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Aerial cableways as urban transport systems

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Cable transport systems are effectively absent from the urban and suburban public transport landscape in France, where gondola lifts and aerial tramways remain essentially perceived as systems for the transport of skiers in winter sports resorts.

Cable systems can, however, be used in urban areas. Europe has a number of ground-based systems (such as funiculars in cities including Lyon, Barcelona, Innsbruck and Le Havre amongst other locations) and a small number of cable cars, largely aimed at the tourist market (for example in Barcelona, Cologne and Lisbon). Several metropolitan areas (Medellín, Caracas, Rio de Janeiro, Portland, New York, Algiers and others) have even incorporated gondolas and aerial tramways into their public transport networks. Emblematic projects such as these can provide an effective urban transport solution.

In France, the law[1] identifies cable systems as one of the alternatives that could offer an efficient solution as part of a policy of reducing pollution and greenhouse gas emissions. And some cable transport projects are currently being run by local authorities.

The context in which cable systems operate, what needs do they meet and what are the costs involved in their development are fundamental questions local authorities must address. This formed the framework for a study undertaken by Ministry of Transport to be published early in 2012. This document provides a summary of this study.

Aerial tramway in Portland - Oregon
(photo Doppelmayr)

1 The August 3, 2009 programming law n° 2009-967 addressing the implementation of the "Grenelle de l'environnement" Disposals

Cable transport systems : terminological clarifications

The vocabulary used varies according to the context : usual language, regulatory, industrial environments… The terminological choices in this document were made only in order to share the same definitions.

Two families of aerial cableways

Aerial tramways are cable transport systems with one or two vehicles moving back and forth on a fixed track (examples: Portland, New York). The vehicles are generally large, varying in passenger capacity from 30 to 200.

Gondolas are systems equipped with cabins moving along on a unidirectional loop. The gondola cabins are small, with each commonly able to accommodate between 4 and 40 people. Systems of this kind generally have a declutching[2] mechanism, which allows one car to be slowed or stopped in a station without any impact on the overall flow of cabins on the loop.

The cableway **stations** include boarding and disembarking buildings and structures.

Monocable gondolas in Saragossa - Spain (photo Leitner)

Technologies differ depending on the number of cables and their function

Monocable technology is a term is used when a single cable is used to pull and support the cars (examples : Medellín in Colombia and Caracas in Venezuela). This type of technology means using small cars (generally fewer than 16 places) and limiting the distancess betweens pylons (maximal distance : 600 to 800 metres).

Bicable or **tricable** technology terms are used when one cable is used to pull the cars whilst one or two others support their weight (example : Coblenz in Germany). This type of system allows longer distances between pylons (up to several kilometres) and larger cars.

2 They are equipped with a device which allows gondolas to be uncoupled from the haul rope on their arrival at the station and to be attached again to the haul rope on the exit from the station.

Tricable Gondola in Coblenz - Germany (photo Doppelmayr)

Other types of cable systems not included in this document

Funiculars are systems pulled by a cable and running on rails. They usually operate out and back. Some comparable systems can incorporate a declutching mechanism and move continuously, for example in Perugia (Italy).
Lifts pulled by cables are sometimes designated as a funicular. They are based on specific technologies and governed by separate regulations to funiculars, applicable to all kind of lifts.

A highly regulated sector in France

French regulations governing the design, safety and operation of cable transport systems are split between the Tourism Code (which applies to specific tourist areas) and the Transport Code.

Systems providing public urban or suburban transport services are governed solely by regulations based on the Transport Code, and in particular decree n° 2003-425 of May 9, 2003 on the safety of guided public transport systems. The regulations are identical whether the system is within an urban transport area or not.

Which authority is responsible for cable system implementation and operation ?

As with other modes of public transport, the transport authority responsible for implementation and operation of a cable transport system depends on the type of service provided, and in particular whether the system runs within an urban transport network or not.

Urban transport authorities will be the competent authority for services provided within an urban transport area (PTU). The *département* (County) or region will be responsible for services provided outside of urban transport areas. In the case of a service between several urban transport areas or between an urban transport area and a non-urban transport area, the competent authority may be the urban transport authority, county or region, based on an agreement drawn up by the various institutions concerned.

