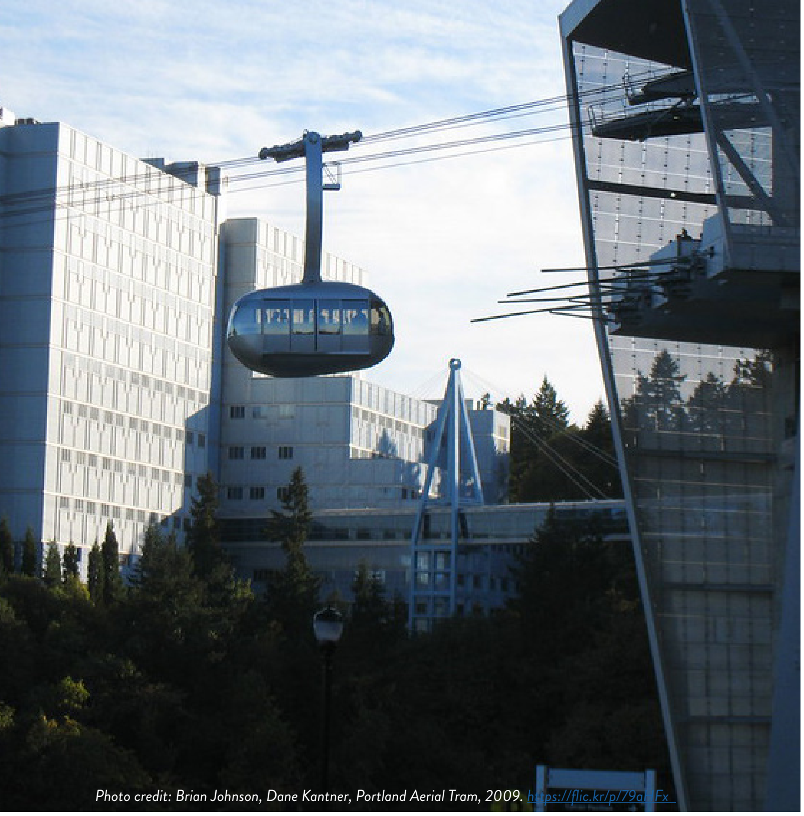

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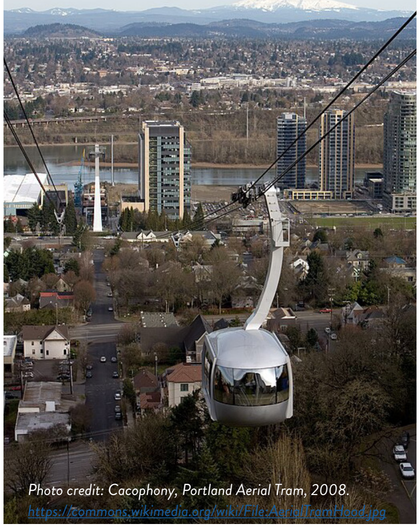

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ACKNOWLEDGEMENTS

Thanks to all who helped us revive the publication of this journal, especially to John Whitelegg, who trusted us with his vision, and to Marianna Grossman, vice president of Transportation Choices for Sustainable Communities (TCSC), without whose seed grant we could not have attempted such a daunting project.

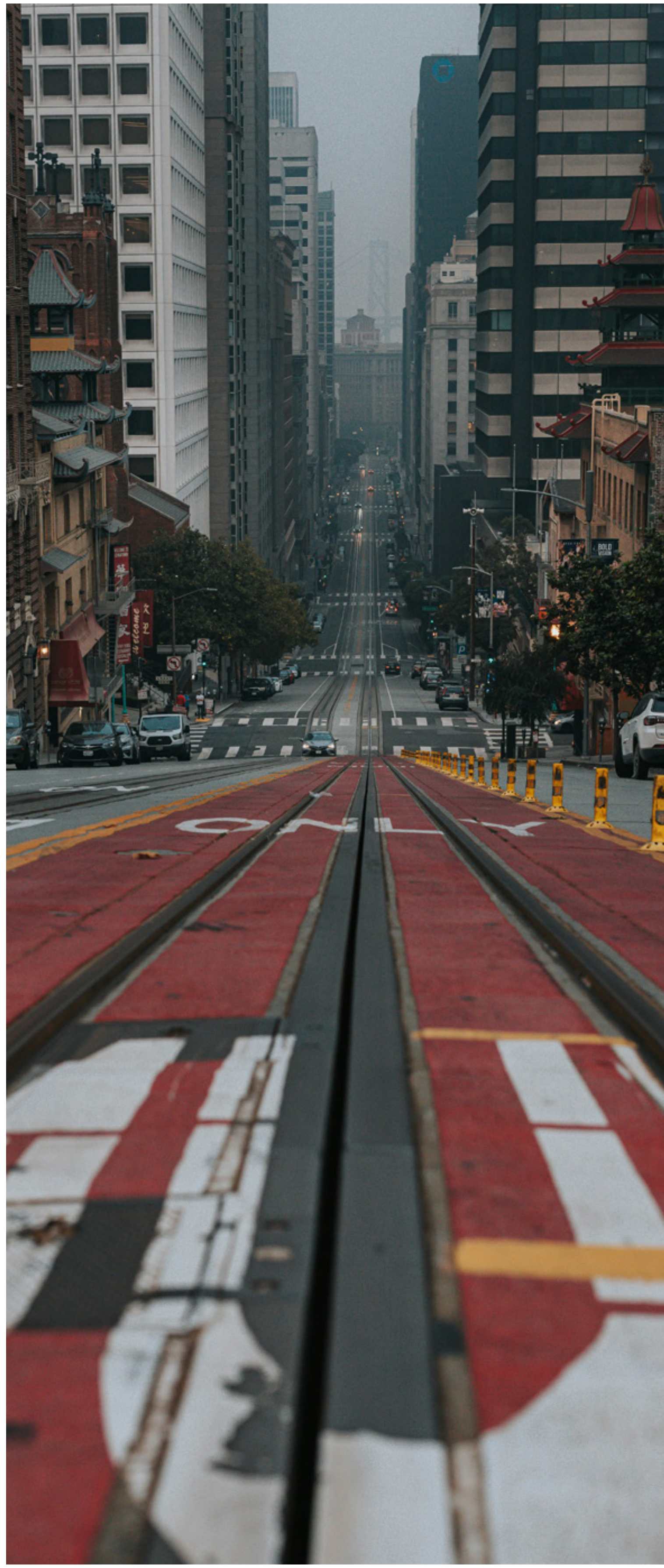
Thanks to the many friends and colleagues who volunteered to do all kinds of tasks from helping us trademark the name, to designing the logo, to answering numerous questions about a variety of topics: **Dave Campbell**, **Carol Levine**, and **Marivic Montilla**.
Thanks also to the **Principals Working Group** — **Chris, Charles**, and **Rick** — who helped to steer among the many decisions that came with the re-start of the journal.

Of course, a journal of this kind is dependent on the dedication and expertise of an editorial board and a vast invisible team of peer reviewers; such a team is an essential component of a professional journal. There are expenses to ensure a high-quality graphically engaging journal on a free and open platform; thus funds are needed from donations.

Please consider making a tax-deductible (USA 501c3 nonprofit) donation here: https://www.worldtransportjournal.org/donate

We are proud to continue the 27+ year tradition of a no-fee journal which enables us to publish practical solutions and analysis to promote sustainable transportation.

We thank all of you.



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As an open-access journal with no paywall and no Article Processing Charges (APC), WTPP depends on donations and sponsors. If you support our mission to publish practices and viewpoints from across the globe on how communities are implementing more sustainable transport options, both policies and infrastructure, please consider donating at least **$10** at ***https://www.worldtransportjournal.org/donate.***

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We sincerely appreciate the generous donation of Marianna Grossman whose seed grant enabled us to publish four issues of WTPP in 2022 and 2023.

EDITORIAL

This issue is dedicated to a unique transport mode: aerial cable cars (ACC). I have often thought this to be an underemployed mode of transport, having used (and enjoyed views from) ACC systems in both rural or mountain areas as well as urban areas including Barcelona, New York City, Rüdesheim along the Rhine River and in the Dolomites. Clearly, I am not the only one who thinks so: in March 2022, the World Economic Forum convened a coalition of cities to work together to advance the possibilities of aerial mobility in urban areas. *The Advanced and Urban Aerial Mobility (AAM/UAM) Cities and Regions Coalition* includes Paris, Amsterdam, São Paulo, Massachusetts, Orlando and Los Angeles.

In this issue, I am very pleased to provide case studies of successful aerial cable cars as well as analyses of potential projects. We first provide introductory articles defining the English and foreign terminology (e.g. gondola vs. tram) and a general summary of the mode's advantages and disadvantages. We then feature an article describing the amazing network of ACC in La Paz, Bolivia. There are also articles on two potential systems, one in Seattle and one in Kenya. We also feature an article about how autonomous vehicle technology combined with aerial systems could conceivably help aerial systems find even broader application in urban areas.

Photo credit: Kalisa Veer, Portland, OR, 2023. https://unsplash.com/photos/a-gondola-with-a-view-of-a-city-in-the-distance-NkVP7t5ogyg

There are many recent examples worldwide of aerial cable cars as urban transport fulfilling a unique **transport niche** in diverse communities. Examples include London, UK; Medellin, Colombia; Portland, Oregon, USA; and even the zoo in Oakland California, USA. We wish we could have included more articles about recent projects' origins including technical analyses of how they were determined to be superior to other alternatives (both economically and in terms of travel time), and how they garnered necessary support from both the community and politicians. However papers do not write themselves; thus this is an open solicitation for those familiar with these and other projects to submit such a paper to WTPP.

To increase awareness of some recent installations, this issue contains fact sheets about two recent projects, London's aerial cable car and Portland's aerial tram, and one potential project in Washington D.C. London's, (formerly called the Emirates Air Line and since June 2022 called IFS Cloud Cable Car), opened in 2012 and is now an established success both as transport and as a tourist attraction. Its origin partly stems from evidence that Professors Phil Goodwin and John Whitelegg (current Editorial Board member and former editor) gave at a public inquiry against the "Thames Gateway Bridge" in 2005/2006. They proposed alternatives to a roadway bridge that included the aerial cable car and a public transport/bike/pedestrian-only bridge. (https://www.liquisearch.com/thames_gateway_bridge/history) For more information about the planning of the London aerial cable car, we recommend papers from AET's European Transport Conference (ETC) in 2011 (A Cable Car for London) and in 2013 (Regeneration Impact of the Emirates Air Line) which are archived here: https://aetransport.org/en-gb/past-etc-papers

Speaking of ETC, (https://aetransport.org/about-etc) in September, I attended this conference in Milan Italy. It was my second time attending (having learned of ETC from colleague and Editorial Board member Charles Rivaslplata, who has been a member of AET for over 20 years). We're always pleased to see how Europe conceives transport solutions as being integral to the success of European cities, including their economic vitality and livability. The next two ETC conferences will be in Antwerp Belgium, in 2024 and 2025.

Photo credit: Freiburg, Michelle DeRobertis, 2009.

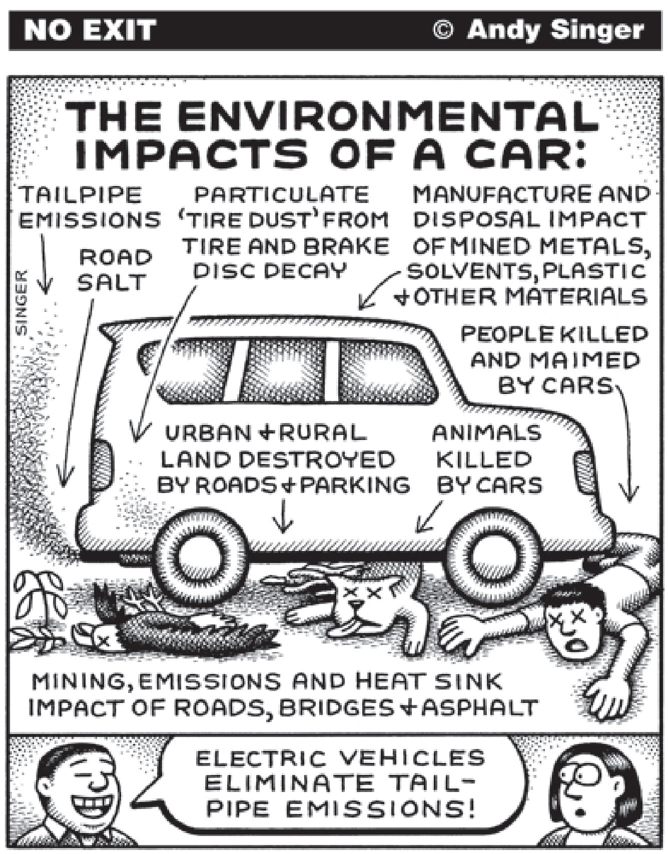
On the subject of livable cities, in October I attended the International Making Cities Livable (IMCL) conference for the first time. It was located in Poundbury and Dorchester, England. Poundbury, as some of you may know, is one of the initiatives of the Duchy of Cornwall built on the principles of architecture and urban planning as advocated by then Duke of Cornwall (now HM King Charles III) in "A Vision of Britain". The goal is to bring excellent architecture, beauty and sense of place to new developments, combining a mix of land-uses within walkable communities. (https://duchyofcornwall.org/poundbury.html)

The location of the next IMCL conference has yet to be decided, but I would like to nominate Vauban outside of Freiberg, Germany. It is an excellent example of new development that is not car-dependent, and where all ages feel comfortable walking and biking as well as having a frequent **light rail transit (Stadtbahn) connection to Freiburg**. https://www.greencitytimes.com/europe-s-most-sustainable-city/

Last but not least, with this issue we welcome **Charlotte Halpern of Sciences Po**, Centre for European Studies and Comparative Politics in Paris, France to our Editorial Board. Her enthusiasm and expertise is very much appreciated, as are the talents and energy of all of our Board members.

Happy reading.

Michelle DeRobertis
Editor



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ABSTRACTS AND KEYWORDS

PRIMER ON URBAN ROPEWAY TECHNOLOGY AND DEFINITIONS

Martin Pagel and Hazem El Jouzou

ABSTRACT

This paper provides a brief introduction to the terminology of aerial ropeways. It also presents foreign terms used for this mode.

KEYWORDS

aerial cable car, aerial ropeway, gondola, aerial tram, monocable detachable gondola, reversible tramway

AERIAL ROPEWAY SYSTEMS ADVANTAGES AND DISADVANTAGES

Hazem El Jouzou

ABSTRACT

The paper briefly compares aerial ropeway systems with other urban transit modes. It describes the advantages that aerial cable cars have in the areas of comfort, availability, reliability, safety, construction time, land take, cost, environment, and energy efficiency.

KEYWORDS

aerial cable car, aerial ropeway, gondola, aerial tram, monocable detachable gondola, reversible tramway

URBAN MOBILITY WITH ROPEWAYS – CONNECTING LIVES: CASE STUDY OF LA PAZ, BOLIVIA

Julia Schwärzler

ABSTRACT

Implementing the world's biggest urban ropeway network in La Paz was an exceptional project – for the investor, for the manufacturer, and especially for the people of La Paz. Building 10 ropeway lines in the space of six years called for an immense effort on the part of the entire team. The reward: happy city residents whose lives have been permanently improved by Mi Teleférico. Mobility affects people's quality of life, especially in densely populated cities such as Bolivia's two largest cities, La Paz and El Alto. Mi Teleférico impressively proves what it means to believe in a new solution and how it is possible to enable the people to accept something new. This acceptance leads to a socioeconomic upgrade with international recognition.

KEYWORDS

ropeways, urban mobility, sustainability, connections, future-proof, state-of-the-art technology

THE POTENTIAL ROLE OF AERIAL CABLE CAR IN PROMOTING SUSTAINABLE MOBILITY IN MOMBASA, KENYA

Evaristus M. Irandu

ABSTRACT

To address mobility problems facing rapidly growing cities around the world, aerial cable cars have been developed to supplement existing public transport systems. However, they have not been adequately studied. This paper discusses role of aerial cable cars in reducing traffic congestion in Mombasa City, examines environmental impacts likely to result from its installation and barriers that may hinder its operation. The research findings may assist policy makers in designing sustainable urban mass transit strategies in Kenya.

KEYWORDS

cable car, ferry service, Integrated public transport, Likoni Channel, Mombasa City

ABSTRACTS AND KEYWORDS

SEATTLE'S GONDOLA AMBITIONS: A CASE STUDY ON HOW GONDOLA TECHNOLOGY HAS BEEN CONSIDERED IN THE PACIFIC NORTHWEST

Martin Pagel

ABSTRACT

Currently gondola technology is often ignored in the environmental impact study process. This article looks at two opportunities in the Pacific Northwest to use aerial gondolas rather than traditional transit technologies and how gondolas may provide a better outcome.

KEYWORDS

gondolas, aerial cable car, carbon footprint

SIDEBAR: HOW AERIAL GONDOLAS MEET GOALS AND OBJECTIVES OF LONG RANGE TRANSIT PLANS

Claudia Hirschey

ABSTRACT

Many communities establish goals and objectives for their long range transit and transportation plans. This brief analysis demonstrates how aerial cable cars fit within those established by Sound Transit in the Seattle Washington (USA) metropolitan area.

KEYWORDS

gondolas, aerial cable cars, carbon footprint, long range plan

"If you can't live longer, live deeper."
-Italian Proverb

ADVANCED CABLEWAYS POTENTIAL FOR TRANSFORMATIVE URBAN APPLICATIONS

Jeral Poskey

ABSTRACT

Autonomous cableways introduce significant new capabilities over existing aerial ropeway technologies. The benefits of advanced cableways could greatly expand the application of cableways as urban transit systems.

KEYWORDS

aerial cable car, gondolas, autonomous vehicles, project Swyft

Photo credit: Sebastian Mantel, "Pan de Azucar" mountain in Rio de Janeiro, 2017. https://unsplash.com/photos/aerial-photography-of-cable-car-above-tree-covered-mountain-8zDww9TzDnE

CALL FOR PAPERS
for Future WTPP Issues

By the Editor

While WTPP publishes articles within the general topic of sustainable transportation that address reducing adverse consequences of transportation on humans and the environment, we are particularly interested in papers that fit into one of the following themes. There are many aspects and issues that could be addressed within each of these themes and indeed, each theme merits a special issue. Given the lead time involved in preparing articles, we are announcing these themes in this first volume of the relaunch of the journal in the hope that potential authors are motivated to share their experiences with these concepts.

We welcome articles that describe the policies and practices within the following themes:

Cable Cars

Case studies of the planning and implementation of aerial cable cars as well as funiculars. Papers would describe the niche in the transport system that the cable cars fill. Please provide data comparing the cable car to other modes considered in terms of travel time, pollution generated, energy / fossil fuel consumption, construction cost / time. Provide a description of the project background, planning considerations and hurdles that needed (or still need) to be resolved to implement the project.

Evaluation Metrics

Papers that describe how cities are expanding their project evaluation metrics beyond vehicle movement to include consideration of other modes as well as environmental, social and economic benefits. Papers could focus on a single metric which has traditionally been overlooked (e.g. noise) or could focus on a single project type since different projects need a different array of performance indicators.

"The most useless are those who never change through the years."

- James M. Barrie

Project types include: congestion pricing, bus-only lanes, pedestrian streets, green streets, shared spaces, low-emission zones, traffic-restricted zones (ZTL), road diets, slow streets, bike boulevards, and woonerfs.

Photo Credit: Jason Blackeye, Parnassos Ski Resort, Kelaria, Greece, 2018. https://unsplash.com/photos/two-person-riding-cable-car-bzJjHwdzBsA

Critique of Standards, Guidelines, Manuals, Textbooks

Papers that describe examples of standards, guidelines, manuals, or textbooks that thwart sustainable transportation. The papers would present examples of problems a specific standard or guideline has created in the past and how it should be (or has been) rectified. If indeed the problem standard or guideline has been changed, then the article would describe the resolution, discussion of benefits, as well as any unresolved issues.

Green Streets

Papers that present Green Streets case studies describing one or more of the many issues and challenges related to their design, implementation and the ensuing quantifiable environmental benefits. These issues range from design options, needed or helpful ordinances or legislation, and obtaining public support or overcoming resistance. Papers could present a before and after evaluation of the quantifiable benefits or describe the process to engage decision-makers and/or the community.

Livability and Transportation

Papers that address the relationship of transportation decisions on the livability of streets and neighborhoods, or on specific populations such as children, elderly, disabled and socially-economic disadvantaged communities. Papers could address how to build residential streets so they don't need to be retrofitted with traffic calming measures; highlight case studies of retrofitting a woonerf on an existing residential street; successful changes to speed limits to improve livability safety and noise; the role of public spaces and plazas in larger and small communities; ensuring transportation improvement funds are spent equitably in a community, or the special needs of elderly, children or other "transit-dependent" populations.

