URBAN ROPEWAY AS PART OF SUSTAINABLE URBAN TRANSPORT NETWORKS IN DEVELOPING COUNTRIES

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1. Introduction

Making urban transport function

Ropeways have been associated with mountain resorts and leisure parks. Technology and operational concepts, however, have evolved to make them a reasonable and attractive proposition for mainstream urban public transport, too. Unlike the cliché ski resort facility, urban cable cars are easy to board and alight, even for mobility impaired travellers and wheelchairs.
Illustration 1: Base station of Koblenz (Germany) gondola system with relatively large cabins (38 passengers)

Note the gapless level entry and large doors. Image onnola http://www.flickr.com/photos/30845644@N04/5537846340/in/photostream/

Basically, two types of aerial ropeways must be distinguished: The so-called “aerial tramway” (téléphérique) with two large cabins permanently attached to each leg of the pulling cable which alternatively turns in one direction and the other obviously stops when the cabins reach the station; and the so-called “gondolas” (télécabines), with a pulling cable revolving constantly in one direction, to which smaller gondolas are attached and detached when entering and travelling through a station.
Generally speaking, the aerial tramway with additional supporting cables offers more stability in very windy conditions and a faster cruising speed (up to 45 km/h), which explains why this type is chosen to services to very high mountain tops. In urban conditions, however, these qualities are less critical and gondolas with or without supporting cables offer a comfortable and safe ride at around 25 km/h.

In regard to capacity, ironically, an aerial “tramway” service is rather comparable to that of a standard bus, while the cosy word “gondola” refers to a system offering capacities comparable to small to medium sized tramways on rail tracks. Gondolas also offer a number of additional advantages, which make them the preferred system in urban transport applications (except for New York and Portland):

- The large number of gondolas offers continuous service, with several departures/minute and thus reduces waiting times (as opposed to come-go tramway services where waiting time = travel time, i.e. several minutes between departures)
- The small gondolas offer seating for most passengers and a more private atmosphere, and double hourly capacity. Typical small gondola systems have up to around 10 seats, with latest cabin innovations cover 35 passengers.
- It is easier to adapt system performance to service demand, by modulating the travel speed and the number of cabins in circulation.
- The infrastructure required for smaller cabins is lighter, more flexible (including curves and intermediate stations) and less expensive.

The idea of using ropeways for urban passenger transport is not new, but it has evolved gradually. Its leisurely image has long kept it in the realm of providing access to Universal Exhibition, Olympic Games, Amusement parks or Garden show sites and to urban parks.

But purely urban applications date back as far as, for example, 1956, the creation of a small arial tramway El Madania in Algers (Algeria), linking two neighbourhoods 83 vertical and 215 horizontal meters apart. Algeria is also a cradle of the modern urban ropeways. In 1982, the El Madania was renovated and three similar, short, steep small aerial tramway systems built in Algers in the following
years. At the same time, Annaba and Blida saw construction of the first gondola systems. But a regional breakthrough of the gondola ropeway as a mainstream urban transport mode dates to the first decade of this century and the construction of the gondolas in Tlemcen, Skikda and the larger cities of Oran and, most typically, Constantine (all Algeria), where the gondola’s three stations make a line of 1517 m total length and 30+ gondolas, connecting three parts of the city (city centre, both sides of the gorge, the hospital and a residential complex).

Illustration 3: Constantine end station, place Tatache Belkacem

Note the compactness of the station (1400 sqm)
Photo from: joni580 [http://www.flickr.com/photos/jmitch700/2441297060/in/photostream/]

A similar history was written in South America, where a ropeway was built in Caracas as early as 1952. But it was closed in the late 1970's and re-built (and extended) in the first decade of this century to a length of 3.5 km, served with 70 gondolas, following the archetypical urban transport gondola ropeway, “Metrocable” of Medellin, Colombia, built in 2004 and opened in 2006. In Caracas and Medellin, the gondolas are planned and operated as feeder lines connecting hillside neighborhoods to the existing rail based high capacity public transport in the valley.

It probably is no coincidence that the latest innovations defining the modern concept of urban mass public transport by gondola ropeway were made in Medellin, the second city of Colombia, after Bogotá, where the concept of BRT, initially from Curitiba, Brazil, was perfected to worldwide model status. Both systems are characterised by the flawless implementation of a coherent, innovative but solid concept that takes into account urban structures, the transport market and economics in the
context of local demand for public transport and the capacities of local public and private actors to serve it.