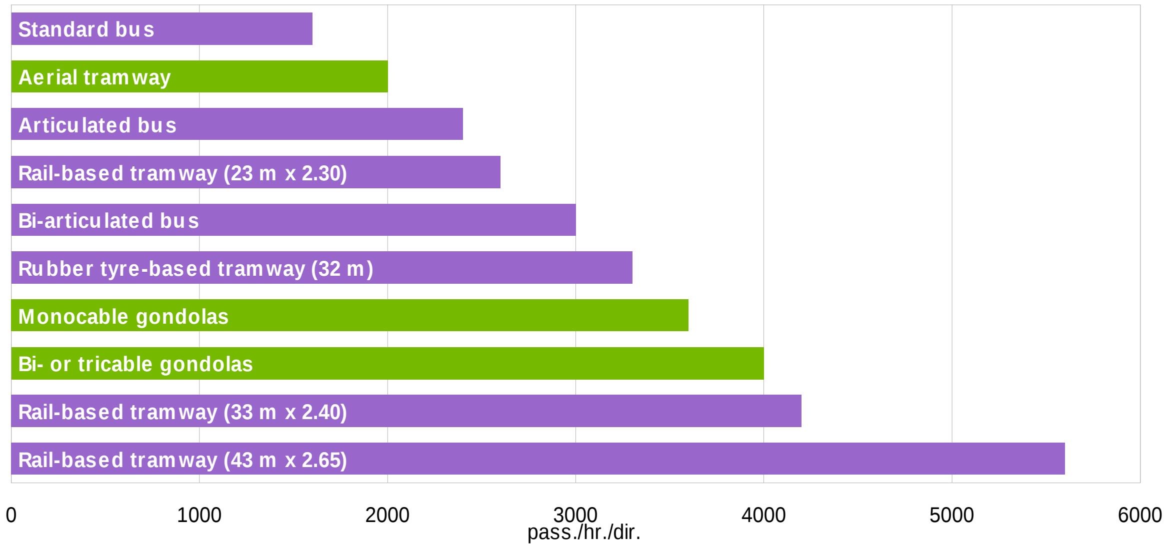
Service levels comparable with "high-capacity" modes of transport

Cable systems achieve relatively high performance and are comparable to transport systems with a high level of service, such as tramways and BHLS.

The **service frequency** of the gondolas at stations varies significantly between systems, from tens of seconds to around 15 minutes. With gondola systems, the cars can arrive into stations and depart on an almost continual basis. One example of this is in Medellín, with cars departing every 12 seconds at peak times. Frequencies are lower, however, in the case of aerial tramways. The Roosevelt Island Tramway in New York departs every 8 minutes during peak times and every 15 minutes off-peak.

The **commercial speed** of cable systems depends mainly on the speed[3] of the traction cable and on the distance between stations. The commercial speeds of the systems in service around the world vary between 15 and 24 km/h at peak times. These are highly competitive speeds in urban environments, particularly where there are significant height differences to be overcome. Commercial speeds can be affected by operational arrangements such as measures to separate passengers getting in and out of cabins or to improve accessibility for mobility impaired people.

The **capacity** of 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. One of the advantages of these 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 may be subjected. This enables consistent journey times throughout the day to be provided together with effective passenger throughput.
The capacity of aerial tramways is directly linked to the rather : entire length of the course and is limited to 2 000 journeys per hour per direction. Gondolas can achieve much higher levels of throughput of around 3 600 to 4 000 journeys per hour per direction, depending on the technology used[4].



Maximum theoretical capacity of systems – 3 minutes frequency, 4 passengers/m² for buses and tramways (source : Certu, manufacturers)

The unique access to gondolas result in separate entry and exit arrangements in the station, to optimize the flow and circulation of passengers.
The theoretical maximum capacity of the cable transport systems is higher than buses capacity on standard conditions of operation and comparable to efficient urban transports like BHLS or 33m tramway.

3 Maximum authorized speed in France : between 6 and 12.5 m/s, depending on systems
4 Based on the characteristics of the systems currently operating

Quality of service

Cable systems provide different levels of service with compared to other transport systems. They also have some technical features which limit passenger comfort in spite of regular technology improvements.

The **availability levels** of cable systems are equivalent to metro systems (generally above 99.5 %, all events combined). As for other urban transport systems, achieving this level of availability means implementing an effective preventive maintenance and checking policy. Poor weather, and in particular high winds, are the main causes for service interruptions. Their real impact on the operation is not so important. The maximum acceptable wind speeds vary from 70 to 110 km/h depending on the technology used. Bicable and tricable systems are more resistant to wind speed.