Photo credit: Jack Finnigan, Val-d'Isère, France, 2018. https://unsplash.com/photos/person-sitting-on-snow-wearing-snow-skis-yQWAzepQZIY

Photo credit: Dustan Woodhouse, Whistler, Canada, 2021. https://unsplash.com/photos/red-cable-car-over-the-clouds-Idq6QxGe95U

Goods Movement

Papers that describe strategies and practices for goods movement that reduce air pollution and carbon emissions and/or reduce the incidence of collisions and other safety issues. Papers could address the environmental benefits of rail, wind (e.g. sailboats), electric vehicle or human-powered deliveries schemes, the legal and policy setting of implementing new practices such as ordinances and permits, the logistical elements implementing a new scheme or the impacts of the global economy on freight transport's greenhouse gas emissions. Specific examples range from last mile deliveries within a car-free area to using rail/ trams or sailboats/barges instead of trucks.

Transportation and Housing

Papers that address the relationship of transportation decisions on housing supply, variety and density. Papers could address Transit-Oriented Development and its relation to housing supply and affordability (a broad issue) or the effect of unbundling parking from housing (a more focused issue). In particular, is unbundling parking effective when transit service is below a certain level? Which comes first: better transit or unbundling parking? What is the relationship between housing density and transit service (both local and regional)? Updated research and data that expand on the works of Paul Mees would be welcome.

UPCOMING 2024 CONFERENCES TO KNOW ABOUT

MAY 15-18, 2024 | CINCINNATI, OHIO

Congress for the New Urbanism (CNU)

More information: https://www.cnu.org/cnu32

JUNE 5-8, 2024 | BALTIMORE, MARYLAND

Project for Public Spaces /
4th International Placemaking Week

More information: https://www.placemakingweek.org/

JUNE 8-21, 2024 | GHENT, BELGIUM

Velo City: the yearly flagship event of the European Cyclists' Federation

More information:
https://www.velo-city-conference.com/

AUGUST 12-14, 2024 | DETROIT, MICHIGAN

Association of Pedestrian and Bicycle Professionals (APBP)

More information:
https://www.apbp.org/2024-conference

"The secret of getting ahead is getting started "
- Mark Twain

KEEP IN MIND FOR FALL

SEPTEMBER 18-20, 2024 | ANTWERP, BELGIUM

The European Transport Conference (ETC) is the annual conference of the Association for European Transport. The conference attracts transport practitioners and researchers from all over Europe and provides in-depth presentations on policy issues, best practice and research findings across the broad spectrum of transport.

More information: https://aetransport.org/etc

TBD (2023 was held in Kigali, Rwanda | October)

Walk 21 began in London in 2000 and has been holding annual conferences since.

More information: https://walk21.com/conference/

TBD (2023 was held in Dorchester, England | October)

IMCL: International Making Cities Livable Conference was begun in 1985 to provide a venue for sharing the best evidence-based lessons of great cities and towns to improve the quality of life for all.

More information: https://www.imcl.online/

Photo credit: Terren, Hurst, Huntsville, TX, USA, 2021. https://unsplash.com/photos/people-watching-concert-during-night-time-blgOFmPIlr0

PRIMER ON URBAN ROPEWAY TECHNOLOGY AND DEFINITIONS

By Martin Pagel and Hazem El Jouzou

This article introduces the terminology of ropeways (also called cable-propelled transit systems, cable car or cableway) in general and aerial ropeway transit (ART) or aerial lift in particular. It is compiled from various sources as indicated. We have also included terms from around the world as there are many such systems outside English speaking countries. The components of a ropeway system are first described followed by a brief discussion of the main technologies. Definitions are presented at the end.

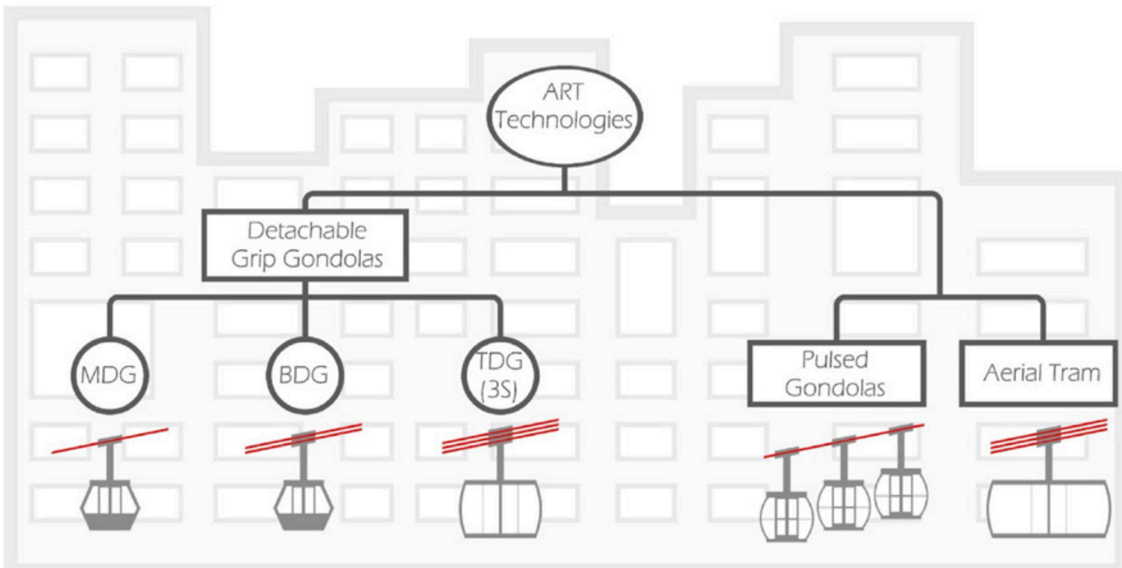

Figure 1: *ART Technologies. Source: Hazem El Jouzou. Data Source: CUP, 2013*

ROPEWAY COMPONENTS

An ART line consists of four major parts: the stations (terminals), the towers with roller batteries, the cables (ropes), and the cabins.

Stations - The stations are the major buildings of a line where riders get on and off the line. Each line has at least two terminals at each end with a bull-wheel. On one end the drive motor turns the bull-wheel which powers the haul-cable to move the cabins and on the other end a bull-wheel redirects the cable to form a continuous loop. Cabins slow down in the stations to allow riders to disembark and others to embark.

Some lines also have a few intermediate- or mid-stations to allow riders to get on and off along the line and change the direction of the line.

Turning-stations only change the direction of the line without allowing riders to disembark. Some mid-stations have two bull-wheels to allow cabins to switch from one cable loop to another.

A station can be at ground level, elevated or integrated into another building. A station may also provide garage space for cabins at night or maintenance.

Towers or Pylons - The towers are the pivot points which carry the cable and cabins between the stations. They bear the weight of the cabins and their passengers. Each tower has a set of roller batteries to guide the cables as the cabins pass on both sides of the tower. While traditionally towers were built as a rather utilitarian lattice structure or using one or two metal tubes, some urban installations have become more architecturally distinct such as in London, Portland Oregon and Toulouse France.

Cable or Rope - The cable supports the cabins as they travel between stations over the towers. They are made of steel strands which are twisted around a core so that they are flexible enough to wrap around the bull-wheel and over the roller batteries. In aerial tramways, there is both a haulage rope and a track rope (aerial tramways) while in MDG systems one rope supports both functions. (Alshalalfah et al, 2012). A **haul-cable** forms a loop which propels the cabins using a motor at one station. In a monocable system the haul-cable also carries the cabins while in multi-cable systems the cabins travel on wheels along one or two additional support cables.

Cabins or Cars - The cabins are the vessels which transport the riders. Circulating ropeways may use hundreds of small cabins with seats while reversible ropeways use two large cabins with passengers usually standing. Cabins are lightweight with large doors on one or both sides; most offer large windows and vents, others heated seats, fans or air-conditioning depending on local climate needs. Some provide Wifi, cameras, lighting and two-way communication systems.

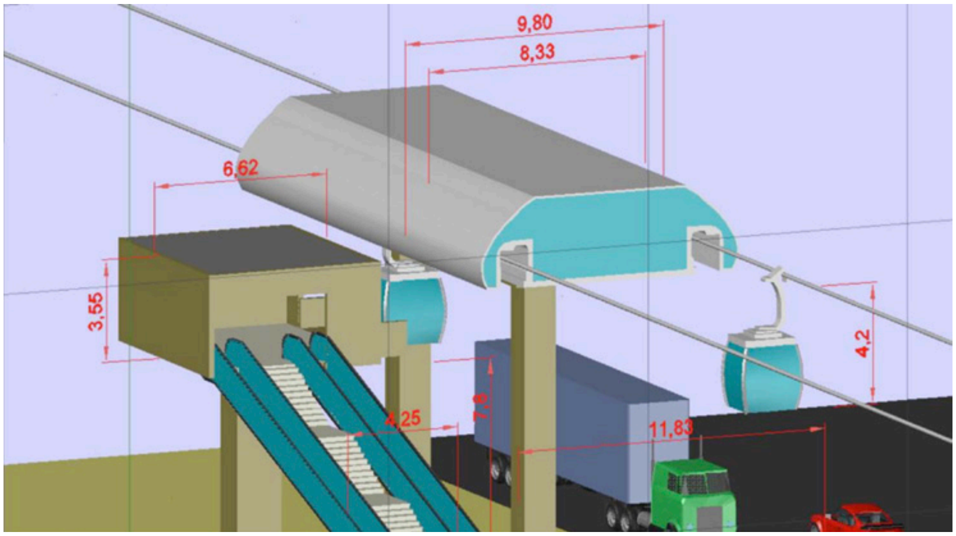

Figure 2: *Example of station design with minimum footprint.*
Source: Hazem El Jouzou. Data source: Doppelmayr Urban Solutions, 2015.

ROPEWAY TECHNOLOGY

Ropeways come in different types; they can be categorized by three different aspects:

- **Support - Aerial ropeways** are supported by cable from the top while **track-based ropeways** are supported on the bottom, with rails on the ground or elevated structure with some type of wheels on rails or track.

- **Propulsion - Reversible ropeways** go back and forth (or up and down like an elevator) whereas **circulating ropeways** keep going around in a loop (like an escalator). Reversible ropeways usually have two cabins which are connected via haul-cable - while one cabin goes up the other one goes down; or one or two cars are each connected by cable with a counter weight.

- **Grip** - While the two cabins of reversible ropeways are always affixed to the haul cable **(fixed-grip)**, with circulating ropeways any number of cabins can either be affixed (fixed-grip, e.g. basic chair lifts) or the cabins get detached in the station **(detachable-grip)**. While propulsion on fix-grip ropeways needs to slow down or stop for boarding, on detachable ropeways the haul-cable loops continuously while cabins detach for boarding.

Track-based ropeways examples of reversible technology are **funiculars** (hundreds worldwide including. Pittsburgh Pennsylvania's Inclines, Hong Kong, Buda castle in Budapest Hungary, and several in Lisbon Portugal; Naples Italy; and Lyon, France) while examples of circulating, detachable-grip technology is the classic cable cars (e.g. in San Francisco California (built in 1870s) or a cable liner (automated guideway transit) which are often used as automated people movers (APM, e.g. Oakland California's airport connector, built in 2014).

Table 1 presents the common terms used for aerial and track based ropeways. Table 2 presents some of the international terms for aerial ropeways.

Table 1 Types of Ropeways		
	Aerial	**Track-based**
Reversible	Aerial Tram	Funicular
Circulating	Gondola lift	Cable liner / AGT / Classic Cable Car

Table 2 International terms for aerial ropeways				
	English	**German**	**French**	**Italian**
Generic	Ropeway (Cable Car)	Seilbahn	Téléphérique	Funivia
Reversible	Aerial Tram(ways)	Pendelbahn	Téléphériques va-et-vient	Funivia a va e vieni
Circulating	Aerial Gondola	Umlaufseilbahn / Gondelbahn	Télécabines	Cabinovia

The following presents a description of the main **aerial ropeway technologies**; which are also illustrated in Figure 1.

Cable car, cableway, and ropeway: Various terms which are used to describe a cable-propelled transit system.

Aerial ropeway (or aerial cable car) - generic term for ropeways where cabins travel between stations and are supported at the top either by the haul-cable (mono cable) or by one (bicable, 2S) or two separate support cables (tricable or "3 Seile", short 3S). The cables themselves are supported by towers. The more support cables, the fewer towers are required and higher wind stability.

Aerial Tram(way) - reversible aerial ropeway between two stations with one cabin operating in each direction at a time. (e.g., Portland Oregon, New York City's Roosevelt Island)

Pulse Gondola - reversible aerial ropeway with groups of two or three cabins operating in each direction at a time. (e.g., Spokane Washington)

Gondola Lift - term used to describe a circulating detachable aerial ropeway.

Ropetaxi - latest technology of circulating aerial ropeway that has multiple stations and where riders can choose which station the cabin stops at.

Photo credit: Christian Meyer, Two crossing cabins of the cable car from Trockener Steg to Kleines Matterhorn above Zermatt in the Swiss Alps, LEITNER ropeways, Trockener Steg, Zermatt, Switzerland, 2022. https://unsplash.com/photos/a-group-of-cars-on-a-cable-HM8HhmYP4N8

Photo credit: Patrick T'Kindt, Roosevelt Island Tram, New York City, USA, 2019.
https://unsplash.com/photos/cable-car-above-vehicles-on-crossing-road-1nZL-AwSp8k

ACRONYMS

ART: Aerial Ropeway Transit

CUP: Creative Urban Projects (www.creativeurbanprojects.com)

pphpd: passengers per hour per direction

STRMTG: Service Technique des Remontées Mécaniques et des Transports Guidés

MDG: monocable detachable gondola

BDG: bicable detachable gondola

TDG: tricable detachable gondola

Author Details:

Martin Pagel is a transit advocate. He grew up in Germany and now lives in Seattle where he has published several transit articles on local transit blogs. During the day he is a security architect for a global cloud communications company.

Hazem el Jouzou is architect, urban planner, and BIM-specialist *(Building Information Modeling)*, who is currently working as a BIM-developer in a construction company that highly values sustainability. He wrote about aerial ropeways for his Masters thesis from Frankfurt University of Applied Sciences

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SIDEBAR

RESOURCES TO LEARN MORE ABOUT AERIAL CABLE CARS

To learn more about aerial cable cars we have assembled a few links of Videos, Blogs and Reports from both the technical, academic and riders' perspectives.

Author/Blog	Title of video, blog or report	Link
City Beautiful, by Dave Amos	Urban Gondolas:Transit by Cable	www.youtube.com/watch?v=vdTE4TCqkZo
Town and Touris	"A Complete Guide to Aerial Tramways in the USA"	https://www.townandtourist.com/aerial-tram-way
Reece Martin @ RMTransit	"Does your city need a gondola?"	https://www.youtube.com/@RMTransit https://www.youtube.com/watch?v=iNr59pNk-CHI
Curbed	"11 urban gondolas changing the way people move" (2017)	https://archive.curbed.com/2017/9/21/16340394/urban-gondolas-cable-cars-cities
Creative Urban Projects, (CUP a small planning shop in Toronto, Canada	The Gondola Project: Learn the Basics: What is Cable Propelled Transit?	https://www.gondolaproject.com/about/ https://www.gondolaproject.com/learn-the-basics-what-is-cable-propelled-transit/
The World Bank	"Urban Aerial Cable Cars as Mass Transit Systems: Case studies, technical specifications, and business models" Sep.1, 2020 (21 case studies)	https://ppp.worldbank.org/public-private-partnership/library/urban-aerial-cable-cars-mass-transit-systems-case-studies-technical-specifications-and-business-models https://www.ppiaf.org/sites/default/files/documents/2020-01/Urban-Aerial-Cable-Cars-as-Mass-Transit-Systems-Case-Studies-Technical-Specifications-and-Business-Models.pdf
Transit Choices (transitchoices.org)	Aerial Ropeway Transportation Systems in the Urban Environment: State of the Art	https://transitchoices.org/wp-content/uploads/2016/01/Urban-Gondola-Report.pdf
UNStudio	Projects in planning in The Netherlands, Russia and Sweden	https://www.unstudio.com/en/page/14084/urban-cable-cars-sustainable-public-transport-for-future-cities
BMDV - (bund.de)	Urban Cable Cars in Local Public Transport	https://bmdv.bund.de/SharedDocs/EN/publications/urban-cable-cars.htm

Author/Blog	Title of video, blog or report	Link
CERTU	Brest se dote d'un téléphérique urbain	http://www.certu.fr
Zatran	Urban cable car and ropeway in public transport	https://www.zatran.com/en/technology/urban-cable-car-ropeway/
World Economic Forum	The Advanced and Urban Aerial Mobility (AAM/UAM) Cities and Regions Coalition	https://www.weforum.org/press/2022/03/local-leaders-join-new-coalition-to-advance-urban-air-mobility-around-the-world/
World Economic Forum	Cable Cars For Paris Commuters To Launch By 2025	https://www.weforum.org/videos/cable-cars-for-paris-commuters-to-launch-by-2025
Leitner-Poma	Aerial Tramways	https://leitner-poma.com/products/aerial-tramway
Doppelmayr	Garaventa 10-MGD "Ciudad Bolívar" Bogotá, Kolumbien (2018) - YouTube	https://www.youtube.com/watch?v=BEu-jUyrN9xk
Doppelmayr	Garaventa 10-MGDs "Mi Teleférico"" La Paz/El Alto, Bolivien (2014-2019) - YouTube	https://www.youtube.com/watch?v=vdCyO-J7fkio
Doppelmayr	Garaventa - "Insights" - Cablebús Mexico City - English (2021) - YouTube	https://www.youtube.com/watch?v=PPzEktoj-F0U&list=PLjPmHZ89FY_KZJk7moF8HVbX-56qXRZU0Z&index=5
Doppelmayr	The Next Level of Mobility: Ropeways as Urban Means of Transport [EN] (yumpu.com)	https://www.yumpu.com/en/document/read/62716866/the-next-level-of-mobility-ropeways-as-urban-means-of-transport-en

Photo credit: Dan Gold, Roosevelt Island Tramway, New York, USA 2017.
https://unsplash.com/photos/aerial-photography-of-high-rise-buildings-wc97fT8KSkc

AERIAL ROPEWAY SYSTEMS ADVANTAGES AND DISADVANTAGES

By Hazem El Jouzou

Editor's note: The following article was excerpted from the much longer article "A Comparative Study of Aerial Ropeway Transit (ART) Systems" published in Issue 22.4, February 2017, which in turn was based on the author's Master's thesis of 2016. Although some of the data and findings can undoubtedly be updated, we believe this basic summary of the main advantages of aerial ropeway transit systems has value.

HISTORICAL OVERVIEW

Aerial Ropeway Transit or in its simple form "ropeway" is one of the oldest modes of transport used by humanity to overcome obstacles. Some drawings of this transport mode date back to the year 250 BC in the south China area (Hoffmann, 2006, p. 1). Because it is a transport mode with a long history, this old mode of transport is simple, cheap, and tested through centuries of human use.

In the modern era, there were only seldom examples of ART used in urban environments. One of the few countries who utilized this technology for public transport in that era was the city of Algiers in Algeria. In 1956 it constructed the first aerial tramway line "El Madania" to link two neighborhoods that were 83m (272 ft.) above one another; the system had a distance of 215m (705 ft). (Bergerhoff & Perschon, 2012, p. 4) (Alshalalfah, et al., 2012, p. 260)

The second attempt was the Cologne Rhine cableway. Constructed in 1957, with a cost of 1.5 million Deutschmark, the cableway was initially an attraction to the Federal Garden Show held on the right side of the Rhine (where the park now lays). The service was so popular that the people of Cologne did not want it to be removed afterwards. It was temporarily dismantled in 1963 because its supports overlapped with the construction plans of the zoo on the right side of the Rhine (Herwig, 2013, p. 49). Further to that period, the cableway was reopened in 1966 after changing its path and moving it southward.

Photo credit: Chris Barbalis, New York, 2017. https://unsplash.com/photos/red-and-white-cable-car-above-grey-roads-at-daytime-sMZN6XJP-aE

The system has 41 four-seat small cabins which result in a 1,600 passengers per hour per direction (pphpd) on a total distance of 935 m (3067 ft). (Herwig, 2013, p. 49)

The third attempt was the Roosevelt Island Tramway (New York City). This system was built in the USA linking the Roosevelt Island to Manhattan. In 1976, and in the efforts to accommodate and to link the new middle- and low-income housing units being built in the island, an aerial tramway system was commissioned. This aerial tramway was intended to replace the old and deteriorated trolley system that was there since 1909. (Alshalalfah, et al., 2012, p. 259) (CUP, 2016).

ART began first to catch steam in 2004, when the city of Medellin in Colombia opened its first monocable detachable gondola (MDG) system (Line K) to connect the informal settlements (the Communes) in the hilly area of Santo Domingo to the metro transport system in Medellin city. After the installation of the aerial system, the residents of Santo Domingo could—in less than 30 minutes—cover the distance that took busses 2 to 2.5 hours (Bergerhoff & Perschon, 2012, p. 4) (Herwig, 2013, p. 52) (Alshalalfah, et al., 2012, p. 259). After the success of the Medellin ART system, many countries, especially in South America, adopted ART systems and integrated them into their public transport systems. The most interesting of these systems were: Caracas (Venezuela), Koblenz (Germany), and La Paz (Bolivia). The timeline of these systems also demonstrates the evolution of ART systems and technologies.