Illustration 4: Medellin K Line, small (8 seats) gondola with single rope

Photo by Steven Dale (the Gondola Project)

2. Energy efficiency and operating costs

The ropeway's unique advantage is of course its capacity to climb steeply and to fly over obstacles and geographical barriers, which seduce many urban planners. The most thrilling opportunities, however, can only remain dreams if the economics don't match.

By design, ropeways are highly energy efficient transport systems, for a number of reasons:

- 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.
- And, apparently, the aerial ropeway does not suffer rolling resistance.

However, ropeways don't provide a free ride and a number of energy consumptions do contribute to the operating bill:
The revolving cable itself represents a considerable moving weight and it also suffers rolling resistance and torsions, when passing through the guiding and revolving wheels.

The numerous flying cabins meet manifold wind resistance

In gondolas, like in all other vehicles, the ancillary systems like heating and cooling consume a large part of the total energy required.

Despite the inevitable losses, ropeway energy efficiency is significantly higher than that of other electric or combustion energy driven transport systems, provided that the number of passengers is significant.

Indeed, more than for transport modes using individual self-propelled vehicles, patronage is absolutely key to the efficiency of the ropeway system: In order to transport the first few passengers, a bus operator only needs to mobilise a single vehicle, while the remainder of the fleet can be held back until patronage swells. In a ropeway system, however, the entire cable and the entire fleet of gondolas attached must be mobilised for the first passenger. This is relatively inefficient. But very little energy is required for every additional passenger and, when approaching a reasonable occupancy rate, the gondola becomes the most energy efficient transport system of all.

A similar arithmetic of high fixed costs and low variable costs applies to the other operating expenditures: all staff required for running the system must be present for the first passenger, but no additional drivers are required as patronage rises. The only possibility for the ropeway to adapt operating costs to patronage is to reduce or increase speed, within the margins of customer acceptance (don't go too slowly) and technical efficiency (don't fly too fast).

The graph below, comparing the operating costs of bus, tram and ropeway with the hourly patronage in the context of Grenoble, France, is purely indicative. The position of each line on the graph depends on the local cost structures of each mode. However, the general picture is the same in any context: in its domain of excellence of about 2000 to 5000+ passengers per direction and hour, the ropeway is probably the most efficient operation of all. Below, buses and maybe trams are better suited, above, heavy rail takes its turn. Only BRT, with long vehicles and no traffic problems can compete with ropeways within this range of patronage.

These considerations regarding operating costs apply in cases where there is a choice between different modes, for instance, a ropeway being operated above an avenue which could also have a bus or tram service. Ropeways may well be the most rational choice, even where buses or trams could do the job on the same itinerary. But in many cases, ropeways can go the shortest way where buses or trams would have to go long detours. In these circumstances, their efficiency in relation to effective passenger x km is simply unbeatable.
3. Physical barriers and Investment costs

Ropeways are best known for coping with, and even taking advantage of, hilly terrains. This feature alone already provides for a variety of applications. However, ropeways do not require hills. Even on flat land, they can be used to overcome many other types of natural and manmade obstacles, such as rivers, lagoons and estuaries, harbours, railways and motorways. Depending on the possibility to place intermediate masts, obstacles of several hundred meter width can be overcome without physical interference with surface or underground infrastructures.

Cities usually grow gradually and organically around these barriers, integrating them into their fundamental structure and habits. Consequently, many barriers are not constantly seen as such, because city dwellers and planners have grown up living with them. But growth changes urban patterns. Formerly peripheral neighbourhoods may gain in importance and formerly neglected barriers are becoming real obstacles to social and economic development. The ropeway may well be the appropriate solution in these situations. Rivers, estuaries and lagoons probably are the most common example for such situations: ferryboats may no longer provide satisfactory service to increased demand and bridges are very costly and intrusive infrastructures. Ropeways may well provide the most elegant connection between urban centres and passenger transport systems on both sides of the water, while ferries and, possibly bridges, can be optimised for vehicle and goods transport.