Duplicating a number of key components (such as the motor, speed reducer, emergency pulley, generators...) also helps to maintain the availability level required. Such measures, not justified for mountain services, are essential in the context of urban public transport. Similarly, in the event of breakdown, it is preferable to use evacuation procedures based on vehicle recovery at stations.
Cable systems are **one of the safest** transport systems in the world, based on the ratio of the number of accidents to the number of people transported per kilometre.
Conversely, the **comfort** of cable systems is not comparable to other forms of public transport. The absence of a live electric current is a restriction despite the progress noticed on the more recent services. On-board batteries provide lighting in the cars but not air conditioning. Research is ongoing and progress could be achieved in the short term. The largest cars used in aerial tramways systems offer very high levels of comfort during the journey (with little noise and limiting swinging) but few seats (generally arranged along the walls of the cars. For example : 16 sitting seats for 110 people in New York). Conversely, smaller cars often guarantee passengers can travel seated (for example : 24 sitting seats for 30 people in Coblenz).

In terms of **accessibility**, cable transport systems are subject to the regulations governing guided transport systems. Whilst the accessibility of aerial tramways does not pose any particular problems, gondolas need specific provisions. At stations, systematic stops of the cabins in a straight line are required. This is not the usual way of operating gondolas which are used to slow down at stations. This measure, compatible with the installation of landing doors, imposes some building restrictions. Otherwise, stopping the gondolas on demand could be possible.

Barcelona : speeds are reduced to make boarding easier at station (photo Anne Le Ruyet – CETE of Lyon)

Operational Safety requires robust estimates of passenger demand

The need for a robust estimate of passenger demand is more crucial for cable systems than for other transport systems.

The capacity of a cable transport is strictly limited by the maximal weight the cars that the cables can carry. Cable supports and other civil engineering components are sized for a predetermined weight. This safety limit imposes a reliable control of the passenger loading on board[5].

It is however possible to **adjust the capacity** of a cable system to respond to periodic fluctuations in demand. The most common operation consists of modifying the speed of the traction cable. Reducing the speed of the cable increases journey times but can reduce energy consumption significantly. It is also possible to vary the number of cars in service, although this has only a limited impact in terms of operating costs and so is rarely implemented. It is only relevant for some components which are less used and thus may have a longer life span.
For practical purposes, these measures have rarely been implemented.

Optimising maintenance and checking is essential to year-round operation

The issue of maintenance is crucial in urban environments, where systems are subjected to heavy use. As for the sizing of the system, the maintenance policy must be carefully planned on the basis of accurate analysis at the design stage. Practical measures (such as a garaging for the cabins, standardised components and choosing more robust components) help to simplify and optimise maintenance. Most tasks can be undertaken outside of revenue service, therefore, do not impact on the commercial availability of the system. Initial feedback of implementations of urban cable transport internationally shows however that it is beneficial to shut down the system for a few days a year to carry out more complex maintenance operations.

Barcelona: maintenance workshop for the gondola lift of Montjuic. (Photo Anne Le Ruyet - CETE of Lyon)

French regulations require that systems are subject to periodic checks including dismantling and reinstalling various components. Nonetheless, these operations do not necessarily imply a prolonged shutdown of the system. They can, in fact, be carried out in phases as background tasks, in the same way as ongoing maintenance.

5 The capacity of buses and tramways is usually calculated on the basis of a 3 minute frequency and a density of passengers of 4 people per m². Yet it is allowed on rush hour to exceed this ratio to reach 6 to 8 people per m²

Limited land take but a challenging implementation of large stations

Cable transport technology requires a **straight line** (or practically) between two stations[6] ; which can be restrictive, especially in urban environments.

However, cable systems do have the advantage of overcoming the difficulties associated with getting over **obstacles** and dealing with changes in level. Their **land take at ground level** is very limited, as the space beneath under the cables can be used for other purposes.

The **integration of the stations** in a constrained area can be problematic. The actual minimum dimensions for stations are around 10 meters wide by 25 meters long (50 meters for intermediate stations). The level at which people enter the cabin influences how much land is needed. Where passengers enter at ground level, the space needed to lift the cars up with sufficient clearance has to be allowed for. Entering when the cars are up high overcomes this difficulty, but requires a much larger building. The lower floors, in these configurations, can be used to store the cars or accommodate other activities (shops...).