COMPARISONS WITH CONVENTIONAL TRANSIT SYSTEMS:

Table 1 shows a comparison between ART transit modes and conventional transit modes. These comparisons are made mainly in terms of system capacity (pphpd), speed, and construction cost per km length; it also contains many other relevant comparisons. This table shows that ART (3S) systems lay in the same band of Bus Rapid Transit (BRT) semi rapid transit systems in terms of speed, capacity in pphpd, and cost.

What this table also shows is how misleading some numbers in isolation might be. For example, although aerial trams (Editor: i.e. reversible cable car) have cabins that carry up to 200 passengers, and have a speed up to 43 km/h (26.7 mph), they actually have a less line capacity than the MDG and BDG (mono and bicable detachable gondola) systems with small cabins (up to 15 passengers) and speed only up to 21.6 km/h (13.4 mph). That is because aerial trams only have 2 cabins while the others have many. Also, and most importantly, that is because MDGs and BDGs have a very high frequency and a short headway of 12 seconds. It has to be mentioned also that the costs of the detached gondolas, which are relatively low, are mainly to build the two stations, since the remaining costs for the towers of cable systems are relatively very low. These stations also remove the need to build maintenance hangars since they contain the areas for repair and maintenance. (STRMTG & CEREMA, 2011, p. 5) (Alshalalfah, et al., 2012, p. 254)

	Transport Mode		Investment Cost ($Million/km)	Line Capacity (PPHPD)	Vehicle Capacity (Passenger)	Operational Speed (km/h)	Cars / TU
Conventional Transit Systems	Street Transit	Bus	0.5-0.6	3,000-6,000	80-125	15-25	1
		Tram	5-10	10,000-20,000	100-300	12-20	1-3
	Semirapid Transit	BRT	5-40	6,000-24,000	80-180	20-40	1
		LRT	10-50	10,000-24,000	100-720	20-45	1-4
	Rapid Transit	Metro	40-100	40,000-70,000	720-2,500	25-80	4-10
		Regional	50-120	25,000-40,000	150-1,800	40-80	1-10
ART Transit Systems	Aerial Tram		15-25	500-2,800	20-200	43.2 Max.	1
	Dual-haul		20-25	2,000 Max.	100 Max.	27 Max.	1
	MDG		5-10	3,600 Max.	4-15	21.6 Max.	1
	BDG		10-20	4,000 Max.	4-17	25.2 Max.	1
	TDG		15-25	7,000 Max.	35 Max.	30.6 Max.	1

Table 1: Service Characteristics of ART and Conventional Public Transit Systems.
pphpd: passengers per hour per direction
Source: Author
Data source: Alshalalfah, et al. 2012; Winter, 2016; CUP, 2016

ART SYSTEMS - ADVANTAGES AND DISADVANTAGES

To be able to understand the main advantages and disadvantages of ART systems, the study (Editor: the Masters thesis) created a list of factors that seem important to identify the Strengths, Weaknesses, Opportunities, and Threats (SWOT).

These factors can be summed in the following keywords:

- Comfort
- Availability /Frequency - Headway
- Reliability
- Environment (noise, visual, carbon footprint)
- Capacity
- Safety
- Construction Time
- Land take / footprint
- Cost (investment; Maintenance and Operational Cost)
- Energy efficiency
- Accessibility

(Editor: The comparisons in the following discussion are primarily to the case studies discussed in the full article in Issue 22.4 and in the author's Masters thesis)

Comfort

Gondolas offer sitting and standing areas in their cabins. The cabins (as well as the stations) can be provided with air conditioning systems which cool or heat their atmosphere depending on the weather necessities (Winter, 2016) (O 'Connor & Dale, 2011, p. 18) (CUP, 2016) (Alshalalfah, et al., 2015). In addition, and since those cabins pass relatively higher than the urban topography, weather conditions in these heights tend to be less humid and less hot than that on the urban surface. This in return reduces the need for air conditioning in summer where the cabins in this case can rely on natural ventilation (The Don Valley Cable Car Community, 2016). Furthermore, newer ART systems (e.g.: La Paz, Bolivia) have even introduced WIFI powered by solar panels on the roofs of the cabins to give even more comfort and connectivity (AJ+, 2016, p. Sec:42).

Availability (Frequency and Headway)

The factor of availability is dependent on many other factors like the cabin size, number of cabins in the system, size of embark/disembark area, and speed of the system. Yet since the cabins in ART systems are in continuous loop movement between two stations, waiting time to board these system often does not exceed one minute. This in return removes the need for schedules (CUP, 2016) and thus gives ART system a large advantage over busses and trains and challenges the supremacy of private transport automobiles in terms of freedom and independence from fixed and sometimes unsuitable schedules (of public transport systems). While some ART systems have a very short headway of 12 seconds (Medellin) (STRMTG & CEREMA, 2011, p. 5), other MDG systems *(choose to)* have a longer waiting time (e.g. 34 seconds, Koblenz) (Dale, 2010); this number is not due to the number of cabins but to operational managerial measures to give enough time gap to separate the passengers getting in from those getting out of the cabins (STRMTG & CEREMA, 2011, p. 5). *(Editor's note: reversible trams typically have longer headways e.g. 7 minutes (peak) to 15 minutes (off peak) for Roosevelt Island aerial tram).*

Reliability

Usually reliability factors in transport systems are deduced from measuring the rates of on-time performance, vehicle failures, maintenance procedures, and other factors like number of stops and distances the vehicles run, (American Public Transportation Association, 2012, p. 5) yet those other factors do not affect ART systems which are on continuous rotation. On the other hand, wind speed is an additional factor to be taken into consideration when measuring ART systems reliability, since the cabins are hung in the air and are subjected to tilting due to wind pressure.

In terms of reliability, ART systems have a big advantage over other transport systems, with a remarkably high reliability rate of 99.3% to 99.9%. This high rate is maintained through strict preventive maintenance guidelines, and through innovative technologies that allow the cabins to resist winds up to 110 km/h (68.3 mph) (e.g.. tricable detachable gondolas (TDG/3S)) (CUP, 2016).

Environment

Visual Pollution: visual impact and visual intrusion remains a major challenge for ART. Since historically ART systems were rarely used as a transport system in urban environments, it is often perceived as unfamiliar to the urban environment and thus sometimes receives opposition from residents (STRMTG & CEREMA, 2011, p. 10). This opposition could largely increase when ART systems pass over the skyline of historic cities. The other factor is visual intrusion, residents and land owners around the area where the ART lines will be installed may have worries of what the cabin passengers can see and intrusions on their privacy, and potential impacts on property values (STRMTG & CEREMA, 2011, p. 10).

In that regard, new technologies have widely reduced the possible negative effects that might appear with regards to urban environment or visual intrusion. In terms of being unfamiliar or unsuitable, for instance in historic cities, the good design of the 3S ART system in Koblenz resulted in UNESCO approval even though Koblenz is a world heritage city (Georgi, 2013). In terms of visual intrusion, new glass technologies (Smart Glass) which are already used in public transport systems (Singapore) allow the glass panels of the cabins to become opaque when passing near houses, blocking any form of intrusion (Dale, 2011).

Photo credit: Jacek Dylag, Smog and heavy trafić at night, Kraków, Poland, 2020. [*https://unsplash.com/photos/a-foggy-city-street-filled-with-lots-of-traffic-mmar_Xs8_mk*](https://unsplash.com/photos/a-foggy-city-street-filled-with-lots-of-traffic-mmar_Xs8_mk)

Noise Pollution: Since the cabins in ART systems do not contain any motor, the system is considered a very low noise producer. Gondolas therefore, are a very quiet transport unit in comparison to other transport systems (Winter, 2016). The noise they generate will be in most cases indistinguishable from ambient noises produced by other transport systems (traffic for instance) (The Don Valley Cable Car Community, 2016). The minimal noises that come out of this system are in the station where the large motor is situated and in the intermediate tower while the cabins overpass them. Yet even those are barely heard (CUP, 2016).

Carbon Footprint: The carbon footprint is a measurement which shows how much carbon a certain system will produce directly or indirectly. The results of such tests deduce how green the subject system is in terms of energy. The calculation is either done directly when the system produces greenhouse gasses, or indirectly by calculating for example how much carbon emissions would be produced to supply a certain system with electricity.

In terms of carbon footprint, many countries like France consider ART systems by law as an alternative system that could (when used in a general policy) reduce pollution and greenhouse emissions. Many projects are under research in French local authorities under that topic. (STRMTG & CEREMA, 2011, p. 1)

In order to explain in numbers the small footprint ART systems produce, the strategy consulting firm *ClimatePartner Austria* conducted a study in 2009 regarding the carbon footprint of ART systems in comparison to cars, busses, and trains. This study showed that when cable cars utilizing 50% capacity and above have the lowest greenhouse emissions of all these systems. This makes ART systems the world's greenest transport system. Table 2 shows the findings of this study.

Table 2: Carbon Emissions by Mode.

Transport mode	CO2 Emissions in g/pkm
Petrol-Powered motor vehicles	248
Diesel-Powered Busses	38.5
Electric Locomotive Trains	30
Cable Cars	27

gpkm=grams per passenger kilometer
Data source: Herwig, 2013

To put this advantage into physical benefit, the city of Medellin used the UN concept of climate protection by "Carbon trading" to sell its share of carbon to other cities and use the money to further develop its transportation systems (Herwig, 2013, p. 52). In numbers, the city of Medellin, like other cities that used ART systems, saw a drop in its greenhouse emissions, and also in their carbon footprint. **Table 3 and Figure 1** show this drop in emissions in the city of Medellin, from 30+ tCO2 to 10+ tCO2 per year (Bergerhoff & Perschon, 2012).

On average, Medellin saves around 20,000 Tons CO2 each year and sells the corresponding emission certificates. This is, in the minds of many, an environmental benefit for all (Herwig, 2013, p. 52).

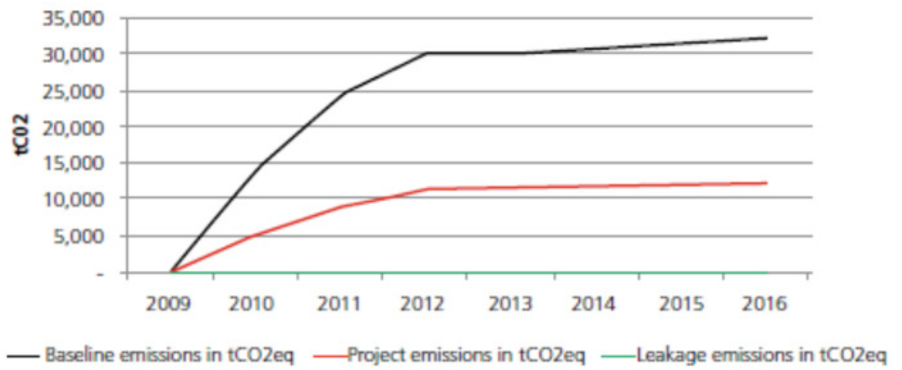

Figure 1: *Medellin projected emission reduction from six aerial cable cars, UN - HABITAT, 2012.*

Table 3: Medellin projected emission reduction from six aerial cable cars

	2010	2011	2012	2013	2014	2015	2016	Total
Baseline Emissions in tCO2eq	14,005	24,434	30,103	30,382	31,189	31,458	32,311	193,881
Project Emissions in tCO2eq	5,135	9,083	11,208	11,450	11,724	11,980	12,274	72,853
Emissions reduction in tCO2eq	8,870	15,350	18,895	18,932	19,465	19,478	20,038	121,029

Data Source: UN - HABITAT, 2012

Capacity

The capacity of ART systems depends on the capacity of the cabins, the spacing between the cabins, the speed of the traction cable, and thus the number of cables used. Because ART systems operate on their own dedicated space, and do not mix with other transport modes, and because they are in continuous automated movement, this allows for a consistent journey time, and a thus a consistent capacity with a consistent passenger throughput (STRMTG & CEREMA, 2011, p. 7).

The capacity of ART systems is in continuous increase. In comparison to other transport modes, the MDGs and BDGs have a capacity nearly equivalent to a small rail-based tram, whereas the TDGs with a capacity of 7,000 pphpd (Winter, 2016) show the potential of overcoming rail-based tramways with cars as large as 43mx2.65m (141 feet by 8.5 feet). **Figure 2** shows a relatively new yet outdated table from 2011 showing a comparison between the capacities of several transport systems including ART. The table was edited to include the capacities of ART systems described by newer sources like Seilbahn Koblenz. As a result, one can see that TDG/3S systems reach a higher capacity than rail-based tramways with cars as large as 43mx2.65m (141 feet by 8.5 feet).

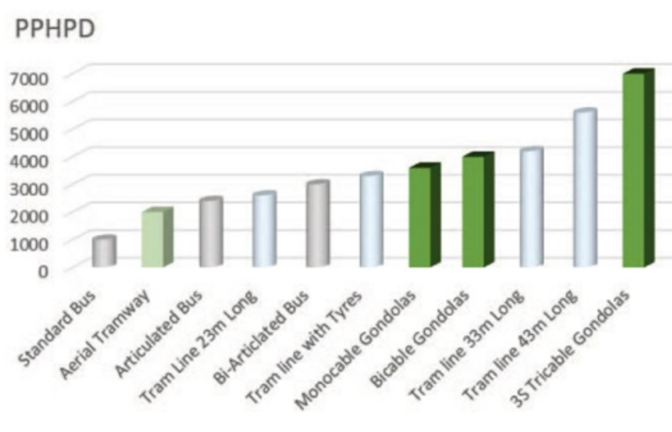

Figure 2: *Capacity in PPHPD of urban transport systems. Source: Author (Figure 5, El Jouzou, WTPP: 22.4). Data source: STRMTG & CEREMA; Winter, 2016.*

Safety

ART systems are systems that operate continuously in loops, without a motor on board and without a driver. This makes the possibility of accidents incredibly low. Therefore, many urban planners and transport engineers call ART systems the safest means of transport in the world. This is based on the ratio of the number of accidents to the number of people transported per kilometer (STRMTG & CEREMA, 2011, p. 6) (Herwig, 2013, p. 51).

Construction Time

ART systems require a relatively short building time. While other modes of transport require 10 to 15 years to build their lines (metros for example), (Herwig, 2013, p. 49) the total building time for these systems has been 13 months in Koblenz (Alshalalfah, et al., 2014, p. 260) (Seilbahn Koblenz, 2011) and two years in La Paz (LAPAZLIFE, 2014). This huge reduction in construction time proves essential to cope with the rapid expansions of some metropolises and the rapid pressure increase on available infrastructures.

Land Take (Footprint)

ART systems can overcome obstacles and topography levels. Their land take on ground level therefore is very limited, and is only confined to that of the station and pylons. The land under the cables can be utilized for other purposes, and thus is not considered as land take. (STRMTG & CEREMA, 2011, p. 8) The standard area of the main stations is usually 250 SQM (2690 sq. ft.) (25mx10m) and 50 SQM (538 sq. ft.) for intermediate stations. These areas are also subjective to the architectural design of the station. Stations that have the embark/disembark area on the ground floor need to have a sufficient clearance area for the cabins that are in this case lowered to the station.

Thus, stations which allow embark/disembark on upper floors require less land, and can utilize the extra floors in creating shops or storage areas for the system (STRMTG & CEREMA, 2011, p. 8).

However, ART systems always move in a straight line between stations or at least between pylons. This in addition to the cable length having a preferable limit of 6 kms (3.7 miles) (Winter, 2016), can be a negative aspect in connecting urban environments. Hence, even though ART systems require small land take, integrating stations in urban environments can be problematic. In addition, regulation in countries require safety margins along the path of the gondolas not to be affected in case of fire in a building that the cabins overpass. Furthermore, any passage of a cable line over private ownership requires compulsory purchase, or negotiation with the owners regarding those lands (STRMTG & CEREMA, 2011, p. 9).

Investment Cost

It is a difficult matter to acquire investment costs data regarding ART systems in urban environments. That is because that data is considered commercial data for manufacturers and prime contractors. Yet to have a general figure, CETE Lyon came up with figures of those systems in mountainous environments. Table 4 shows figures and costs of ART systems in mountainous environments. Comparing those numbers to known costs of ART systems built in urban environments (like Koblenz) prove those numbers could be even smaller in urban context.

Table 4: Breakdown of investment costs in mountain area

System Component	Cost	
	Monocable Gondola	3S Tricable Gondola
Start/End Station	€2.5 to 3M	€4M to 5M
Intermediate Station	€1.2 to 1.5M	-
Pylon	€0.1M	€0.5M
Cabins	4 to 15 Seats	35 Seats
	30,000€	300,000€

Data source: STRMTG & CEREMA, 2011
M=million

Maintenance and Operational Cost

In ART systems, operating the system typically requires only four personnel. These four personnel provide assistance in boarding and un-boarding the cabins, overlook the system, and do the necessary maintenance. The operational cost is thus related to the overhead cost of those employees and that of the spare parts for the system. As an example, a simple MDG system requires an annual operational cost of 1.5 M€ on a 7000-operating hour basis (STRMTG & CEREMA, 2011, p. 9). These running costs and life cycle costs are drastically smaller than those of individually motorized vehicles such as busses. This is because the whole system has a single stationary motor that runs the whole system. This criterion therefore, gives advantages for ART systems over other motorized modes of transport (STRMTG & CEREMA, 2011, p. 9).

What makes ART systems even more feasible and gives them the upper hand over conventional UPT (urban public transport) is that unlike trams and busses, the increase in capacity in ART systems has a minimal effect on the operational cost of the system. **Figure 3** compares the increase in the running (operational) cost of buses, trams and ART systems with respect to the increase in capacity. The cost increase is rather very small during the expansion of the ART systems and the increase of passengers per hour rate. This is contrary to bus and or rail systems which push the costs dramatically with the increase of capacity. The relatively low operational cost and low building cost show great potential for a wider implementation of ART systems in urban context, and so does the evolution in ART specification and design. **Figure 3** shows a comparison of operational cost with respect to capacity increase, over the same route between road-based modes of transport and ART systems taken from the city of Grenoble, France.

Energy Efficiency

Cable cars are considered highly efficient in terms of energy consumption. Although the whole system has to be activated even if one passenger is riding it, at a 50% load it is considered a very energy efficient transport system that produces the least carbon footprint in the world (Herwig, 2013, p. 49). That is due to the following criteria as explained by Joachim Bergerhoff and Jurgen Perschon (Bergerhoff & Perschon, 2012) and also by CERTU (STRMTG & CEREMA, 2011, p. 11):

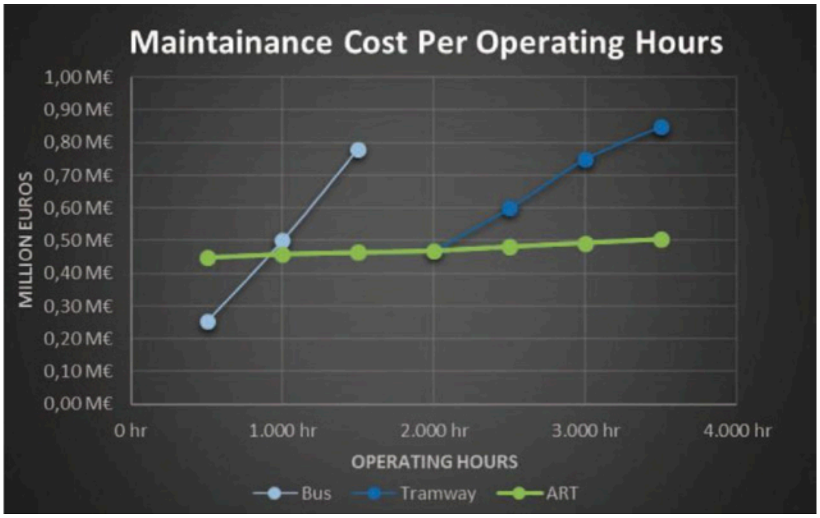

Figure 3: *Comparison between operational costs of Buses, Trams and ART systems. Source: Author (Figure 6, El Jouzou, WTPP: 22.4). Data source: Bergerhoff & Perschon, 2012; Dopplemayr Urban Solutions, 2015*

- A single stationary electric engine moves the entire system at a steady, efficient pace.
- The gondolas do not have to carry engines, fuel, wheels, suspensions, reinforced chassis and thus are of relatively low weight and drag.
- Descending gondolas help pulling up ascending gondolas; hardly any additional energy is required for acceleration of individual cabins or is lost when slowing down cabins in (rare) stations.
- Apparently, the aerial ropeway does not suffer rolling resistance.
- Load and changes in level have a limited impact overall.