Overcoming obstacles is useful and will probably lead to the creating of several (dozens) modern urban ropeways in the coming years.
Illustration 6: London gondolas over the Thames River

London is rather flat and the mast are much higher than technically required by the gondola, in order to leave space for big ships and to offer a nice view on the entire city. (Photo from: www.greenwich.co.uk / the Gondola project)

But the more fundamental challenge is the urban fabric itself. On the one hand, dense housing and narrow streets of historic or “informal” organically grown, car free neighbourhoods are obstacles to high capacity transport systems. They also often lack other basic infrastructure and services. The traditional technocratic answer to this infrastructure challenge is to erase and re-build. On the other hand, these urban structures should not be erased, because they are often well adapted to modern forms of urban cohesion and efficiency. They need to be rebuilt and upgraded. But this can and should not be done in the traditional way, for economic and social reasons. It should be done gradually, preserving functioning structures and leaving space for constant renewal.

The picture below of a ropeway under construction in Rio de Janeiro perfectly illustrates this point. The base and intermediate stations are built more vastly as necessary for the transport function, in order to accommodate additional services that will be ideally located at these central places. A temporary access road for the construction of an intermediate mast is clearly visible. If necessary, such intrusion can be limited by choosing an itinerary causing the least damage, or be avoided completely through the use of helicopters. It can also be transformed into an opportunity to create pleasant public spaces, with safe pedestrian paths and mini-parks.
Illustration 7: Rio de Janeiro is preparing to host the Olympics and the Football World Championship

This new gondola system is not designed to serve these sites, but the favelas at the Northern edge of town. Photo of the construction phase. Note a base station (orange, top left), an intermediate angular station (blue, top right) and a pole (bottom left)

Photo from http://www.buzzecolo.com/rio-de-janeiro-adopte-un-tramway-aerien/

In comparison, the construction of a tramway or BRT with similar transport capacity would have cost the destruction of many hundreds of houses and created a new barrier for pedestrian movements and source of noise and air pollution. One considerable advantage of ropeway system thus lies in their reduced so-called external costs. But the system infrastructure costs themselves are also considerably lower than those of surface or underground systems of comparable capacity:

- The cable itself is rather inexpensive compared to rail or tarmac tracks of the same length. Not to mention bridges or tunnels. Traffic lights are obsolete. But of course, masts are required every couple of hundred meters (very variable according to terrain and the number of cables). The masts are solid infrastructures and their cost cannot be neglected. But, in any case, they are considerably less expensive than the foundations of a new road or rail track, especially if you include the need to refurbish, redirect or create all sorts of underground infrastructures for water and electricity. Orders of magnitude, in Europe, for monocable gondolas, such as the systems mentioned in this paper: cable: 70 EUR/meter; masts: 100,000 EUR/mast.
The stations, on the one hand, need stronger foundations than those of BRT and LRT. On the other hand, they are much more compact since they do not need to provide berths for several long vehicles. The machinery, is a considerable investment. Order of magnitude: 2.5 million EUR for station with engine, 1 million EUR for station without engine. A gondola may cost up to 30,000 EUR. (Estimates from Schneider, Clément-Werny, Transport par câble aérien en milieu urbain, CERTU, 2012).

Hence, as a rough estimate of order of magnitude, a monocable gondola system similar to those described in this paper of 2 km, with 3 stations, 10 masts and 30 gondolas may infer investment costs of around 0.14 + 1.0 + 4.5 + 0.9 = 6.54 million EUR.

Even if it were as costly as the equivalent bus or tramway capacity, its life cycle costs are necessarily much lower than those of individually motorised vehicles, because the maintenance costs are drastically smaller for the very robust stationary engine and all other moving parts that are heavily and solidly built and operated in a controlled, safe, environment. Anybody familiar with the difficult task of rolling stock maintenance knows the benefit of this.

4. Intermodality & Governance

The principal point made in the chapters about operating efficiency and overcoming physical barriers of all kinds, including urban structure itself is that the real of modern urban ropeways is not limited to short, steep, low capacity point to point services, like, for instance, the first generation installations in Algiers, the cross-harbour gondola in Barcelona, etc.

On the contrary, modern installations are several kilometre long, feature several stops and are integrated into an intermodal public transport network at the metropolitan scale. Furthermore, ropeways are not only a possible alternative to surface and underground transport. They also offer totally new opportunities to access neighbourhoods which cannot reasonably be reached otherwise and which can, thanks to improved accessibility and urban structure created by the ropeway, gradually evolve to become particularly sustainable neighbourhoods.