Lower station on the bicable gondola in Bolzano (photo Leitner)

Aerial tramway station of Roosevelt Island in New-York (photo CETE of Lyon)

For the same length of line, a monocable system will require more **pylons** than bicable or tricable gondola systems or an aerial tramway.

The relevance of cable transport systems is limited by operating and construction constraints to **services covering a few kilometres and with a small number of intermediate stations.** Current technologies allow 5 kilometres routes with a maximum of about 5 stations (the system opened in 2011 in Rio de Janeiro includes 6 stations for 3.5 km).

Regulatory constraints

French regulations in relation to fire prevention limit the development of cable transport systems. Safety margins (8 meters horizontally and 20 meters vertically) need to be left around any building the cable passes over. These can be reduced provided all necessary measures have been taken to prevent a fire in the building endangering the users of the cable transport system.
In addition, there is no provision for imposing a public utility easement for passing over buildings and private land at an altitude of less than 50 meters. This therefore requires a compulsory purchase or entering into an agreement with the owners concerned.

6 Which means that direction changes require intermediate stations

Ongoing difficulties in estimating investment and operation costs

Identifying the various **investment** costs is a complex matter, as this is commercial data for manufacturers and prime contractors. In addition, there still is too little data available on urban cable transport systems to be able to calculate average investment costs accurately.

Several recent projects in mountain environments can be used to define orders of magnitude for each item of expenditure.

System	Monocable	Tricable
Drive station[7]	2.5 to 3 M€	4 to 5 M€
Intermediate station	1.2 to 1.5 M€	
Return station	1 M€	3 to 4 M€
8 to 10 seats cabin	30 000 €	-
35 seats cabin	-	300 000 €
100 seats cabin	-	1 M€
Pylon	100 000 €	500 000 €

Breakdown of investment costs in mountain area (source CETE of Lyon, manufacturers)

In urban environments, constraints on development and architectural decisions could increase the overall cost of a project significantly, in particular in relation to civil engineering costs.

The information from international systems show that civil engineering costs can represent more than 50 % of the global investment cost. The costs of the land are not similar to those of the mountain systems. Finally, ensuring that the system provides a high level of service for user's means allowing an additional investment of 3 to 5 % of the overall cost of the project in order to anticipate purchases of spare parts and optimise system maintenance.

Maintenance and operation costs of cable systems are not well understood outside the manufacturing base. For, example: for a simple cable systems (one section of line and two stations), these costs are estimated at €1.5 million a year on the basis of 7,000 operating hours. Operating costs are closely related to the salary and overhead costs of operational staff.

Operating a system with two stations requires four staff to be on hand at all times to provide assistance with entering and exiting the cars, supervision and ongoing maintenance of the system. Technical solutions, such as stopping the cars completely in stations or providing landing doors would help to reduce the number of operational staff required and therefore help to cut costs.

7 Including electromechanical equipment, structure building but excluding architectural design and special measures

Effects on the environment and the urban landscape : a sensitive subject for the inhabitants

Visual impact and intrusion

The visual impact of cable transport systems is a subject eminently subjective and complex to describe. The lack of pilot projects in France means that this type of infrastructure is unfamiliar in urban environments. The visual impact remains a major factor in opposition to this type of system.

More communication from project managers on this topic along with specific efforts by the manufacturers on the ergonomics of the cars, of the stations and of the pylons could make the degree of intrusion more acceptable and less of a constraint.

Inhabitants to convince
« Aerial cableway : the Burnaby mountain residents have concerns
Burnaby residents whose house is located under the cable put forward for the aerial cable system leading to the Simon Frazer University are worried about the impact of the project on their private life and their property value […] The layout put forward would carry the passengers gondolas above the housing cooperative Pine Ridge. Glen Porter, owner of one of these residences, says that his neighbour and he have many questions regarding the project. He emphasizes that a gondola would fly over the cooperative every 19 seconds, and that the residents ask themselves what the passengers could see and what impact it could have on their private life and the value of their property […]»
Radio-Canada May, 6 2011

System noise

Nowadays in France noise of the system is still not well assessed in urban environments. The origins of the System noise assessment in urban environments is an emerging consideration in France. The origins of the emission of noise coming from the cable transports systems are mainly located at the station and as they pass under pylons. The bicable and tricable systems help to reduce the level of noise significantly, unlike monocable systems which require more pylons and have more moving parts.