Accessibility

Both the station design and cabin design allow the system to be a barrier-free, which allows transport for people with disabilities and even bicycles.

CONCLUSION

ART proves to be an old yet innovative transport method which, in light of its latest innovations, can be proposed not just as a feeder or a touristic element in a ski resort, but as a transport mode that holds very significant potential. This relatively new urban transport mode shows a rapid pace in innovation and upgrades in the last decade. These innovations and this rate of upgrade prove the mode has a promising future and bigger role in future city transportation systems. In comparison to traditional transport modes, the advantages of the ART systems can be seen in various aspects. Those aspects are ones of comfort, availability, reliability, safety, construction time, land take, cost, environment, and energy efficiency. In all of those areas, ART systems have the upper hand on conventional transport modes. It is in light of those advantages that the research finds potential in implementing ART systems as full urban public transport systems that can function as a backbone, yet also complement other existing systems.

Photo credit: Bess Gaby, Baja California Sur, MX, 2018.

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He wrote about aerial ropeways for his 2016 thesis for a Master of Science in Urban Agglomerations from Frankfurt University of Applied Sciences, available at: https://www.researchgate.net/publication/310888600_A_Comparative_Study_of_Aerial_Ropeway_Transit_ART_Systems_Advantages_and_Possibilities

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URBAN MOBILITY WITH ROPEWAYS – CONNECTING LIVES: CASE STUDY OF LA PAZ BOLIVIA

By Julia Schwärzler

INTRODUCTION

Limited roadway capacity combined with topographical challenges make it difficult for residents to conduct their daily business including getting to and from work and other needed trips. However aerial ropeways have addressed this challenge and indeed significantly improved the transport options by reducing travel time and improving access between La Paz and adjacent cities.

Take the case of Maria Salazar, who lives in El Alto, a vibrant city adjacent to La Paz in the Bolivian Andes with around 940,000 inhabitants. She spends her mornings working in her small shop and the afternoons with her family. Getting around by public transport is now very convenient for her because she can use Mi Teleférico, the world's biggest most extensive aerial ropeway network. Since the advent of Mi Teleférico in the metropolis that includes the country's seat of government – the city of La Paz (800,000 inhabitants) – her life has become so much easier. The reason is that there is now a new means of transport that brings her huge time savings in her daily life. It used to take her about two hours to get to work by bus; however with the ropeway, she the trip now takes only 20 minutes. Now, Maria can open up her shop on time every day and also has more time with her family, all thanks to a pioneering and courageous mobility approach and state-of-the-art technology.

PROBLEM TO BE SOLVED

Before the big cities of El Alto and La Paz were connected by this innovative mobility solution, traffic jams, long waits, chaos on the roads and travel planning uncertainties dominated daily schedules. During peak hours, a trip from El Alto to La Paz could take up to two hours. The often narrow, winding, and steep roads are quite dangerous and it is difficult to pass slower vehicles. Furthermore, the two cities are divided by a significant altitude difference of 525 meters (1,675 feet) – an obstacle that is hard to overcome. Finding a mobility solution that can conquer all of these challenges has been pending for a very long time—the idea of ropeways goes back some 50 years.

Photo credit: Julia Schwärzler, Linea Amarilla, La Paz, Bolivia.

In early 2010, the traffic situation was about to collapse and a solution was badly needed. But how could the narrow streets, steep routes, and altitude differences be managed? Thus, the idea of choosing ropeways using available air space was revived. Feasibility studies were conducted to investigate potential solutions and answer questions such as: Would it be possible to install ropeways in this area? Would it be a lasting solution into the future? After review of the planning and engineering evaluations, the government decided in favor of the ropeway solution – and not just one single ropeway but a full-scale network of ten lines.

ROPEWAY SOLUTION

In 2012, a contract for the turn-key project was signed with Doppelmayr, and construction began shortly after. In 2014, the first three lines went into operation: Línea Roja, Línea Amarilla and Línea Verde – matching the colors of the Bolivian flag. In 2017, Línea Azul and Línea Naranja were opened. In 2018 Línea Blanca, Línea Celeste, Línea Morada, and Línea Café followed, and in 2019, Línea Plateada completed the world's most extensive ropeway network. The network not only connects both cities – El Alto and La Paz – with each other, but also creates new connections within each of these population centers. See Figure 1. The ropeways relieve traffic on the roads, directly connect crucial locations, and expand the transportation network. They are environmentally friendly and ensure better air quality and less noise – compared to other means of transport.

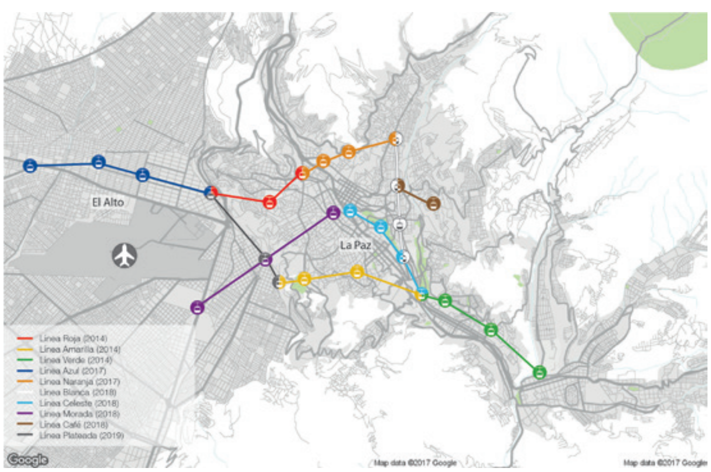


Figure 1. *Image or map of the ten lines*

The world's biggest urban ropeway network encompasses ten lines, with an overall length exceeding 30 kilometers (see Figure 2). Currently, over 200 million passengers have been transported. Every day, about 300,000 persons ride Mi Teleférico as a means of getting to work, going shopping, going to school, or accessing leisure-time activities. On record days, that figure has reached as many as 600,000 passengers and the system is capable of transporting up to 68,000 passengers per hour.

Figure 2. *Photo of one or more cabins (from a distance), depicting topographical challenges*

IMPROVED QUALITY OF LIFE

The impact of this new mobility solution was quite significant. It highly improved transportation quality and also started to create socioeconomic changes due to the fact that people are now able to move around more efficiently and more reliably. The area of opportunity for finding suitable employment for El Alto residents has increased, as the ropeway network has opened up new connections. Passengers can now move around more and travel further than before. In the 10-passenger ropeway cabins, they often meet individuals of different social backgrounds, creating a new form of togetherness. This social change is also one of the major positive effects of this mode of transport: it is available to anyone.

The Doppelmayr ropeways between El Alto and La Paz help make residents more mobile, shorten their travel times, and guarantee that they arrive on time. They can travel completely relaxed, with an opportunity to enjoy the stunning views. Thus, Mi Teleférico has brought about a fundamental, positive change in the lives of local residents.

They are proud to have such an innovative public transport system that has also gained a lot of international recognition. Delegations from around the world, including North America, South America, Europe, Asia, and Africa have visited La Paz to see how a ropeway network can work. In addition, tourists consider it the number one sight to visit when traveling to the city of La Paz. Since the first line was opened in 2014, the ropeway network has continually held the number one position among the tourist attractions on TripAdvisor, i.e., 98 percent of all visitors rate Mi Teleférico as "very good" to "excellent".

ELEMENTS OF SUCCESS

However, this relative success has required a great deal of effort. Ropeways used to be seen as something strange in Bolivia, as many were not familiar with this kind of transportation. Therefore. Information and communication campaigns were organized to familiarize people with the ropeway and to eliminate their doubts about it. It was important to inform residents of its benefits: greater personal safety and expanded opportunity. This demonstrates how important it is, in the implementation of major infrastructure projects, to listen to concerns and address important issues, so that trust can be established and the project will be successful.

Another crucial element of the successful integration of the network not only in the city but also in its people's lives was station design and development. Not only are stations fully accessible to everyone – passengers with wheelchairs, bikes, strollers, physical impairments, elderly, etc. – they also offer very useful services. Here, the stations are not merely seen as entry, exit, and transfer stations, but also fulfill important socio-economic purposes. For instance, in four cable car stations of the Líneas Roja, Verde, Amarilla, and Azul, health centers called "Mi Centro Vida" have been included, where free medical care is provided for all, i.e., adding enormous value for the population.

In many stations, there are shops, supermarkets, pharmacies, restaurants, or kiosks, perfect for purchasing key items on the way home. Stations are also popular as gathering or meeting places. They are modern, colorful, safe, well-lit places where trained ropeway personnel can be found at all hours (see Figure 3). The stations offer free wifi, which also makes it attractive for young people to meet and surf the Internet. In sum, the new ropeway infrastructure has contributed to a socioeconomic upgrade and a new quality of life for the communities of El Alto and La Paz. New jobs have been created, generating new passenger flows and a boost to local economies.

Figure 3. *Photo of Station*

Furthermore, there is a historical museum of Bolivia on Línea Blanca that is an exceptional place not only for tourists and visitors, but also for school classes, universities, and of course, local residents. What is special about this museum is its artifacts. The pieces that are displayed here are archaeological findings from the construction excavations of the ropeway system. During construction of the ropeway, experienced archaeologists teamed up with the construction crew to preserve the findings—many of them dating back to 1,000 - 3,000 years ago—and make them available to the public through this museum.

TEAMWORK WAS KEY TO SUCCESS

Developing such a project takes a great deal of effort. Project construction in a vital and busy urban surrounding holds various challenges in managing several construction sites and maintain project schedules. In total it took six years to complete this unique project. Up to 1,000 employees from the ropeway developer and subcontractors were involved at peak times. In total, 1,809 40-foot containers of ropeway equipment were delivered to La Paz and installed.

According to Ignasi Gibert, general project manager for Doppelmayr: "Added to that is the fact that we were the general contractor for this project. In addition to the ropeway technology, we were also responsible for studies, the geology, architecture, and construction of more than 90,000 m^2 (square meters) of the station and additional buildings, for the design of well over 100,000 m^2 of integrated outdoor areas, and for ticketing." Torsten Bäuerlen, project coordinator for Doppelmayr, explained: "The complexity of this mega project was certainly a challenge. We proved that we can deliver a turnkey project of this magnitude on schedule. Our team, comprising nine nationalities and covering a wide range of expertise, accomplished a phenomenal achievement with an incredible amount of passion and commitment throughout the entire project."

Inner city logistics are particularly challenging with such a project. Urban space is limited and city life doesn't stop. Thus, for the ropeway construction, the teams had to learn how to coexist with everything that was happening in the city and how to work with little space. A perfect orchestration of all processes was key to the success of the project, especially in densely populated areas such as El Alto and La Paz, where extremely chaotic traffic in narrow and steep streets persisted. The teams were working on different construction sites – stations, tower locations – in parallel. This required very dynamic project coordination and the existence of a Plan B, C or D to react flexibly and to keep up with the schedule.

CONCLUSION: MI TELEFÉRICO - A FLAGSHIP PROJECT FOR URBAN ROPEWAYS

Mi Teleférico illustrates the versatility, variety, and possibilities that ropeways have to offer, fulfilling essential functions for innovative mobility concepts: relevant travel time savings, minimal use of land and resources, and the opportunity to integrate attractive community services, to name but a few.

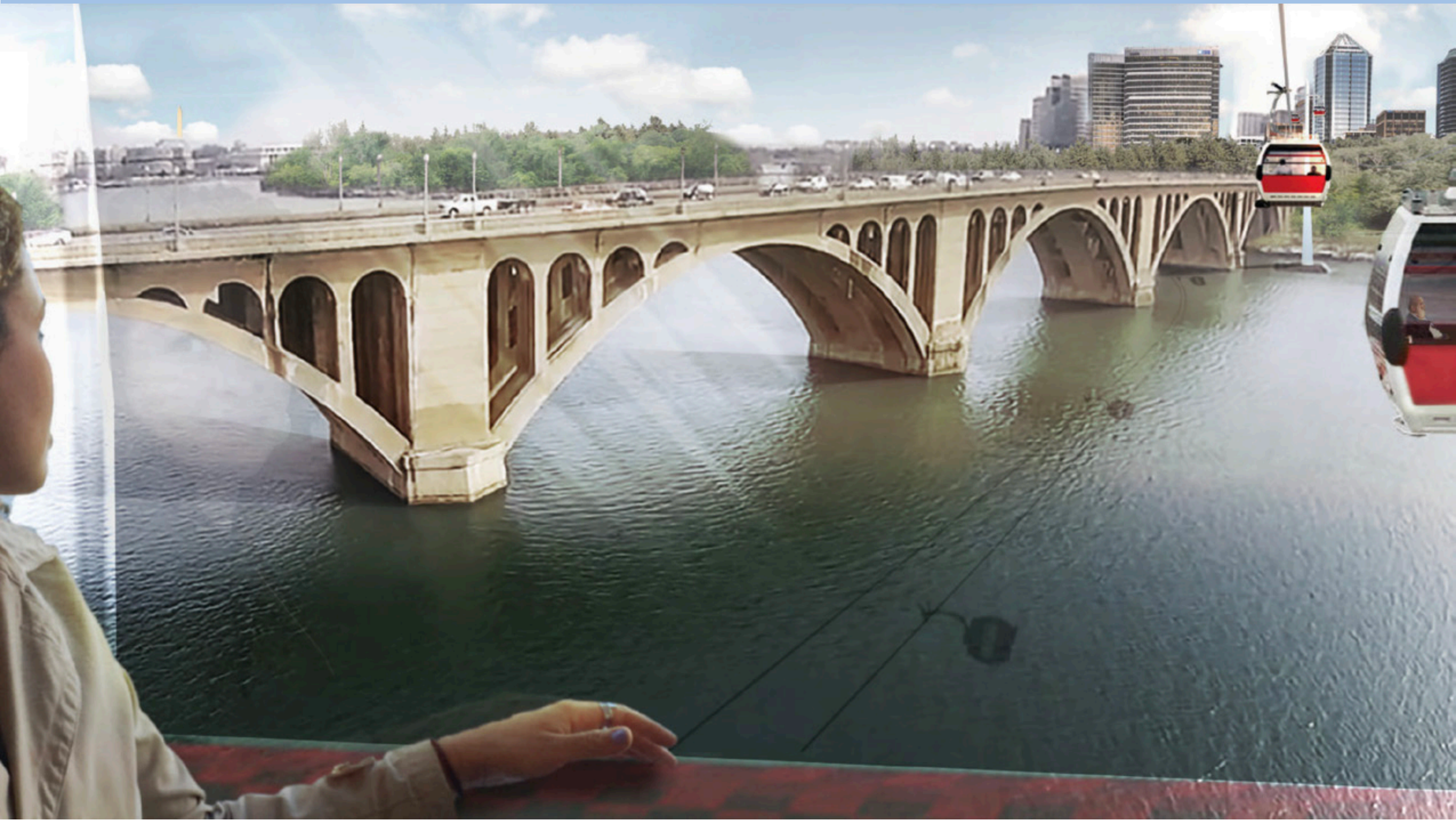
The rapid pace of urbanization presents huge challenges for cities. There is a growing awareness of topics such as environmental protection, inclusion, or infrastructure as they affect residents, commuters, and visitors just as much as decision-makers. As a major factor influencing economic growth and quality of life, the question of mobility calls for new concepts, especially when it comes to traffic management. As a key part of a multimodal transport system, the Mi Teleferico ropeway system provides mobility in an independent dimension. It effectively delivers the next level of mobility.

Photo credit: Julia Schwärzler, Linea Celeste, La Paz, Bolivia

Impressive facts and figures highlight the dimensions of this unique project. If all 254 towers of the ten lines were placed one on top of the other, they would reach a height of 5.7 km (3.5 miles) and would therefore be almost as tall as Huayna Potosí – a popular mountain close to La Paz. The 1,396 cabins are propelled above the streets and houses of these communities, using a total of 62.7 km (40 miles) of rope – and operate 17 hours a day. Other facts are presented in Table 1.

Table 1. Facts and Figures of the La Paz Mi Teleférico Ropeway Network

Number of lines	10
Overall length	33 km
First opened	2014
Number of stations	26
Number of cabins	1,396
Passengers per cabin	10
Number of towers	254
Elevation of the highest station	14,105 m
Passengers per day	≥ 300,000
Record passengers per day	~ 600,000
Capacity per hour (passengers) (whole network)	68,000



AERIAL TRAMS WORKING IN LONDON AND PORTLAND, WITH PROPOSED PLANS FOR GEORGETOWN

The following fact sheets are about two recent projects, London's aerial cable car and Portland's aerial tram, and one potential project in Washington D.C.

London's, (formerly called the Emirates Air Line and since June 2022 called IFS Cloud Cable Car), opened in 2012 and is now an established success both as transport and as a tourist attraction.

Photo credits:

Georgetown-Rosslyn Gondola Feasibility Study. *https://static1.squarespace.com/static/56be0bf0f85082283a801769/t/581b3129be6594f54cc7a225/1478177085024/GR-Gondola-TechSummary-110316.compressed.pdf*

Kate Olfans, Emirates Cable Cars, London, UK, 2021. *https://unsplash.com/photos/white-clouds-and-blue-sky-during-daytime-bR46TpkM4OQ*

LONDON, ENGLAND, UK

LONDON IFS CLOUD CABLE CAR

Name of aerial cable car	IFS Cloud Cable Car. Also known as "The London cable car." It is the UK's only urban cable car.
Owned by	Transport for London (TfL)
Operated by	Mace and maintained by Doppelmayr
Description of location	Connects Greenwich Peninsula to the Royal Docks, crossing the River Thames
Background project proposal	The idea for a cable car linking the Greenwich Peninsula with the north bank of the Thames first emerged during the development of the transport strategy for the Millennium Dome (now The O2) in the late 1990s. In 2010, Transport for London (TfL) announced plans to develop a cable car crossing over the River Thames, which would be the first urban cable car in the United Kingdom.
Alternative options investigated	Several options including a footbridge (impractical/unaffordable due to the height it would need to be) and a ferry service (not deemed commercially viable).
Number of stations	2 terminals
Number of towers	3 main towers but 7 towers in total including compression towers
Year open for service	6/28/2012
Construction time	Approximatey 14 months
Total capital cost	£60 million
Annual operating cost	Unknown

Technical Statistics	
Number of lines	1
Line length	1,100 m (3,600 ft)
Size of cabins (passengers)	10 passengers per cabin
Max capacity (pphpd)	2,500 PPH
Speed in m/s:	6 m/s (13.4 mph)
Travel time point to point	10 minutes
Travel time to drive a car point to point	Up to 20 minutes depending on congestion (*according to google maps)
Frequency/headway	14.4 seconds cabin interval time (on line at max speed)
Total number of cabins operating at once	34
Total number of cabins in system	36
Propulsion: reversible or circulating	Circulating 10-MGD UNIG L
Grip	Detachable A108C type, Grip pulling force (horizontal min 26kN)
Other	Clockwise drive direction, Tensioning force of 750kN, Siemens main drive motor (375kW / 1470 rpm), cabin spacing on line (86.4m), rope length (2225.3m approx.)

Source: Transport for London (TFL), https://tfl.gov.uk/

Operations	
Fare (adult)	£6 (£12 round trip)
Needed staffing	4 minimum
Ridership	Average daily ridership: weekdays 3,639; weekend 6,108 (April 2022 - April 2023)
Days and hours of operation	The aerial tram operates 7:00 to 22:00 Mon-Sat; opens at 8:00 on Saturdays and at 9:00 on Sundays and holidays, and runs till 23:00 on Friday and Saturday nights.

PORTLAND, OREGON, USA

AERIAL TRAM

Name of aerial cable car	Aerial Tram
Owned by	The City of Portland Bureau of Transportation
Operated by	Oregon Health & Science University (OHSU)
Description of location	Connects the Oregon Health & Science University (OHSU) and Hospital to the South Waterfront district, which also contains OHSU faclities.
Background project proposal	Proposed in 2001 by the Mayor's office as a possible solution to link OHSU to a proposed expansion site on a brownfield; the two sites were separated by 27 lanes of traffic, 500 feet in elevation and a narrow single lane access roads. Overall there was support to find a solution so that the brown field property along the river could be developed. As with all projects like this, the first wave of opposition came from those who would be directly impacted by the alignments of any one of the transportation solutions. Second wave of opposition came due to budget escalation from initial analysis until final budget numbers were delivered.
Alternative options investigated	Several including: shuttle buses along 4 different routes; underground people mover with elevators; funicular railway; streetcar; aerial (circulating) gondola and aerial (reversible) tram.
Number of stations	2 terminals
Number of towers	1 (150 sq ft footprint)
Year open for service	2007
Construction time	2 years
Total capital cost	$57 Million
Annual operating cost	$3.4 million

Source: Ray Gardner and Brett Dodson, Oregon Health & Science University

Technical Statistics	
Number of lines	1
Line length	3,300 linear feet (1,005 m)
Size of cabins (passengers)	79 passengers per cabin
Max capacity (pphpd)	1,014 PPH per direction
Speed in m/s	9.8 m/s (22 mph)
Travel time point to point	3 minutes
Travel time to drive a car point to point	20+ minutes
Frequency/headway	5 minutes
Total number of cabins operating at once	2
Total number of cabins in system	2
Propulsion: reversible or circulating	Reversible
Grip	Fixed
Other	None

Operations	
Fare (adult)	$8 round trip ($40 per month)
Needed staffing	6 per shift: 4 cabin and station attendants and 2 technician supervisors.
Ridership	Average of 9,000 per day as of date June 2023
Days and hours of operation	The Tram operates Monday through Friday from 5:30 am to 9:30 pm, and Saturday from 9:00 am to 5:00 pm. Closed Sundays and observed holiday

TRANSPORT FOR LONDON (TFL)

- Cabins can also accommodate bicycles and 2 wheelchairs plus companions. Cabins have been adapted to accommodate motorised wheelchairs. The service is completely step-free.
- During term-time, when booked in advance, all school parties can travel for free during off peak times and for £1 per child during peak times.
- The Greenwich Peninsula (south side) terminal is next to North Greenwich station on the Jubilee line and the Royal Docks terminal (north) is next to Royal Victoria on the DLR and a short walk away from Custom House for the DLR and the Elizabeth line.