As mentioned above, thanks to very large vehicles, rail and BRT systems outperform ropeways as we know them today on lines with 6000+ passengers per direction per hour. Standard or smaller buses, on the other side, are more flexible physically and economically and, therefore, are relevant on less frequented routes.

It is interesting to note how urban ropeway projects are often linked to rail transport projects: In one group of large cities, metropolitan railways have been operating for decades and urban ropeways are introduced in order to complement that existing metropolitan rail network (Medellin, Caracas, Rio de Janeiro, London, etc.). In other, smaller, cities like Constantine and Oran, the ropeway was introduced first and tramway implementations are following.

But many developing cities do not have mass transport system installed at all. BRT is being promoted as a solution, but many cities that want to...
implement it meet serious obstacles and we must face the fact that BRT implementations are still very rare in Africa and elsewhere in the developing World. The ropeway may well be an alternative to small to medium-sized BRT projects, because it overcomes a series of typical BRT (let alone LRT) project obstacles in developing metropolises:

- The physical barrier: it is extremely difficult or almost impossible to secure several kilometres right of way for BRT in the right place. If a corridor can nevertheless be found, it most likely is at the expense of handicapping concessions leading to unsatisfactory situation, access, priority, robustness. Ropeways can be built in the wrong place, too. However, it is relatively easy to find and secure the right spot for a first ropeway implementation across a water or relief barrier. For the rest, “bad compromises” are not allowed.

- The governance barrier: BRT projects often suffer the opposition of well organised informal road transport operators, because, after all, BRT, buses and taxis compete for the same customers on the same lines. Only massive BRT schemes that include a total re-creation of the entire road transport governance and market structure can overcome this obstacle. Ropeways that go where public transport services could hardly go before are not competitors. On the contrary, they bring new customers to the market and works as feeder to massive BRT and metro systems.

- Cost is the ultimate obstacle. BRT infrastructure is expensive and if it is built cheaply, it makes operations expensive and unattractive. BRT infrastructure investment must be massive, because BRT corridors shorter than 10 km are unlikely to make a difference in the transport system. BRT rolling stock is expensive and many projects are proposed with an operating subsidy. Developing cities cannot afford loss making public transport. A relatively short ropeway at the right place, on the contrary, can be less costly to implement and generate profit thanks to its efficiency and unique service.

These arguments do not pretend that urban ropeways should be implemented instead of BRT or LRT schemes, although, indeed, in some cases this could be considered. The point is that in many developing metropolises, it will be more appropriate to begin the implementation of modern, high quality public transport services with the ropeway projects, because:

- ropeway projects are easier to implement and to operate than BRT projects
- ropeway projects provide greater added value and less financial risk
- therefore, ropeway projects act as a catalyst for public transport, creating public support, institutional and technical know-how as well as economic resources for further projects, including the necessary BRT or LRT projects.

5. Outlook

Ropeways have always been highly efficient. The latest technical innovations made them a comfortable, high capacity public transport system. They can create direct links where other modes require long detours or massive infrastructure. And the gondolas still offer an enchanting experience at each ride.

Once awareness and knowledge on the key characteristics of modern ropeways are have been widespread among planners and political decision makers as well as the public, ropeways have the potential to become an important complement to established metropolitan transport systems, as feeder lines, for access to entire neighbourhoods, as landmarks and icons.

In many developing country metropolises, it will eventually be better to begin the implementation of
modern, high quality ropeway projects. Especially in smaller and medium-sized cities without rail or BRT systems they can be pioneers in changing urban mobility and achieving sustainable cities and safe and secure neighbourhoods. Of course the relevance and feasibility of ropeways vary greatly between cities. It is least obvious in spacious cities built on flat and sandy terrain. In all other cities, ropeways will not be able to weave a full net of public transport for the entire city. But

- they offer unique opportunities to provide public transport where it was deemed to the impossible
- they offer a sound technical and economic model for mass public transport at a fair and inexpensive price
- they well can be first high level public transport system in many developing cities, opening the minds and creating the environment for entire multi-modal systems.

The current discussions around the applicability of urban ropeways in European and North American cities indicate that they are increasingly recognised as a global urban transportation option.