First investigations on these systems were made by the STRMTG (Technical service in charge of safety for ropeways and guided transport) in order to describe this phenomenon on more objectives basis. A few significant conclusions can be drawn :

- In stations, the noise of the machinery and the noise made during the slowdown and the acceleration of the cars are the most problematic.
- The operating speed is an significant parameter : the level of the measured surrounding noise is less than 2 dB(A) when the speed decreases from 6 m/s to 5 m/s
- All pylons don't produce the same level of noise : the line support structures compression and support-compression are noisier than the support tower in the gap range of 10 dB(A).

The manufacturers have already worked to reduce the noise pollution. In stations, keeping the mechanical components separate, for example by installing them underground, ensures quieter operation. Reducing the level of noise on the platforms, however, requires further technological innovations.

Energy consumption

Cable transport systems are relatively energy efficient overall. Monocable systems are less efficient because of the friction generated by passing over numerous pylons. Load and changes in level have a more limited impact than the speed of the cable. Therefore there is a real advantage in adjusting speed in line with the level of use.

This analysis remains insufficient in estimate energy consumption : a global assessment of LCA type (life cycle analysis) of itemized elements of infrastructure will be required. Stock lists of items are not available. This assessment is also valid for all the other urban transports modes.

Long term effects on urban environments

As any new form of transport infrastructure, the development of a cable transport system can have contrasting effects on the area from opening up, developing and redeveloping particular neighborhoods and renovating the built environment and public spaces, to increased pressure on land and suburbanization.

Project sponsors therefore need to anticipate changes in the region based on an overall and forward-looking vision.

The CableTrain in Medellín takes is helping to open up and develop some of the city's neighborhoods (photo Pomagalski)

Conclusion

Aerial cable transport systems are particularly well suited to overcoming obstacles and other divisive features in the urban landscape, such as railway lines, water courses, large depressions, changes in level, etc.
They help avoid the need to build highly expensive infrastructure.

Unlike other forms of transport, they are not limited by maximum acceptable inclines and can run in a straight line even if there is a change in level.

Cable transport systems can achieve the same levels of capacity and commercial speed as tramways or BHLS (Bus with a high level of service). But cable transport systems are not sufficient to form the backbone of an urban transport network in a large conurbation because of the length of the lines (which is limited to a few kilometers), the small number of stations on the same line and the significant difficulties associated with construction in a dense urban fabric.

Cable transport systems do, however, offer a solution to demands which traditional transports systems (buses, tramways, and metro systems) are unable to address satisfactorily because of technical or financial constraints. They can open up areas which were previously poorly served because of obstacles or changes in level. They can thus complement, rather than compete with, other transport systems.

Nowadays, the development of cable transport systems is still slow. This is particularly because of public acceptability considerations, regulation, property impact and safety aspects. Land regulation is a central subject, to improve implementation timescales of cable transport systems.

Lessons must still be drawn from the experience and assessments of larger international urban implementation, to inform future discussion in France.

Gondolas in Caracas – Vénézuela (photo Doppelmayr)

Acronyms

BHLS : Bus with a high level of service
CERTU : Centre d'études et de recherches sur les transports, l'urbanisme et les constructions publiques (center for studies on urban planning, transportation, and public facilities)
LCA : Life cycle analysis
PTU : Périmètre de Transport Urbain (Urban transport area)
STRMTG : Service Technique des Remontées Mécaniques et des Transports Guidés (Technical service in charge of safety for ropeways and guided transport)

Contributors : Cécile Clément-Werny (CERTU), David Dubois (CETE de Lyon), Anne Le Ruyet (CETE de Lyon), Michaël Potier (CETE de Lyon), Sandrine Rousic (CETE Méditerranée), Yves Schneider (STRMTG).

David Dubois, Anne Le Ruyet and Michaël Potier are members of the innovative and knowledge cluster "daily transports"; Sandrine Rousic and Michaël Potier are members of the innovative and knowledge cluster "Public transports and public roads interface". They all belong to French ministry of sustainable development.

The whole study will be available on CERTU and STRMTG sites from April 2012.

http://www.certu.fr/
http://www.strmtg.developpement-durable.gouv.fr/

Contacts

Cécile Clément-Werny (CERTU)
cecile.clement@developpement-durable.gouv.fr
DD.certu@developpement-durable.gouv.fr

Yves Schneider (STRMTG)
yves.schneider@developpement-durable.gouv.fr