RAY GARDNER AND BRETT DODSON, OREGON HEALTH & SCIENCE UNIVERSITY (OHSU)

- VMT reduction per year is averaging roughly 820,000 miles.
- The aerial cable car has saved almost 675,000 gallons of oil, and removed 863,000 pounds of CO2 from the atmosphere.
- During term-time, when booked in advance, all school parties can travel for free during off peak times and for £1 per child during peak times.
- The Greenwich Peninsula (south side) terminal is next to North Greenwich station on the Jubilee line and the Royal Docks terminal (north) is next to Royal Victoria on the DLR and a short walk away from Custom House for the DLR and the Elizabeth line.
- 85% of riders are visiting OHSU and 15% are members of the general public and tourists.
- Were advocates important? Yes they made the project happen. Across the city there was support for this project as the City was developing an old brown field area and creating a new neighborhood within the downtown core of the city. There was an advisory group developed that included city and hospital staff along with neighborhood representatives who met monthly and helped guide the communications teams on the project.
- Aerial Tram had least environmental impact, one of the lower cost, only one tower between the top and bottom terminals and the ability to have cabins stationary when loading for ADA and patient mobility concerns were all reasons why the Aerial Tram was selected.

Name of aerial cable car:	Proposed: Georgetown - Rosslyn Gondola
Description of location	Proposed to connect the west side of the Georgetown Commercial District and Georgetown University to the Rosslyn Metro Station's Blue, Orange, and Silver Lines.
Proposed Estimated Frequency	20 - 60 seconds
Ridership forecasts	4,600 to 15,600 per day
Travel time point to point:	4 minutes
Current Travel (bus) point to point:	10-15 minutes and subject to traffic delays

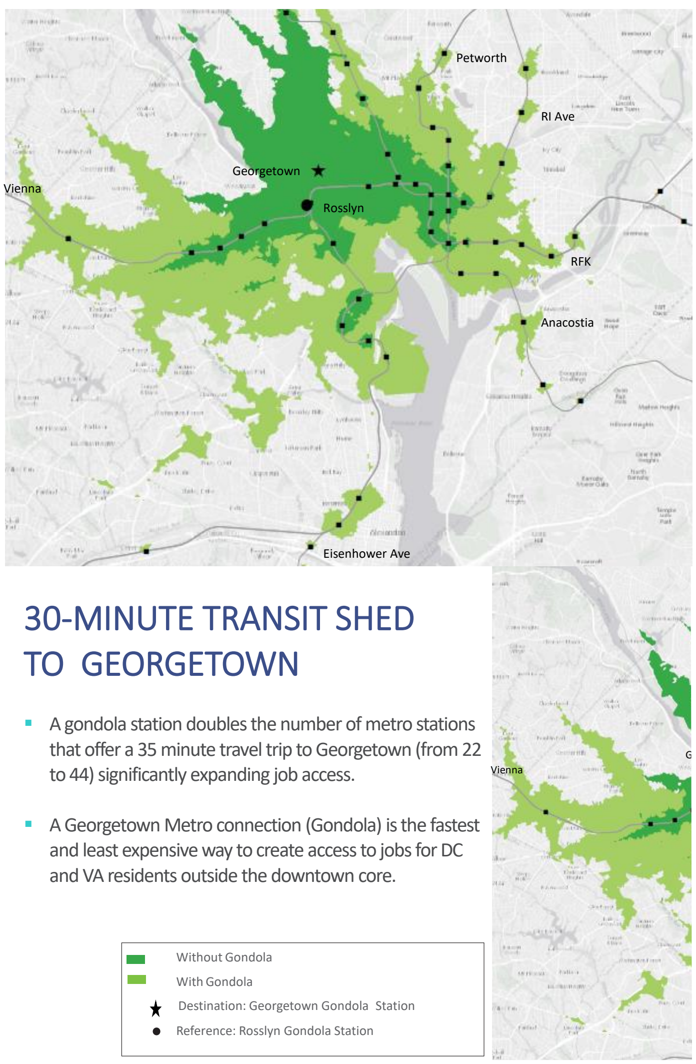


Photo credit: Georgetown Transit Shed, Georgetown-Rosslyn Gondola Feasibility Study.

GEORGETOWN, D.C., USA

PROPOSED: GEORGETOWN - ROSSLYN GONDOLA

Transportation niche	The Georgetown area of Washington D.C. is the largest employment center (23,000 jobs) in DC not served by a Metro station. Currently busses connect to the metro, but they are slow and impacted by congested road and bridge conditions. The aerial cable car would provide frequent and reliable transit service across the Potomac River in 4 minutes, (compared to a 10-15 minute bus ride) and the time between the Georgetown Gondola Station and the Rosslyn Metro Platform would be 6 minutes. The main advantage is that the gondola would be completely reliable mode of transit that would not be impacted in any way by traffic.
Environmental benefits	The aerial gondola could replace over 50,000 annual bus crossings (164 per day) of the Key Bridge, and a significant number of car trips.
Transportation equity benefits	In addition to reducing travel time and increasing convenience, it would also more than double the size of the 35 minute transit travel shed to Georgetown. See map. This makes Georgetown's job market accessible to a much larger swath of the DC and regional populations, especially those who rely on public transportation and work in service jobs. Thus there is a significant equity improvement to this investment.
Scope of feasibility study	Both gondola and aerial trams were considered as part of the feasibility study which analyzed their respective benefits and challenges to implement. Based on the potential ridership and the desire to provide minimal waiting times at each station, a gondola system (monocable circulating gondola) was determined to be the most effective system type for the Georgetown-Rosslyn corridor

Source: Joe Sternlieb, President & CEO of Georgetown BID, and the 2016 Georgetown-Rosslyn Gondola Feasibility Study

Challenges to surmount	Building a novel transportation system in the District of Columbia that crosses into the State of Virginia across land controlled by the National Park Service presents considerable bureaucratic challenges. The Feasibility Study from 2016 identified over 20 different local, state, regional and federal agencies that would either have to permit or opine on the project. These range from the Federal Aviation Administration (FAA) (because it crosses beneath an active flight path to National Airport) to the Old Georgetown Board and Federal Commission on Fine Arts that protects historic view sheds. There is probably no place in the nation more challenging to build a project than where this is proposed.
Main project proponents	Georgetown Business Improvement District, Federal City Council, and Georgetown University are the three main proponents who have been organizing the effort. There are other organizations and institutions that signed on to be part of a coalition in 2019 - listed on our website. Most have not been actively engaged since then.
Public and political support	There is a general support (people like the idea) on both sides of the river, but it isn't organized into a powerful lobbying coalition. There's more political support on the DC side than on the State of Virginia side, but until the Mayor of D.C.makes it a priority, there aren't enough people in the city working on it to push it forward. The final challenge will be funding. The 2016 study estimated about $110 million in capital costs and $3.5 million in annual operating costs. Getting federal funding is an incredible challenge and local dollars from multiple jurisdictions is also a tall hurdle.
Lessons learned	Like all long-term transit projects, they take a long time and cross many political careers. So it's important to have champions who can institutionalize the organizing effort so that it keeps moving forward when the players change.

Source: Joe Sternlieb, President & CEO of Georgetown BID, and the 2016 Georgetown-Rosslyn Gondola Feasibility Study

GEORGETOWN, D.C., USA

PROPOSED: GEORGETOWN - ROSSLYN GONDOLA

Status	A pre-NEPA alternatives analysis was published in October 2023. The proposal was to build the Rosslyn station over the street in the public right of way. On the DC side, a landing station site would need to be acquired. The DC Council put funds in the 2024 budget to do this, but the Mayor and property owner could not come to terms and the funding lapsed. The project is currently paused until the Mayor and DDOT decide to continue to move it forward.
For more information	https://www.federalcitycouncil.org/initiatives/georgetown-to-metrorail-project/
Link to feasibility study	http://www.georgetownrosslyngondola.com/feasibility-study
Current Travel (bus) point to point:	10-15 minutes and subject to traffic delays

Photo credit: Georgetown-Rosslyn Gondola Feasibility Study, Existing travel across the Potomac River in the Georgetown -Rosslyn corridor by transportation type and volume.

THE POTENTIAL ROLE OF AERIAL CABLE CAR IN PROMOTING SUSTAINABLE MOBILITY IN MOMBASA, KENYA

By Evaristus M. Irandu

INTRODUCTION

People and freight can be transported from origin to destination by different means such as cars, buses, bicycles, ferries, trains and planes. However, over the last few decades, urban areas and/or cities throughout the world have experienced exponential growth both in population size and in urban sprawl. This has led to the need for providing mass urban transit due to the rapidly growing population and increasing distances travelled. (Tubei 2018)

Besides, rapid growth of motorised transport has led to major socio-economic and urban sustainability externalities, such as traffic congestion and road traffic accidents (RTAs) (Elrayies. 2017). The externalities adversely affect the quality of life of urban residents as well as environmental impacts resulting from pollution caused by fossil fuel combustion, global warming/boiling and noise pollution (Elrayies. 2017).

Rapid urban growth coupled with widening income inequality condemn the poor to living in crowded informal settlements on the periphery of large cities. As Cervero (2000) states, it is difficult to serve these areas with conventional public transit systems such as buses or trains. As a result, the urban poor either forgo trips or endure long and costly travel times to get to their jobs or carry out less paying menial tasks near home, which exacerbate existing social inequalities (Ardila-Gomez, 2012). Affordability of transport is another challenge, as travel expenditures account for 30 percent or more of income of the poor in informal settlements (Kaltheier 2002).

To address mobility problems facing rapidly growing cities around the world, aerial cable cars have been developed to supplement existing public transport systems. Although aerial cable cars were primarily developed for rugged terrain (Sever, 2002; Alshalalfah, et al. 2012; Detter, 2015) they can be used for all types of natural barriers such as rivers, lakes, ports, and railways, as well as informal settlements (Carlet, 2016).

Photo credit: Stuart Price, Ministry of East African Affairs, Commerce and Tourism (MEAACT), Mombasa Port, 2015.
https://www.flickr.com/photos/meaact/20316460356

Today, aerial cable cars are increasingly used as low-carbon means of transport in congested cities and at touristic sites. They have also been used to serve crowded low-income informal settlements such as in Medellin (Colombia) (Davila and Daste, 2011).

Aerial cable cars have also been proposed for Mombasa City (Kenya) due to its unique morphology, inadequate capacity of the ferry service linking Likoni on the south coast with the Island and traffic congestion caused by increased use of private vehicles, boda bodas and three wheelers(Tuk-tuks)[1] (Figure1). Despite the growing trends in recent years towards the use of aerial cable cars in urban areas (Detter, 2015), their use in urban areas as a public transit system has not been adequately studied (Težak et al., 2016; Elrayies, 2017).

Fig. 1: *Author, Traffic Jam in the CBD in Mombasa City caused by three wheelers (Tuk Tuk), 2023.*

This paper examines the potential role of aerial cable car in promoting sustainable mobility in Mombasa City. The paper set out to achieve three major objectives. These were to: a) discuss the potential role the proposed aerial cable car will play in reducing traffic congestion between Likoni on South coast and Mombasa Island; b) examine potential environmental impacts of installing the proposed aerial cable car in Likoni Channel; and c) examine any barriers that may hinder the effective implementation of the proposed Likoni Channel aerial cable car. The research findings may assist policy makers in the City and the country as a whole in designing more innovative and sustainable urban mass transit strategies in the future.

HISTORY OF AERIAL CABLE CARS

Global overview of the emergence of aerial cable cars

In recent years, aerial cable cars have become popular worldwide as attractive and cost-effective transit routes for the urban areas (Elrayies, 2017; Premanand et al., 2021). Aerial cable cars are conventionally used in areas of difficult terrain such as mountains due to their ability to bridge steep sections and avoid areas that are difficult to construct on. They are commonly used at ski resorts throughout Europe (Doppelmayr, 2021a). As Williams (2019) observes, today, a number of cities around the world use aerial cable cars as their public transport mode. Some examples include cities like Rio de Janeiro (Brazil), La Paz (Bolivia), Medellin (Columbia), London (United Kingdom) and New York (USA).

The integration of aerial cable cars with the existing public transport system in these cities has conferred numerous benefits. As Sengupta (2021) has observed, aerial cable cars have provided working-class communities living on difficult and inaccessible hills with a reliable, cheap and quick transport to Bogotá (Colombia). Medellin City (Colombia) has also experienced reduced road traffic accidents (RTAs), greater social inclusion, and fewer respiratory diseases resulting from improved air quality after installing aerial cable cars (Abinal, 2019;World Bank, 2020; Sengupta, 2021). In almost all the cities, they also serve as major tourist attractions (Williams, 2019). Given Mombasa's topography, distribution of urban economic centres and share of the tourism in the national economy, it is important to consider introducing aerial cable car technology to take advantage of some of its benefits.

Aerial cable cars are now increasingly being used as a form of public transit system in urban areas (Winter et al, 2016; Carlet, 2016). Although they have primarily been used in developed countries, recent projects in the Global South such as in Colombia, Bolivia, and Nigeria have proven successful in reducing traffic congestion (Detter,2015), and in improving accessibility in informal settlements (Heinrichs and Bernet; 2014) such as in the Metrocable in Colombia. Medellin was one of the first cities in the world to link vulnerable communities to the city's public transport system and central city (Carlet, 2016).

[1] Kenya mulls first aerial cable car system in Sub-Saharan Africa. Available from: https://cceonlinenews.com/2018/07/06/kenya-mulls-first-aerial-cable-car-system-in-sub-saharan-africa/.

Figure 2 shows an aerial cable car in Medellin (Colombia). Construction of a new road network in densely populated areas such as informal settlements may lead to massive displacement of poor urban residents. However, the provision of an aerial cable car system adds capacity to the transport network without any further pressure on the existing road network or displacement of populations (Winter, 2016).

Aerial cable cars are divided into two types, namely the aerial tramways and gondolas. Aerial tramways (reversible aerial ropeways) transport passengers using one or two cabins that move back and forth on cables. With only two cabins, aerial tramways can overcome greater gradients than gondolas (Brand and Davila, 2011).

***Fig. 2:** Julio Davila, Aerial cable car in Medellin, Colombia. 2010. https://www.flickr.com/photos/uclnews/7256239732/*

Gondolas are uni-directional aerial cable cars with circulating cabins that can arrive with short headways in between each cabin. They consist of several cabins that can carry up to 30 persons each and thus have greater capacities than aerial cable cars, up to 4,000 persons per hour. Dwell times are shorter than aerial cable cars since their cabins are smaller. Gondolas are ideal for public passenger transport, which requires maximum capacity (Alshalalfah et al, 2012).

Development of Aerial cable cars in African cities

To-date, aerial cable cars have been installed in a number of cities in Africa. Aerial cable cars in Africa began as a transport mode for freight. The Italians built the Massawa-Asmara Cableway in Eritrea in the 1930s to carry freight from the Red Sea up to the Eritrean and Ethiopian highlands, where roads were already distributing goods into the hinterland. The aerial cable car was built to prepare for the Italian invasion of Ethiopia. The cableway was over 75 Kilometres in length and linked the two towns of Massawa and Asmara. It had over 1400 gondolas, 13 Stations and moved about 30 tons of goods per hour in each direction (Nuessgen, 2015).

After the introduction of cable transit for goods on the African continent, the French built a first urban aerial cable car in Algiers in Algeria in 1956. After independence, Algeria continued developing urban aerial cable cars. In the 1980s, three aerial cable cars were built to facilitate easy access to three popular destinations in Algiers. In 2008, Constantine, the third largest city in Algeria, was the first in Algeria to construct an aerial cable cars connecting the upper and the lower parts of the city. Constantine is located on difficult terrain, has large elevation differences and natural barriers to overcome (Nuessgen, 2015). The aerial cable car drastically reduced trip duration by bus from over 2 hours to about half an hour on completion. Almost concurrently, three more new generation aerial cable car systems were installed in Algeria, in Algiers, Tlemcen, and Oran. All the aerial cable car systems were entirely integrated into the public transport system leading to significant improvement in mobility and accessibility within the cities. Algeria now has multiple aerial cable car systems including three gondolas systems and several short-haul aerial trams. The gondolas are all multi-station systems. The Skikda gondola system connects two hillside communities to the city's downtown, located in the valley. In Tlemcen, the gondola is a seemingly tourist-oriented attraction, connecting the city's south end elevated park to an amusement park in the north. (Tubei, 2018).

South Africa boasts of two cableways. The first is the famous Table Mountain Aerial Cableway located in the Table Mountain National Park and World Heritage Site (Figure 3). It commenced its operations in 1929 and today, approximately 1 million travellers use it annually.

Before the construction of the aerial cable car, the only way of climbing the Cape Town's iconic mountain was by foot, usually by adventurous people. Aerial cable cars take about five minutes to reach the top of the Table Mountains.

The aerial cable car rotates to offer travellers a 360° views (According to Peterson (1983), the visitor impact of the huge traffic flow on the fauna and flora of the area is enormous. Another also well-known cableway is the Harties Cableway in Hartbeespoort in the North West province. This is the longest mono-cableway in Africa, about 1.2 km long. It was built in 1973 but fell into disuse between 2005 and 2010, but it is now operational.

Fig. 3: *George M. Groutas, Table Mountains aerial cable car, South Africa, 2010. https://www.flickr.com/photos/jorge-11/4787173724*

Photo credit: Fazielah Williams, Table Mountain Aerial Cableway, 2016. https://commons.wikimedia.org/wiki/File:Table_Mountain_Aerial_Cableway_2016.jpg

In Nigeria, an aerial cable car was constructed in the Obudu Ranch Resort in 2005. It was built over the Obudu Plateau. The aerial cable car brings travellers from the base of the mountain to the summit of the Obudu Ranch Resort. When it was built, it was the world's longest aerial cable car system. The resort is located on the Obudu Plateau, close to the Cameroon border in the northeastern part of Cross River State. Recently, the Resort has seen an influx of both domestic and international tourists because of the development of tourist facilities by the State Government. This has transformed the ranch into a renowned holiday and tourist resort centre in Nigeria.

LITERATURE REVIEW

This section provides a review of previous studies on urban aerial cable car transport. The findings of these studies are relevant to the present study because they would provide insights on the potential benefits and disadvantages of installing aerial cable cars in Mombasa City (Kenya). They would also demonstrate how aerial cable cars could be integrated with the existing urban transport systems and any possible barriers that could prevent their installation. The uses of aerial cable cars in non-urban environments such as in mountainous areas and for tourism are well researched, but, researches on the use of these systems in urban areas and city centres as part of public transport networks are limited (Težak et al., 2016; Elrayies, 2017).

Aerial cable car transport technology has long been associated with highland, rugged, rough or difficult terrains (Joachim et al., 2013; Oluwatuyi, et al., 2018).

Today, aerial cable cars are not only operated in developed but also developing countries. Aerial cable car transport system has many benefits. The system is attractive for urban public transport and is used in some cities such as Medellin (Colombia), La Paz (Bolivia), Rio de Janeiro (Brazil), Ankara (Turkey), and London (UK) (Joachim et al., 2013).

A study by Težak et al., (2016) established that aerial cable cars have several advantages compared with other transport modes (Table 1). Routes for aerial cable cars are not affected by surface configuration such as steepness, infrastructure barriers and need for extra land for transport facilities is limited. This reduces or eliminates the need to remove large amount of vegetation cover on the hillsides and preserves green urban spaces for recreation. Aerial cable cars have lower carbon footprint because they use electricity, especially one derived from renewable energy sources. Noise pollution and traffic accidents are minimised. Aerial cable transportation is also comfortable. Težak, et al. (2016) also found out that despite their positive characteristics, aerial cable cars also have certain disadvantages. Their speed and capacity are limited (when compared with urban passenger transport such as underground metros and modern Light Rail.) The distance covered is about 7km. Rescue operation in aerial cable cars in case of an accident is difficult. However, the most disturbing aspect of aerial cable cars is their negative visual impact on urban landscapes (Težak, et al., (2016).

Table 1: Advantages and disadvantages of Aerial cable Cars

Advantages	Disadvantages
Barrier-free transport system	Slow speed (up to 43.2 kph) compared to LRT and trains
Eco-friendly: emissions-free, improves air quality, reduces noise pollution	Limited capacity (4,000 persons/hour)
Electrically operated and energy saving	Suitable for distances of up to 7 km
Congestion free mobility because of dedicated right of way in the air	Extensive maintenance and controls
Provide direct and shorter routes, often reducing travel time of alternatives including buses	Weather-sensitive transport system especially strong winds
Relatively cheaper to implement than road or rail; Cheaper to operate and maintain than road or rail	Expensive infrastructure especially for faster detachable cable cars, but still much cheaper than rail
Safest public transport system	No heating or air conditioning in cabins typically
Comfortable transport	Potential negative visual impacts
No need of surface for transport	
Ideal for tourist sites	
Suitable for intermodal transport links	
Quick to install	
Quick and regular transport system, (low headways)	
Source: Modified from Težak et al, 2023.	

Alshalafah et al., (2013) observed that in recent years, unconventional public transport technologies such as aerial cable cars were increasingly being used in many urban areas around the world. The speed of aerial cable transport systems depends on the speed of the traction cable and on the distance between stations. The capacity of aerial cable transport systems depends primarily on the capacity of the cabins, on the spacing of cabins on the cable and the speed of the traction cable. According to Alshalafah et al., (2013), the advantage of the aerial cable transport systems is that they operate within their own dedicated space and are therefore independent of constraints to which other modes of transport operating on the road network face such as traffic congestion.

Oluwatuyi, et al., (2018) observed that application of aerial cable cars with proper management could be a major source of revenue in developed and developing countries. For example, the Obudu cattle ranch in Calabar Crossriver (Nigeria) provides a source of revenue to the state and attracts tourists worldwide. Oluwatuyi, et al., (2018) established that less than 8% of the world's aerial cable cars are located in Africa. This could point to a possible investment opportunity in aerial cable transport system.

Available literature indicates that aerial cable car transport systems can be integrated with the existing urban public transport systems (Clément-Werny et al, 2011; Mayer, 2013). These studies demonstrate that applications of conventional transport technologies in urban areas might not be always possible due to several factors that may not necessarily be attributed to passenger demand. Some of the factors include high capital outlay of these systems, limited availability of space to expand or create new systems and the presence of geographical and topographical barriers. Aerial cable cars can help reduce traffic congestion and greenhouse gas emissions. Seoul is a good example of a city that was experiencing serious traffic congestion and poor air quality from the mass use of private vehicles, while public transport was in need of a thorough upgrade. Installation of an aerial cable car system helped in easing traffic congestion and improving air quality (Mayer, 2013). Already, several metropolitan areas such as Medellin (Colombia), Caracas(Venezuela), Rio de Janeiro (Brazil), New York (USA), Algiers (Algeria) and others have incorporated aerial cable cars into their public transport systems. This shows that aerial cable car projects can provide an effective urban transport solution (Clément-Werny et al, 2011).

A study carried out by Elrayies (2017) established that traffic congestion and air quality deterioration are major problems in the high- density areas of Greater Cairo (Egypt). This is where the two banks of the Nile River are linked with eight bridges, which, along with the Cairo Metro and other surface transport projects have not been able to solve these problems. Elrayies (2017) highlighted the possibility of applying aerial cable car transport system in Egypt as a means of addressing traffic congestion and air quality problems in Greater Cairo. According to Elrayies (2017), if traffic congestion problem in the Greater Cairo is not addressed, its negative impacts are expected to increase exponentially. The study recommended introduction of aerial cable cars system in the City as well as expanding surface transport networks.

Premanand et al., (2021) carried out a study on aerial cable cars in Mahé (Seychelles). They set out to demonstrate how aerial cable cars could be a solution to Mahé's traffic congestion. They also observed that "operating a successful aerial cable car route demands specific actions from people's representatives, government agencies and investors, apart from wider behavioural changes and acceptance amongst the residents and visitors of the Seychelles'" (Premanand et al., 2021: 77). This implies that certain barriers have to be overcome for the successful installation of aerial cable cars in any given urban centre.

PROPOSED AERIAL CABLE CAR IN MOMBASA CITY

Location

Mombasa City is located on the eastern coast of Kenya. In recent times, the City has experienced serious traffic congestion due to increasing private car ownership, inadequate public transport system and large volumes of trucks moving goods to and from landlocked countries of Eastern and Central Africa. The City possesses the biggest seaport in Kenya and serves as the "Gateway" of the Northern Corridor (Irandu, 1982; ITDP, 2020; Watanabe and Opiyo, 2023). Rapid population growth and urban sprawl contribute to an increasing challenge of providing well-organised, high quality public transport (ITDP, 2020).

Physiographic Features

Relief features are the major determinants in the development of Mombasa. The two large intrusions of the ocean, namely Port Tudor on the east and Port Reitz on the west provide the chief reason for Mombasa's birth and continued development (Figure 4). However, they also present the most significant problem for the development of the City, including transport networks. Port Tudor and Port Reitz divide Mombasa into four physically separate areas, namely, the Island, the North, South and the West Mainlands (Irandu, 1982).

The subsequent rise in sea level led to the submergence of the valleys and the creation of Mombasa Island surrounded by deep natural creeks, ports and harbours such as Kilindini, Tudor, Makupa, and Old Port creeks.

Figure 4 shows Mombasa City; it is apparent that accessibility of Mombasa Island to and from the mainland areas poses major challenges. Given Mombasa's topography, geographical distribution of urban economic activities and contribution of its tourism industry in the national economy, there is need to deploy an aerial cable car technology to help solve some of the perennial transport problems experienced in the rapidly growing urban metropolis.

Fig. 4: *Jasiński, Artur, Satellite Image of Mombasa City.* [*https://www.researchgate.net/publication/332920211_Colour_as_a_tool_in_shaping_the_city_image_-_based_on_the_case_of_Mombasa*](https://www.researchgate.net/publication/332920211_Colour_as_a_tool_in_shaping_the_city_image_-_based_on_the_case_of_Mombasa)

Socio-demographic Profile

Population distribution and settlement patterns in the City are influenced by proximity to vital social and physical infrastructure networks such as roads, housing, water and electricity. Other factors that influence settlement patterns include accessibility to employment opportunities and security. Its population grew steadily from 0.2M in 1969 to 1.2M in 2019. Between 2009 and 2019, its annual population growth rate averaged 2.5%. (KNBS, 2019: ITDP, 2020).

As per the 2019 census, Likoni area of Mombasa Island, had a population of 21,805. The average age is 40-50 years. Those above 50 years constitute 31.3 % of the Likoni estate residents (KNBS, 2019). About 30.6 % of the Likoni residents are self-employed while 19 % are employed by the County government of Mombasa. The average monthly income of Likoni tenant is about Kshs. 28,000($ 250). Majority of the tenants have little or no income and the installation of aerial cable car at Likoni may offer opportunities for some livelihoods for them and other City residents.

Transport System

Figure 5 shows that majority of residents (45%) in Mombasa City use walking as their main mode of transport while 36% of the residents use public transport. Although three wheelers (tuk-tuks) account for only 4% of modal split, they are a major cause of traffic congestion in Mombasa City. Mombasa City faces very serious mobility challenges. Residents encounter daily traffic snarl-ups on the roads leading to Mombasa Island, which is the commercial hub of the City. Due to inadequate public transport system and lack of non-motorised infrastructure, the city has witnessed a significant modal shift to private cars and taxi services such as boda bodas and tuk-tuks.

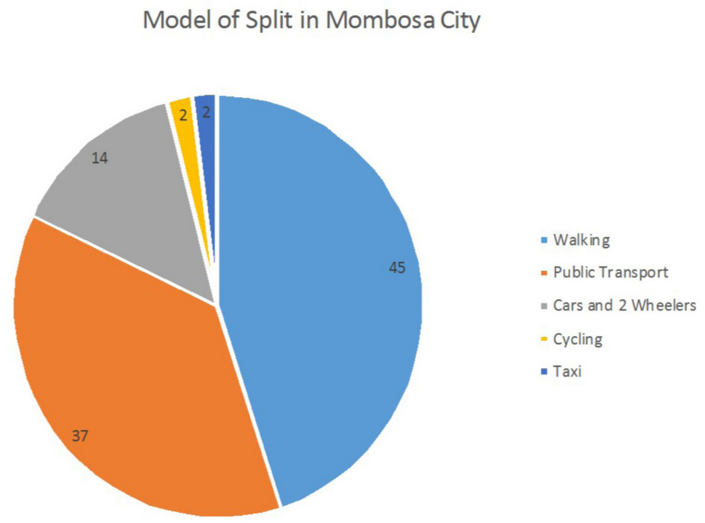


Fig. 5: *Modal Split in Mombasa City, JICA.* [*https://africa.itdp.org/planning-mombasas-public-transport-system/*](https://africa.itdp.org/planning-mombasas-public-transport-system/)

The city centre of Mombasa City is situated on the island and separated from its suburbs by various basins and channels (Figure .4).

Whereas bridges connect Mombasa Island to the North coast and West mainland, only ferry service provides transport between Mombasa Island and Likoni on the South coast (Figure 6). About four ferries operated by the Kenya Ferry Services (KFS) transport up to 300,000 passengers and 6,000 vehicles daily across the 500-metre channel. The Likoni ferry service is a very important part of the city's transport system. However, it faces a number of challenges that render it inefficient. For example, pressure is exerted on the existing ferry services especially during peak times, which results in lost person-hours. During this time, long vehicle queues may be experienced. Ramp approaches at the Likoni Ferry are narrow thereby limiting the number of ferries that can load and offload simultaneously. Ships entering and leaving the Kilindini Port pose logistical challenges by disrupting ferry movements across the Likoni channel. Over the years, both human and vehicular traffic using the Ferry service has increased exponentially, putting more strain on the existing facility (ESIA, 2020).

Fig. 6: *Author, Commuters alighting from a ferry at Likoni Channel, Mombasa, 2023.*

Proposed Aerial Cable Car in Context

An aerial cable car in Mombasa has been mulled since 2013. The project is estimated to cost KShs 4.1 billion ($40 million) and will be funded by the Kenyan and Australian companies that will run it for 25 years before transferring it to the government in what is known as Build Own Operate Transfer (BOOT) public-private partnership. The project got approval of Cabinet in 2018 and construction was scheduled to begin by the end of 2019.

The plan is to erect a suspended 1.3 km cableway linking Mombasa Island to the South Coast. The proposed aerial cable car will have up to 28 cabins crossing every four minutes carrying about 40 people, thereby facilitating 11,000 commuters per hour to cross the channel. The proposed aerial cable, if constructed, will increase the reliability of the crossing for the passengers. Besides, more commuters will be able to cross at once since the aerial cable car will provide fast passenger crossing with no waiting time (Mair, 2022). Movement within the City and its surrounding areas will be eased following plans to extend the Likoni aerial cable cars project to Moi International Airport, Nyali and Kilifi County. The aerial cable car is not an alternative to road transport but a complement in decongesting the city. Currently, commuters take about 40 minutes from Mwembe Tayari on the Island to Nyali on the North Mainland due to traffic jams. The aerial transport solution will also not conflict with shipping traffic. It will offer a reliable and fast connection in case of emergency.

The proposed Likoni Aerial Cable Car can be integrated with the existing public transport modes such as the Standard Gauge Railway (SGR), the ferry services, mini-buses (matatus) and three wheelers (Tuk tuks). When the SGR is extended to the South Coast, some rail extensions can be built to link with the aerial cable car. This would enable train commuters to catch an aerial cable to and from Mombasa Island. The aerial cable car would be integrated with the railway transport at the railway station built nearby for ease of movement from one mode of transport to the other. The same could be done with minibuses or matatus operating on the Island. Some matatu (minibus) terminals could be built near the Likoni Aerial Cable car to allow faster transfer of travellers from one mode to the other depending on their destinations. Three wheelers (Tuk tuks) could also pick and drop passengers who wish to travel by aerial cable car at the matatu terminals.

A ride in the proposed aerial cable car when complete is estimated to cost between KES20 ($0.14) and KES100 ($0.7) varying between off-peak and peak hours respectively. This may be unaffordable for the poor people, majority of whom are unemployed and live in poor informal neighbourhoods.

The government could make ridership more affordable for poorer residents of the City by subsiding fares. Revenue obtained from tourists who are expected to use aerial cable car can be used to subsidise fares and make its operations financially sustainable. The aerial cable car is also expected to reduce the long queues at Likoni Ferry and open the South Coast for more tourism development.

However, to date, the installation of the proposed aerial cable car has not yet started. With other mega projects being undertaken there are doubts as to whether the proposed Likoni aerial cable car project will ever take off (Mwambingu, 2021). Recently, the Government has embarked on other equally ambitious infrastructure development programs within Mombasa City. These include the construction of the Liwatoni floating bridge and the plan to construct Mombasa Gateway Bridge.

METHODOLOGY

The research used a descriptive and qualitative analysis design using both primary and secondary data. Secondary data was obtained through literature review of published theses, journal articles, documents from the City County of Mombasa and the State Department of Transport in the Ministry of Roads and Transport Infrastructure of the Republic of Kenya.

Primary data was obtained through questionnaire survey of commuters and key informant interviews (KIIs) of Central Government and Mombasa City County officials. Eighty (80) people were interviewed in the study. A questionnaire survey was administered to 20 commuters drawn from each of the three mainland areas (North, West and South) and 10 from the Island, making 70 interviewees. Commuters to interview were randomly selected by being asked to pick a random number from a basket. Once a given random number was picked, it was not returned to the basket. Since the study was qualitative in nature and descriptive statistics were used in analysis, any sample size was considered sufficient (Israel, 1992).

The commuters interviewed were expected to provide views on the advantages and disadvantages of the proposed aerial cable car in Mombasa City. This was important because the 70 commuters interviewed represented the expectations of the travelling public in the City. The ten (10) key informants were not randomly selected but purposefully selected based on their expertise on the new aerial cable car technology. These included two (2) Kenya Ferry Services (KFS) officials, two (2) Kenya Ports Authority officials, two (2) City County officials, two (2) Ministry of Transport officials and two (2) technical experts drawn from the Private sector.

Content analysis was employed in analysing secondary data from published sources. After thorough search and review of published and unpublished data, it was subjected to critical evaluation. Any possible negative environmental impacts likely to result from the installation of commuter aerial cable cars were established after critical review of the existing Environmental and Social Impact Assessment (ESIA) report carried out on the proposed project. These impacts were compared with those experienced in cities where cable cars are already operational. Primary data was obtained such as commuters' opinions on possible benefits of introducing aerial cable car at the Likoni Channel.

To discuss the potential role the proposed Likoni aerial cable car would play in Mombasa City, the ten (10) key informants were all asked the following open-ended questions: a) What do you consider to be the advantages and disadvantages of the Likoni aerial cable car to Mombasa residents? b) What are the likely barriers to the installation of the proposed Likoni aerial cable car?

To discuss the potential role the proposed aerial cable car will play in reducing traffic congestion between Likoni on South coast and Mombasa Island, the 70 commuters were asked the question: 'What are your expectations of the proposed Likoni aerial cable car before construction?' It was expected that the proposed aerial cable car would be useful in reducing traffic congestion in Mombasa City if commuters would be willing to use it. To find out whether commuters in Mombasa City would be willing to use aerial cable car after completion, the 70 commuters were asked the following question. Do you agree with the following statement? 'I would use the proposed aerial cable car when complete.' The responses to this question were on a 5-point Likert scale. Responses to the two questions above were presented through cross tabulation and chart.

RESULTS AND DISCUSSION

This section presents the results and discussion of the potential role the proposed aerial cable car will play in reducing traffic congestion between Likoni on South coast and Mombasa Island, examination of the potential environmental impacts of installing the proposed aerial cable car in Likoni Channel and examination of the potential environmental impacts and possible barriers to effective installation and operation of aerial cable car at the Likoni Channel in Mombasa City.

Potential role of the proposed aerial cable car

Literature reviewed revealed that building an aerial cable car in a developing country such as Colombia, Rwanda or Egypt has both advantages and disadvantages (Mayer, 2013; Težak et al., 2016; Elrayies, 2017). Some of the advantages identified in these studies are: reduction of traffic congestion, not affected by topography, have lower carbon footprint and noise pollution. However, the studies also established that installation of aerial cable cars has some disadvantages. Some of the disadvantages identified include loss of biodiversity through clearance of vegetation, invasive species introduced by construction equipment, visual intrusion and high operation and maintenance costs (Težak et al., 2016; Elrayies, 2017).

To discuss the potential role the proposed aerial cable car will play in reducing traffic congestion between Likoni on South coast and Mombasa Island, the 70 randomly selected commuters were asked to give their expectations on the Likoni Channel aerial cable car before its construction. Their expectations were varied as shown in Table 2. The study found out that residents of Mombasa City expected the Likoni Channel aerial cable car to reduce traffic congestion. This was revealed by an overwhelming majority (96%) of the respondents interviewed (Table 2).

Table 2: Residents' expectations of the Likoni aerial cable car before construction (percentage)

Expectation	Percentage
Reduction of travel time	72
Comfortable travel	76
Reduction of waiting time	84
Much safer	90
Reduction of traffic congestion	96
Reduction of road traffic accidents	64
Increase accessibility of the South mainland	80
Increase trips made per day	48
Improve frequency of service	60
Affordability	40
Improvement of air quality	76
Provide better view of the City	62
Improving quality of life	52

Source: Compiled by author, 2023

The expectation of overwhelming majority (96%) of respondents interviewed is not surprising since Mombasa City faces serious traffic congestion especially at peak times at the Likoni Ferry and the CBD. The ferry service often experiences massive delays and frequent breakdowns. The respondents expect the proposed aerial cable car to complement ferry services at the Likoni Channel. This finding is consistent with what other previous studies established (Irandu, 1982; ITDP, 2020).

The cost of building a bridge across the Likoni Channel would be prohibitive due to topographical, land use and height challenges. (African City Planner, 2015) Therefore, installation of aerial cable car would ease traffic congestion at the Likoni Ferry crossing, as some of the commuters would very likely prefer to use the aerial cable car (Figure 7). If the aerial cable car were integrated with public transport system and non-motorised transport infrastructure, there would be a great improvement in reduction of traffic congestion in the City.

Potential environmental impacts of the proposed aerial cable car

To examine the potential environmental impacts of installing the proposed aerial cable car in Likoni Channel, an in-depth review of the available literature was undertaken. The study established that an aerial cable car is an environmentally sound transport system when compared with private cars and buses (Težak, et al., 2016; Elrayies, 2017; Premanand et al., 2021). Besides, critical review of the Environmental and Social Impact Assessment (ESIA) report prepared by experts licenced by National Environment Management Agency (NEMA) revealed that construction of aerial cable car across the Likoni Channel would have no serious and irreversible environmental impacts in the area it will pass. It was also revealed that generation of noise and exhaust fume emissions was negligible (ESIA Report, 2020). Aerial cable car operated by electricity in Mombasa City is feasible since about 68% of Kenya's energy generation is from green or renewable energy (MoEP, 2018).

Barriers likely to hinder implementation of the proposed aerial cable car

To examine the likely barriers that may hinder effective implementation of the Likoni Channel aerial cable car, thorough review of available literature was undertaken and questionnaire survey and key informant interviews carefully analysed. The information obtained from in-depth literature review, questionnaire survey and key informants revealed that installation of aerial cable cars in the Likoni Channel would face some barriers.

Literature review established that technical barriers are a major limitation of aerial cable car connection or route (Premanand et al., 2021). It was established that integrating aerial cable cars with other modes of public transport such as roads and railways networks might be difficult and expensive especially in an urban area facing spatial constraints such Mombasa City (Clement-Werny, 2011; Davila, 2013; Premanand et al., 2021). Mombasa's physiographic features may hinder further extension of aerial cable car in the future even after completion of the Likoni Channel project. Construction of aerial cable cars is subject to very stringent requirements for alignment. It is much easier to alter road or rail alignment or expand it as need arises than an aerial cable car.

Key informant interview (KII) with the Kenya Ferry Services and Ministry of Transport officials revealed that financial barriers would also hinder the installation of the proposed aerial cable car. It was established through discussion with key informants that proposed Likoni aerial cable car would require a whopping $40 million to install. This is a huge amount for a poor developing country such as Kenya. The local City County Government of Mombasa cannot be able to raise such a colossal sum. Therefore, financing has to be sourced from Central Government and/or external sources. The proposed aerial cable car is to be financed through a public-private partnership (PPP) model. When the aerial cable car is built, it may be unaffordable to the poorer members of the City and tourists may be the ones able to use it.

Another financial barrier identified by the key informants was that residents in neighbourhoods where the proposed aerial cable car would pass were concerned about possible intrusion and loss of their privacy. This is a genuine fear because aerial cable cars would be passing overhead (100 metres). The residents also feared that their property values would plummet because of loss of privacy. Some of the likely barriers identified through literature review and key informant interviews are summarised in Table 3.

Table 3: Barriers to the implementation of aerial cable cars in Likoni Channel, Mombasa

Type of Barrier	Description
Technical barrier	a. Post-construction changes may be difficult due to proximity of port facilities. b. Inefficient over distances greater than 7 kms. c. May be used mostly by tourists, locals may be reluctant to use them. d. Slower travel speed compared to cars, buses or trains (but not necessarily slower on a point to point basis) e. Lack of technical expertise to operate and maintain the cable cars.
Economic/financial barrier	a. Integrating aerial cable cars with other modes of public transport may be difficult and expensive. b. Charges for ridership may be high. c. Reduction of property values
Social barriers	a. Visual impact and intrusion (loss of privacy). b. Commuters may prefer to be picked and dropped at convenient points. c. Preference of private cars for prestige.
Political barriers	a. Difficult to get public consent b. Lack of political good will from local (county) authorities
Source: Compiled by author, 2023	

The 70 randomly selected commuters were asked to choose from a 5-point Likert scale, whether they would be willing to use the aerial cable car when completed. As shown in Figure 7, it is apparent that about two-thirds (66%) of the respondents agreed, to varying degrees, that they would use the aerial cable car when completed. However, a significant proportion (34%) of the commuters disagreed to varying degrees. Possibly some of the commuters fear height or felt the aerial cable car would be for tourists. This finding is consistent with the findings of Premanand et al., (2021) in their study of the impact of aerial cable car in Mahe City in Seychelles.

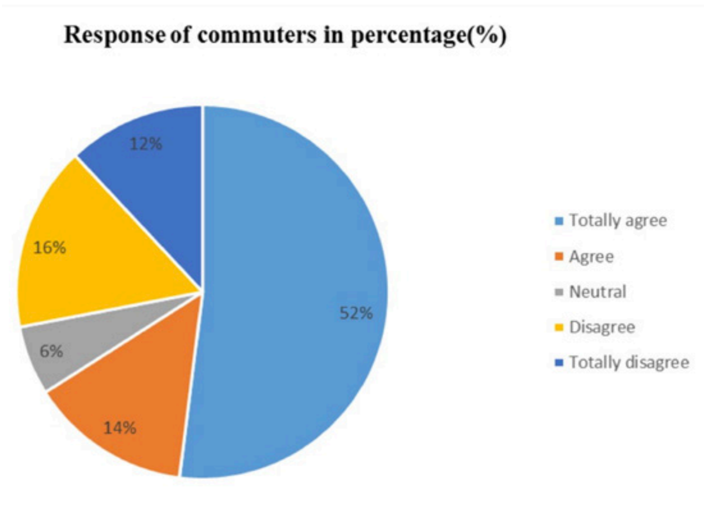


Fig. 7: Author, Responses of commuters on a 5-point Likert scale,

Generally, a major project such as the Likoni Aerial Cable Project would face some financial barriers such as poor residents' ridership due to high fares charged.

However, discussions with experts from the State Department of Transport of the Ministry of Roads and Transport of the Republic of Kenya revealed that the proposed aerial cable car project could cater for the needs of residents who travel daily from Likoni Ferry to Mombasa Island for work and other trip purposes by providing affordable, safe and comfortable transport. The experts from the State Department of Transport also indicated that the Likoni Ferry Aerial Cable Car Project could generate revenue from both residents and tourists and that stable residents' ridership could help fill the gap during off-peak season, which corresponds with Northern Hemisphere Summer.

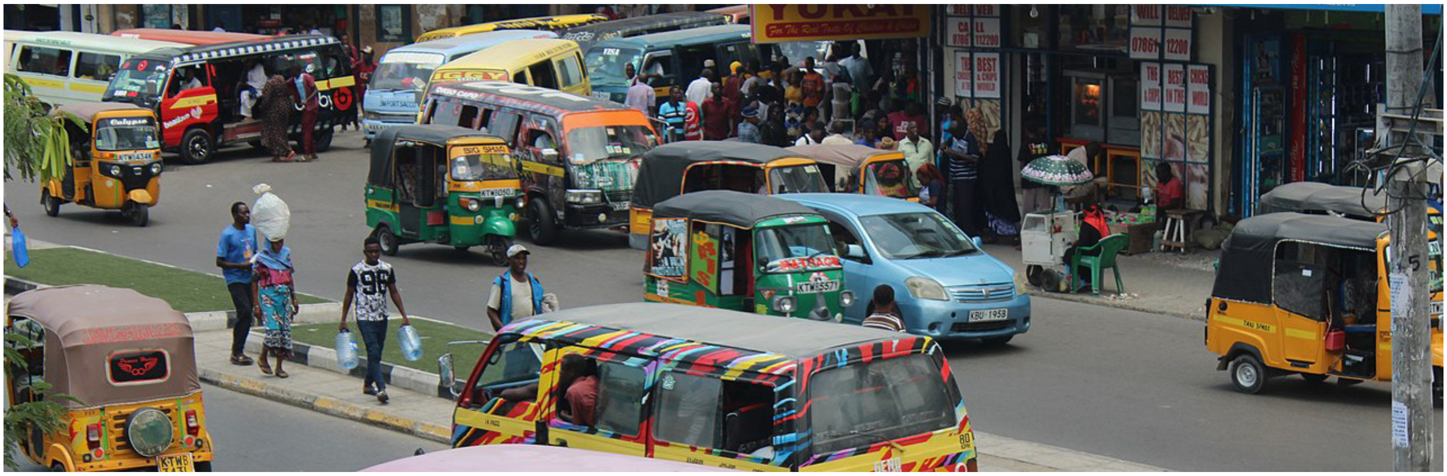


Photo credit: Tumo Maokisa, Colorful Matatu in Mombasa, 2020. https://commons.wikimedia.org/wiki/File:Colorful_Matatu_in_Mombasa.jpg

CONCLUSION

This section provides a summary of the key findings, lessons learned and recommendations based on in-depth literature review and analysis of questionnaire survey and key informant interviews. Some recommendations have been made to guide policy makers in designing integrated and sustainable public transport system in Mombasa City and in other rapidly growing urban areas in the country, which also incorporates aerial cable cars.

A key finding of the study was that the construction of aerial cable car at the Likoni Channel in the Mombasa City is expected to reduce traffic congestion. This was the expectation of the majority (96%) of the respondents (commuters) interviewed. As already discussed, Mombasa City experiences serious traffic congestion especially at peak times at the Likoni Ferry and the CBD. To ease traffic congestion and overcrowding in public transport vehicles, aerial cable car transport system should be developed in many parts of Mombasa City. There is need to provide adequate connectivity between the Island, which is the core of the City with the mainland areas. Aerial cable cars can be integrated into the existing public transit system in Mombasa City. Terminals can be located near bus stations and taxi lanes to allow for easy interchanges and thus ensure seamless transport. This is what has been done in La Paz (Bolivia) (Winter, 2016). As studies have shown elsewhere (Carlet, 2016), the integration of aerial cable car into the existing transport infrastructure is cheaper when compared to the costs of bus transport or commuter rail. Therefore, it can be concluded that aerial cable car is a promising technology and one worth considering as Mombasa City continues to evaluate its approach to an integrated public transit system.

Another key finding was that aerial cable cars have less carbon footprint than other public transport modes. In-depth literature review including the Environmental and Social Impact Assessment (ESIA) report for the Likoni Channel aerial cable car project, it was established that aerial cable car systems have low carbon footprint because of using electricity and generate zero emissions. This is the type of transport system ideal for assisting the City in combating climate change. Mombasa City would develop a more sustainable transport system by integrating aerial cable car technology with other public transport modes such as the BRT and the Standard Gauge Railway (SGR).

Review of available literature on aerial cable cars in Medellin (Colombia), La Paz (Bolivia), Rio Janeiro (Brazil), Cape Town (South Africa), Cairo (Egypt) and Kigali (Rwanda) among others, offers valuable lessons for cities that plan to adopt the new technology (Joachim et al., 2013; Oluwatuyi, et al., 2018; Davila, 2021). It has been proven that aerial cable cars are a sustainable mode of urban transport especially where topography and informal settlements pose challenges to the development of other modes of public transport. Therefore, introduction of aerial cable cars may improve accessibility, mobility and reduce poverty in a city.

Another important lesson is that aerial cable car transit system alone may not automatically lead to greater integration of informal settlements (slums) with the rest of the city and to poverty reduction. Other necessary elements are improving mobility, making public transport affordable and reducing traffic congestion.

Thus, when designing, planning and installing aerial cable cars the expectations and lifestyles of the inhabitants of the affected area should be prioritised. This is important because it may influence the use or not of the new technology by residents.

However, as a long-term solution to the mobility problems faced daily by commuters in Mombasa City, there is need to promote a well-integrated public transport system. This would involve developing a reliable, efficient, affordable and environmentally-friendly public transport system such as the Bus Rapid Transport (BRT) and integrating it with Non-motorised transport (NMT) infrastructure and aerial cable car technology. The Ministry of Roads and Transport of the Republic of Kenya should formulate a policy framework to guide the construction, operation and integration of aerial cable cars with the existing transport system in urban areas throughout the country. Efforts should be made by the Central government to develop requisite expertise for successful operation of aerial cable cars once installed in urban areas such as Mombasa City.

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SEATTLE'S GONDOLA AMBITIONS

A case study on how gondola technology has been considered in the Pacific Northwest

By Martin Pagel

INTRODUCTION

The cities along the west coast of the United States are hemmed in by a coastal mountain range and most have various hills which make it challenging to connect all neighborhoods with rail lines. San Francisco California relied on their historic cable cars to get up its hills. Portland Oregon built an aerial tram, Vancouver, BC (Canada) and Los Angeles California are planning 3S gondolas, and San Diego California, Oakland California, and Seattle Washington have considered various gondola projects in the past. Sound Transit has focused on building light rail (aka Link) lines to connect Seattle with some cities across the Puget Sound region. They also run a few Express bus lines and soon bus rapid transit (BRT) (aka STRride) lines. Starting in 2021 a group called West Seattle SkyLink has been advocating for an urban gondola as an alternative to one of the light rail lines which would serve the West Seattle neighborhood. In addition, Kirkland, a city across from Lake Washington, is considering a gondola line to connect their STRide station with downtown. This article looks at these two opportunities to use aerial gondolas rather than traditional transit technologies and how gondolas may provide a better outcome.

CASE 1: WEST SEATTLE LINK EXTENSION (WSLE)

When in 2014 Sound Transit considered its next set of Link extensions, Ballard (Northwest Seattle) was high on the list due to housing density and estimated ridership. Politicians from (South)West Seattle however didn't want to get left out and a 4.7 mile WSLE was added to the list of projects ultimately approved by the voters in the region in 2016 as part of the Sound Transit 3 (ST3) measure.

Photo credit: Robert Ritchie, Seattle ,WA, 2021. https://unsplash.com/photos/a-view-of-a-city-with-a-tower-in-the-middle-of-it-JEicDFy5Cd8

Even before the vote, Sound Transit had evaluated various high-capacity transit (HCT) modes: various bus technologies (Express, BRT), rail systems (streetcar, light rail, heavy rail, DMU, commuter rail, high speed rail or maglev), and more local solutions (people movers, gondola/aerial tram, personal rapid transit). They decided for their regional expansion efforts to continue with light rail as it fit in with the existing downtown tunnel and at-grade lines though they found that other technologies may have advantages as long as those lines were separate. However, when the WSLE was added, it was assumed that it would use light rail technology.

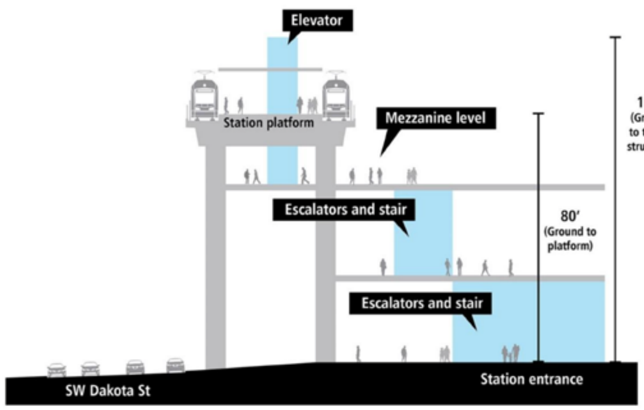

Figure 1: *Delridge station (Source: Sound Transit WSBLE DEIS)*

Figure 2: *SW Genesee St. with a rendering of the proposed light rail guideways (Source: Sound Transit WSBLE DEIS)*

Originally the light rail line was going to closely follow the route of the West Seattle Freeway but that would have made it difficult to provide decent access to the stations. When Sound Transit realized that more riders would arrive at light rail stations by bus rather than by walking, bus access became a priority which ultimately pushed the line further away from the freeway into the neighborhood. Sound Transit also realized that West Seattle has difficult terrain and surface obstacles: there are multiple rail lines, the West Seattle Freeway, a steel plant and the Port of Seattle with its freight rail and truck lines, the Pigeon Point hill and the Junction hill, the Duwamish Waterway, and various parks, wetlands, and tribal lands. At some point most of the light rail line was proposed to be elevated 80 to 160 feet up to get up to the Junction, and some of the stations were proposed to be more than 100 feet high requiring 3 levels of escalators. (Figures 1 and 2). There were no wide road corridors the extension could just follow. As Sound Transit requires clearing at least a 60-foot corridor for any rail line, it would have been necessary to take many businesses and residential units via eminent domain, including a major mental health facility and one of the largest childcare facilities in Seattle. Additional tunneling was proposed but ultimately not pursued as too risky and expensive.

Ultimately, in mid 2022 the Board decided to favor a route for the final Environmental Impact Statement (EIS) which reduces the impact on land taken somewhat though it also reduces the station walkshed. The end of the line with the Junction station will be tunneled which will increase the carbon footprint and cost not just for this project but will also make it more expensive to extend the line further South later. To mitigate the cost, Sound Transit is considering dropping the middle station. While Sound Transit originally planned ridership of 32,000 to 37,000, they reduced that estimate to 27,000 right before the pandemic and have not updated it since. But initially the line will only connect to the main North/South line; to reach any location outside of West Seattle riders will have to switch tracks (two escalator rides) and wait for a connecting train which may take up to 12 minutes. Sound Transit does not expect much ridership until it gets connected to the new downtown tunnel. This was anticipated for 2035, has already been delayed until 2037, and will probably slip further as the downtown route has not been finalized yet.

Figure 3: *Source: Sound Transit*

While Sound Transit markets themselves as being the greenest transit agency in the U.S., (Figure 3) this only considers operational power needs, not overall carbon footprint. Once the line connects downtown, Sound Transit expects only 400 daily riders (see: DEIS Appendix N Table 2-9) to switch from cars to light rail going downtown. If they all sell their cars and switch to transit it may reduce [carbon emissions] by 1840 tons annually. Though Sound Transit's Draft EIS claims that the light rail line will reduce carbon emissions, it also estimates that construction will generate 614,000 tons of carbon (see: DEIS Appendix L4.6D). With only 400 new riders you may need to wait 300 years to realize the advantage (or longer with electric cars).

Currently, buses take riders straight from multiple locations in West Seattle on a freeway straight to downtown. Ultimately it is expected that buses will drop off riders at one of the light rail stations. For people walking to the station light rail may be slightly faster once it connects downtown directly, but not until then. For anybody who transfers from a bus, the total travel time will increase; if you have any mobility challenge, it may take a lot longer if they can make it all.

The cost estimates have more than doubled from originally $1.4 billion to $3 to 4 billion.

WEST SEATTLE SKYLINK PROPOSAL

In 2021, a group of residents got together to urge the Sound Transit Board to study an urban aerial gondola line alternative (they called it SkyLink) to avoid the cost increase far beyond what was approved by the voters as well as to avoid massive destruction and construction impact of their neighborhood. A gondola line would be able to cross the waterways, hills, freeways, freight lines, and neighborhoods without building high guideways and bridges and destroying green spaces and tribal lands. (Figure 4.)

Figure 4: *Author, West Seattle Light Rail Extension (Source: Sound Transit) with teal SkyLink overlay*

There would be far less loss of homes and businesses along the line because a gondola only needs a few towers, reducing the property acquisition cost, utility relocations, disruption to the neighborhood, and construction related carbon emissions, which would also help simplify the environmental impact study. (Figure 5.) A gondola could be planned and built within four years rather than requiring decades of planning, tunneling and guideway construction work. In addition, finishing a gondola this decade would allow for actual carbon reductions much sooner. Smaller stations could be built above roads or even intersections and buses could stop right underneath rather than having to divert to a larger light rail station underground or elevated high. Due to its high-frequency and automatic operation, a gondola line may speed up transfers and allow longer operating hours while reducing the annual operating budget to about a third ($12 million vs $40 million).

Figure 5: *Similar view point of SW Genesee St but with SkyLink rendering (Source: framewiz.com)*

During an initial meeting, Sound Transit staff told the SkyLink proponents that the voters had approved the light rail transit mode and that it couldn't be changed; the SkyLink team, in turn, pointed out that the ballot measure had given the Board the ability to change the plan if it became infeasible or too expensive. After more than 1500 residents had signed a petition to ask Sound Transit to at least study the alternative and media coverage in various publications, Sound Transit agreed to do a study. However they didn't hire gondola experts for the study, but produced their own gondola feasibility study internally and provided it to the media without even discussing the gondola proposal with the SkyLink team. The SkyLink team pointed out that Sound Transit mostly relied on their High-Capacity Transit (HCT) mode study from 2014 and added a few new references (incl. a 2020 study by the World Bank) but didn't update their findings accordingly. Many details the Sound Transit author added demonstrate that he neither understood the systems he quoted (e.g., CableBus) nor urban gondola technology in general.

For example, while the report admitted that current demand could be met with a gondola with 2,500 passengers per hour per direction, it questioned whether a gondola system could meet future demand, failing to mention that the World Bank study listed existing gondola systems carrying 4,500 passengers (e.g., Santo Domingo, Colombia).

In most cases an urban gondola is not a substitute for a light rail line, but for West Seattle it is a feasible alternative due to the complex topographical challenges West Seattle presents and mid-level ridership as SkyLink advocates point out. While this may be the case, even in an otherwise progressive city like Seattle, approval and implementation of an aerial gondola very much depends on whether the local transit authority is open to the use of technologies they may not be familiar with. Though the Pacific Northwest has plenty of ropeway experience (e.g., SCJ Alliance) in both the recreational and urban use, it does not mean politicians and key decision makers take the technology seriously.

CASE 2: KIRKLAND NE 85TH BRT STATION ON I-405

While Sound Transit is building out their light rail "spine" roughly parallel to I-5, it's also connecting it to the eastern shore of Lake Washington over the I-90 bridge and across I-405 where they plan to operate their STRide BRT line. (Figure 6) It will run all the way from the light rail station in Lynnwood in the North via Kirkland and the Bellevue light rail station to Renton, the Tukwila light rail station to Burien in the South.

Downtown Kirkland is located along the shore of Lake Washington almost a mile apart from the huge 3-level station and intersection Sound Transit is building up the hill along NE 85th Street. City planners are trying to make the best out of it and upzoning the area around the station for transit-oriented development (TOD). Google already has two major facilities in Kirkland and was considering adding a 3rd next to the station.

Sound Transit had promised to help with improving access between the station and Kirkland's downtown transit center and the city was trying to tie the new urban TOD village to downtown and the other Google facilities to encourage the new residents to do business within the city rather than going elsewhere.

KIRKLAND GONDOLA PROPOSAL

City planners determined that the grade and traffic along NE 85th is not conducive to people walking between downtown and the intersection and therefore started to look at high-frequency transit options to complement the buses along the road. They considered aerial tramways, gondolas and funiculars even though Sound Transit preferred adding more buses. The city finally contracted for a gondola feasibility study for a 2- or 3-station gondola line.

Figure 7: *Proposed NE 85th Gondola line (Source: City of Kirkland)*

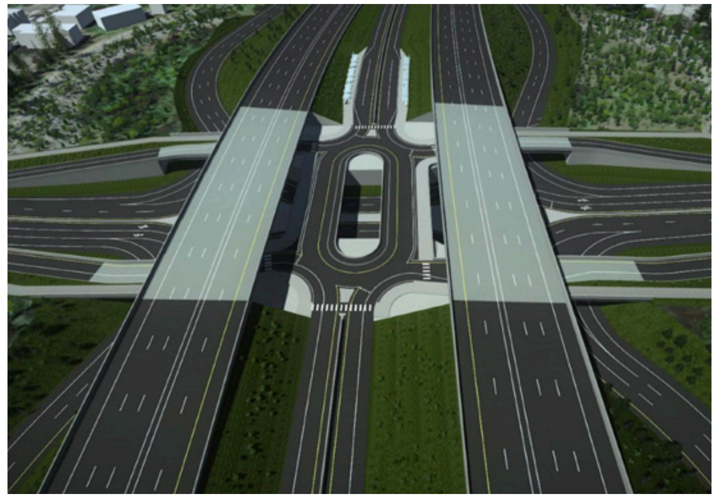

Figure 6: *Rendering of NE 85th STRide Station on top/North (Source: Sound Transit)*

It would not only connect the freeway BRT station to the downtown transit center, but also stop at a business center midway which also houses one of the existing Google facilities, the other one is a bit further South from there. (Figure 7.)

The study was concluded in 2021 and showed that a monocable line could be built along the existing corridor without much interruption.

It could provide a convenient transit connection closing an important gap while avoiding the wait time typical for bus transfers. It would provide downtown residents with convenient access to regional transit connections. A 2-station line could be built for $47 million and 3-station line for $81 million in a relatively short time. Annual operating cost was estimated at $4 million vs $7 million. It would be a great way to connect the various facilities quickly and with a breathtaking view of the lake and may even attract additional visitors to the city.

The city is still working with the residents and interested developers on the scope of the TOD project. Depending on the number of housing units, the ridership demand may or may not justify the cost of the gondola. This January Google announced that they will not acquire the property next to the BRT station.

Photo credit: Ian Sane, Follow Station Approach For Docking, 2016. *https://www.flickr.com/photos/31246066@N04/29994612241*

CONCLUSION

Both the West Seattle and the Kirkland lines are examples of how urban gondolas can be used to extend the reach of High-Capacity Transit (HCT) lines into neighborhoods close by, one driven by citizen advocates and one by open-minded city planners. (See sidebar for example of how aerial gondolas fit within a region's transportation goals and objectives. Both demonstrate that gondolas should be evaluated alongside bus or rail connections in situations where ground transportation faces any obstacles and where the length of the line is less than about 5 miles. Currently, in the Seattle area at least, gondolas don't seem to be taken seriously in the EIS process, as they are in Germany, France, Mexico, and many Central and South American and Asian countries. Furthermore, any feasibility study to evaluate the advantages and disadvantages of an aerial system in a particular setting should be conducted by ropeway experts, to ensure that aerial systems' capabilities and applications are assessed properly.

For details:
West Seattle and Ballard Link Extensions (participate.online)

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SIDEBAR: HOW AERIAL GONDOLAS MEET GOALS AND OBJECTIVES

By Claudia Hirschey

Aerial gondolas, when considered in a technical evaluation of High-Capacity Transit (HCT) modal options, meet or exceed the performance of other HCT modes, especially over challenging terrain or waterways and other obstacles on the ground including multi-lane highways, rail corridors, nature preserves, and existing developments. The long-range plan goals and objectives of Sound Transit's Regional Transit Long Range Plan, adopted December 2014 (1), that were prepared to provide the ST3 Program to Puget Sound Voters are presented below, followed by an analysis of how gondolas help meet them.

SOUND TRANSIT GOALS:

Regional Transit Long Range Plan Goals (1)	How Aerial Gondolas Meet this Goal
Provide a public transportation system that helps ensure long-term mobility, connectivity, and convenience for the citizens of the Puget Sound region for generations to come.	Gondolas and their stations are equivalent to bus, bus rapid transit (BRT), light rail, and commuter rail. Connectivity is simplified compared to tunnels and elevated rail stations. High frequency and longer operating hours provides for increased convenience.
Preserve communities and open space.	Gondolas require much less right-of-way than rail and use much less street capacity than buses or BRT making it easier to add bike lanes. Gondolas keep neighborhoods livable and connected by reducing the negative effects of bus congestion on the street, or the complexities and safety issues of at-grade rail.
Contribute to the region's economic vitality.	Gondolas, providing high-capacity transit, would be equivalent to other HCT modes.
Preserve our environment.	Gondolas conserve land, have less of a carbon footprint for vehicle and facility construction, generate less emissions and consume less energy than other HCT modes, and as an HCT mode reduce greenhouse gas emissions equal to other HCT modes in as much as drivers shift to high-capacity transit.
Strengthen communities' use of the regional transit network.	Gondola stations would encourage the development, or redevelopment, of areas around transit stations and centers and park-and-ride lots providing opportunity for a mix of transit-oriented activities at a pedestrian scale.

Source: [1] *https://www.soundtransit.org/sites/default/files/documents/2015123_lrpupdate.pdf*

SOUND TRANSIT OBJECTIVES:

Regional Transit Long Range Plan Objectives (1)	How Gondola Meet the Objectives
Keep the region moving.	Gondolas can run cost-effectively all day, seven days a week serving work and non-work trips. Gondolas have a competitive and predictable travel time with other HCT modes in exclusive right-of-way at higher frequency. Gondolas have better reliability during inclement weather. The small footprint of a gondola station allows for closer connections to other modes.
Offer cost-effective and efficient transportation solutions.	Gondolas cost much less to construct and operate than buses or rail. Gondola cabins and power cost much less than bus or rail propulsion. Gondolas are a cost-efficient mode to cross steep terrain or travel over waterways compared to building long bridges or tunnels.
Create a sustainable regional transit system that provides community, social, economic, and environmental benefits.	Gondolas surpass other HCT modes in maintaining open space and protecting natural resources. Gondolas are easy to reach on foot, by bicycle, on transit and by people with disabilities. The Gondola platform and floor provide level boarding. Gondolas use less energy, and consume less land.
Develop equitable transportation solutions.	Gondolas' efficient 24/7 operations provide reliable transit service for all trip types and income levels.
Create a financially feasible system.	Gondolas are more affordable to build, run, and use.
Offer regional services that work well with other transportation services.	Gondola stations and fare payment is completely comparable with the regional system.

Source: [1] *https://www.soundtransit.org/sites/default/files/documents/2015123_lrpupdate.pdf*

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ADVANCED CABLEWAYS POTENTIAL FOR TRANSFORMATIVE URBAN APPLICATIONS

By Jeral Poskey

INTRODUCTION

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

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

The Long, Distinguished History of Cableways and Ropeways

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

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

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

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

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

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

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

From Shale Rock and Skiers to Urban Settings

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

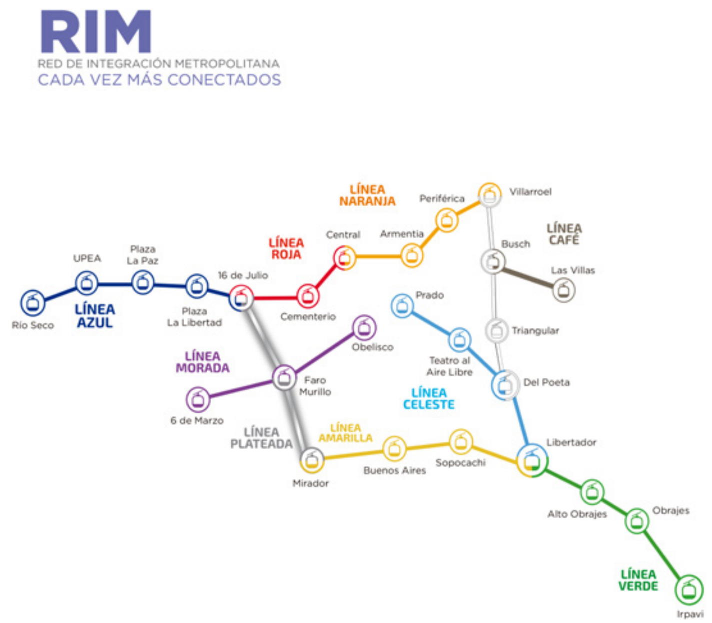
Source: France 1978, licensed under [CC BY-SA 2.0](https://creativecommons.org/licenses/by-sa/2.0/?ref=openverse).
https://creativecommons.org/licenses/by-sa/2.0/?ref=openverse

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

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

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

Photo credit: Ben Bowes, Medellin Metrocable, 2008.
https://flic.kr/p/5SPE1K



Mi Teleferico Cableways Route Map; Source: Mi Teleferico

Medellin: The Transformative Power of Urban Cableways

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

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

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

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

Enabling and Enhancing Multimodal Systems

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

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

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

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

Limitations and Ingrained Use Cases

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

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

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

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

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

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

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

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

Project Swyft

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

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

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

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

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

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

1. Electric Self-Propulsion

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

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

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

2. Cable-to-Rail Interface

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

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

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

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

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

3. Line Switching & Merging

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

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

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

4. Autonomous Control System Software

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

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

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

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

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

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

Table 1 – Capacity By Transportation Mode

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

pphpd: passengers per hour per direction

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

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

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

Potential Second- and Third-Order Effects of Urban Cableways

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

1. The Need for Multimodal Transit Feeder Systems

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

CONCLUSION

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

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

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

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

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Photo credit: Lison Zhao, Chongqing, China, 2022. https://unsplash.com/photos/a-red-chairlift-in-the-air-3QpgObmxP4o

TRAFFICATION. HOW CARS DESTROY NATURE AND WHAT WE CAN DO ABOUT IT

WRITTEN BY PAUL F DONALD | REVIEWED BY JOHN WHITELEGG

Pelagic Publishing, London * 2023 * 294 pages *
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ABOUT THE AUTHOR

Dr. Paul Donald worked in the research department of the RSPB for over twenty years, latterly as Principal Scientist, before moving to BirdLife International as Senior Scientist. He is a recipient of the prestigious ZSL/Marsh Award for Conservation Science and an Honorary Research Fellow of the University of Cambridge.

This is one of the best books on traffic and transport published in the last 30 years. It is written by a scientist at the UK organisation, the Royal Society for the Protection of Birds (RSPB), and unsurprisingly, there is a strong thread throughout the book about the huge damage done to birdlife by roads, cars, pollution, light and noise.

Photo credit: Divya Mudappa, Cattle Egret roadkill, Anamalai hills, India, 2017. https://commons.wikimedia.org/wiki/File:Cattle_egret_roadkill_DM_IMG_5875.jpg

The attention to birds is most welcome, pertinent and informative. In UK public health discussions in the last 100 years we often used "the canary in the cage" (or the "canary in the coal mine") metaphor to emphasise the need to take urgent action to save human life. The canary alerted coal miners to a much bigger and immediate problem, lethally high carbon monoxide levels in the mine (Eschner, 2016).

This original meaning transfers very well to the notice we should take of traffic impacts on birds if we want to protect not only nature, but human health and climate, and we would be well advised to take note of the canary "message". Wildlife in general and birdlife in particular tells us a great deal about what we should do before it is too late to sort out multiple assaults on nature, the environment and climate from cars.

As important as these are, the book should not be filed under “birds, wildlife or nature”. It is bigger, wider, deeper, more thoughtful and a clearer call for action on the totality of our approach to traffic and transport than most other books on “transport” that I have read in the last 30 years. In many respects it partners very well with another important publication, Rachel Carson’s “Silent Spring” published in 1962. “Silent Spring” alerted the world to the damage caused by pesticides and “Traffication” alerts us to the real dangers caused by motorised traffic. Traffic is a bigger problem than pesticides in the sense that our love affair with cars embeds a strong attachment to a deviant and damaging technology at a very personal level.

A scientist or campaigner might be taken seriously with an intelligent, evidence-based call for eliminating pesticides, but I can assure all the readers of this review that calling for a completely new approach to transport (Whitelegg, 2016)—that embraces (for example) a 50% reduction in car-miles, no new road building, zero carbon transport by 2030, and 75% of all our trips in urban areas every day by bike, feet and bus—will result in abuse. Possibly to avoid such abuse, the author of “Traffication” does not ask for these outcomes but he does present a wealth of evidence that moving in this direction will eliminate or significantly reduce a lot of the problems he cites.

Photo credit: Simon Speich, Roadkill in der Dämmerung, www.speich.net

SIDEBAR

The list of highly original and insightful discussion and information in this book, with references, is impressive e.g.:

- “Motoring is one of the most contemptible soul-destroying and devitalising pursuits that the ill-fortune of misguide humanity has ever imposed upon its credulity” C M Joad, 1927 (page 18)
- 1.5 million people die in road traffic accidents each year, more than are killed by malaria, and 20-50 million more are injured. Road accidents are the world’s leading cause of death among people aged 5-30 (page 28)
- Outdoor air pollution “much of it from traffic” kills over 4 million each year (page 28)
- The number killed by noise pollution from traffic is “hundreds of thousands” (page 28)
- Road traffic brings a global pandemic of death and injury that no government seems willing to lock down (page28)
- 50% of all British cars drivers exceed the speed limit and as a car’s speed increases it produces more pollution, exhaust gases, noise, micro particles from tyres and brakes (page 34)
- Britain is the most pervasively trafficated country in the world. The 80% of our land that falls within 1km of a road is well above the comparable value measured across the whole of Europe which is just under 60% (page 40)
- The number of birds killed on USA roads (2014) is in the range 89-340 million (page 51)
- In Sweden (1992) the road kill totals were 13,500 Moose, 59,000 Roe Deer, 81,500 hares, 33,000 badgers and 12,500 red foxes (page 51)
- Counts of road killed butterflies at several sites in Illinois were estimated at 20 million per week in that one state alone and that half a million of them were migrating Monarch butterflies (page 52)
- During lockdown (Covid) in California, reduced traffic flow produced a 60% reduction in mountain lion roadkill (page 53)
- Tasmania has been dubbed the roadkill capital of the world. Estimates suggest that more animals have been killed per km of road than anywhere else in the world leading to a Tasmanian joke “the best way to see the island’s rare and endemic wildlife is a glass-bottomed bus.” (page 54)
- Roadkill is listed as a significant threat to the survival of more than 20 federally-listed threatened species in the USA (pages 55-56)
- The problem (roads carving up the landscape thereby reducing biodiversity) is a global one and major roads alone have carved the planet’s land surface into more than 600,000 tarmac-edged traffic islands, most of them further subdivided by smaller roads (page 73).

REQUIRED READING - WEALTH OF EVIDENCE

The Traffication book should be required reading for any education, training or course for students and transport professionals including engineers, traffic planners, town planners, urban designers, politicians and all those undertaking courses with the word "transport" in the title

The author has a remarkable ability to summarise large areas of scientific work and evidence in ways that are attractive to those (mainly politicians) who make decisions about the future of traffic, roads, nature, biodiversity and climate change. The "Traffication" book has more than enough material to support a rational, evidence based discussion leading to a conclusion that new roads should not be built.

More importantly there is a rich evidence base that common objectives supported by politicians (e.g. economic growth and job creation) can be delivered by smarter things than new roads. Unfortunately, however, in my experience this does not increase the chance that politicians will read material relevant to their decision-making tasks and the evidence (sadly) is that they don't. Politicians (with few exceptions) do not base support for new roads on evidence to be found in "Traffication" or anywhere else. The North West Relief Road in Shrewsbury UK, discussed below, is a recent case in point.

Noise pollution: Nevertheless, the author provides examples of clear policy relevant discussion supported by high quality science including noise and its impacts on animals, birds and human health. The impacts of traffic noise are strongly negative (pp 90-110) but in all public inquiries and discussion about building new roads, the unholy alliance of poor science, poor quality advice from local and national government officers and disinterested politicians ignores the evidence producing the worst outcomes.

Air pollution: The same story is repeated for air pollution in the chapter titled "Emission Creep" (pp 111-131). Air Pollution just like noise pollution is a killer. In 2019, 300,000 premature deaths across the EU were linked to chronic exposure to fine particulate matter, PM 2.5 (page 116).

Electric vehicles: Donald is 100% correct on his assessment of electric vehicles (page 184). EVs are not a solution to the problems raised by current transport policies. They are part of the problem.

> *"EVs encourage us all to drive more than we now do" (page 184) so more roads, more traffic and more deterrence to walking and cycling.*

CRITIQUES

On page 167, there is an example of something that I believe is not supported by evidence or by contact with decision-takers, politicians, transport consultants and businesses. The author makes a bold statement:

> *"Active Travel England (ATE) has promised to take back England's streets from motor traffic and return them to cyclists and pedestrians. The tide is certainly turning against the car, at least in cities"*

Sadly the "tide" is not "turning". Like all "tides" it is still happening every day in regular and predictable ways. Active Travel England (ATE) may have made this "promise" but to quote a very old and rather unusual English expression "Fine words butter no parsnips". I do not know of any example where ATE has actually intervened in the decision-making process around building new roads or specifically advising a Council to "immediately adopt a 20 mph (30 km/hr) speed limit on streets and roads where people live" or made a specific recommendation in favour of car-free towns and cities.

Paul Donald is also mistaken (page 182) when he says "our car addiction appears to be beyond any hope of recovery". I strongly recommend that anyone subscribing to the "beyond any hope" position visit Lund (Sweden), Gothenburg (Sweden) and Freiburg in Breisgau (Germany). They do not rely on hope. These cities are "doing it" and are achieving modal split outcomes of 75% of daily trips by non-automobile modes (e.g. walk, bicycle, public transport) and only 25% by car. That is enough to change the world.

Photo credit: Michelle DeRobertis, passenger waiting areas with bicycles in Freiburg, Germany.

Sadly, and I wish I was wrong, I do not share Donald's optimism when he says he is "hopeful" that "things could improve in the next few decades" (page 185). He misses the main point when he says "we have laws in place to limit vehicle speeds" (page 186). In the UK 60% of car trips break the speed limits and enforcement is a very low priority and speed limits are not obeyed.

EIA system is a failure

He misses the main point when he suggests that environmental impact assessments (EIA) have any effect whatsoever on the case for a new road. The EIA system is a failure. If he or a reader of his book are in any doubt about this point, please look at the documentation (Shropshire Council, 31 Oct. 2023) in support of the very damaging new road through attractive green space and nature-rich countryside in Shrewsbury (UK). The EIA supports this new road despite all the documented damaging consequences for air pollution, carbon, tree loss and loss of countryside, including the destruction of a 550-year-old oak tree in the very countryside that Charles Darwin explored as a child (Gayle 2023). The planning committee of Shropshire Council (UK) voted to approve the "North West Relief Road", rejecting the evidence from 5000 objectors and nature protection organisations.

CONCLUSION

I find it very hard to understand why an author of the calibre of Donald can write "The national mood has changed, road building hubris replaced by doubt and self-reproach" (page 189). It has not changed. It is as bad as ever and the damage to nature, countryside, landscape, birds, animals and human health is fuelled by a £36 billion budget (public funds).

I like this book very much but, like all books (including my own), it will not change anything.

The lemmings are in charge.

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Professor John Whitelegg is a visiting Professor in the School of the Built Environment at Liverpool John Moores University and a transport consultant. His PhD was in industrial location theory and change over time in the opening, closing, decline and growth of the firm.

He has worked on transport projects for over 40 years, written 10 books on transport and was the former editor of the journal "World Transport Policy and Practice". His projects include ex-post evaluation of job creation and inward investment following new highway and motorway investments, the impact of new highways on air quality and greenhouse gases and the performance of non-highway building measures on reducing congestion and pollution and stimulating local economic performance.

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UK English vs American English

We have made the editorial decision to let authors write in the English of their choice. We will not be editing word choice or spelling to either UK English or American English; we will retain the English style chosen by the author. This means that English usage may be inconsistent within a single issue. Therefore we provide this legend of primarily transportation terms to help not only non-native speakers but native speakers as well. However in the interest of clarity, we will try to put **sidewalk** in parentheses after the British use of **pavement** since these two words have opposite meanings in American English.

UK	USA	Canada
Word choice		
pavement	sidewalk	sidewalk
road surface	pavement	pavement
motorway	freeway, interstate	freeway
dual carriageway	divided highway	divided highway
main road	highway	highway
coach	bus	bus
Petrol, diesel	gas/gasoline	gas/gasoline
public transport	public transportation, transit	public transportation, transit
lift	elevator	elevator
boot (of a car)	trunk (of a car)	trunk (of a car)
bonnet (of a car)	hood (of a car)	hood (of a car)
barrister, solicitor	attorney, lawyer	attorney, lawyer
Lorry, artics/semi-trailer (1)	Truck (1)	truck, semi (1)
return (ticket) (transit context)	round trip	round trip
underground; underground railway (2)	Subway (2)	subway, metro (2)
puncture	flat tire, flat	flat
tyre	tire	tire

Spelling		
kerb	curb	curb
-ence (defence, licence, offence)	-ense (defense, license, offense)	follows USA
-our (colour, honour, labour, neighbour)	-or (color, honor, labor, neighbor)	follows UK
-ise; (e.g., prioritise, organise)	-ize (prioritize, organize)	follows USA
- yse (e.g., analyse)	-yze (e.g., analyze)	follows USA

(1) Professional papers may differentiate between tractor-trailers, semis, and single-unit trucks

(2) Term used is very colloquial, i.e. Tube in London, Subway in New York, the "L" in Chicago, the "T" in Boston, Metro in Washington DC. Much of Western Europe, regardless of language, calls it *metro*, or at least understands the word.

Photo credit: Doug Kerr, Portland Aerial Tram, Portland, Oregon, 2014.
https://commons.wikimedia.org/wiki/File:Portland_Aerial_Tram_-_Portland,_Oregon_%2814430109998%29.jpg