Aerial Ropeway as a Mode of Urban Transport: Review of the Technology and its Suitability for Hill Cities in India

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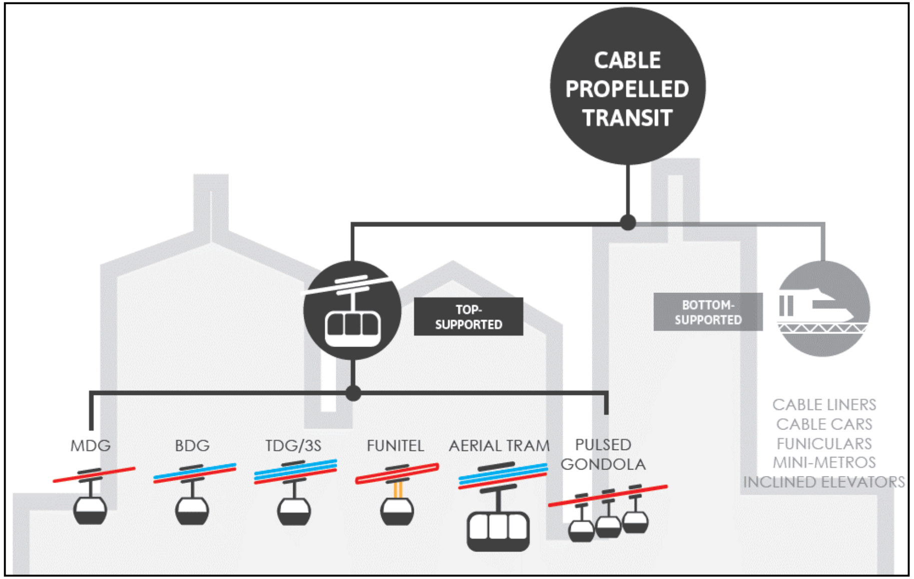
Different Types of Ropeway Systems



Advantages & Disadvantages of Ropeway Systems

- Provides shortest and Faster Connectivity, Faster Construction, installation
- 2nd level transportation (all other transport is on ground level)
- Low footprint, and low space/land requirements
- 1 electric engine for the whole system (More than 1 in case of long systems)
- Easy obstacle overcoming
- Faster mode of transport in hilly & urban conditions
- Hilly topographies no problem - Potential for developing on large slopes
- Changes in elevation, steel climb - no problem
- Touristic and aesthetically pleasing (good views)
- Environmentally friendly, Sustainable mode
- Economical Mode of Transportation: Low cost in comparison to many other modes where conditions favor ropeways, yet can carry up to 8000 PPHPD
- One of the safest mode of transport
- Goods Transport Possible

- For making angles/curves/change in direction - stations are required (for more than 5 degrees)
- 6000 PPHPD limit, Challenging Maintenance
- Extreme wind above 100km/hr - operations to be shut
- Customised trips not yet possible, Complex rescue systems

Key Drivers in India

– **Hilly areas** in India still have **limited last-mile & intermodal connectivity – poor road network** (50.3 km road density) and **rail network density** (1.65% of total length) – leading to:
  – Slow pace of economic development
  – Inconvenience and poor quality of life

– Hill regions are **below potential** compared to both local tourist spots and global destinations in terms of **tourism & related activities**

– **Congested areas in cities** are not able to realize their **economic and tourism potential** due to lack of access

– There is high scope of investment in **ecologically sustainable & safe** alternative modes of transport

– Hill city Issues
  – High level of congestion, land constraints
  – lack of public transport, parking

Parvatmala - National Ropeways Development Programme

Announced during Union Budget for 2022-23
Envisaged as an economical, faster and ecologically sustainable alternative
to improve connectivity and convenience for commuters, besides promoting tourism
For Hilly terrain & Congested Urban Areas
To be taken up on PPP mode - Hybrid Annuity model and Build Operate Transfer
As per Budget, contracts for 8 ropeway projects (length-60 km) would be awarded in 2022-23
presently started in regions like Uttarakhand, Himachal Pradesh, Manipur, Jammu & Kashmir
and the other North Eastern states
Agencies - MORTH, NHAI, NHLML

Development of a ropeway project pipeline:

- Enhanced connectivity & accessibility in hilly & congested urban areas
- Prioritization of proposals basis technical feasibility, financial viability, impact on mobility & environment and ease of implementation

Design of policy framework and standards based on global benchmarks:

- Technical standards & regulatory policies
- Incentives to promote manufacturing of ropeway components in India e.g. PLI scheme

Sustainable connectivity

Private sector investment-led

Technology-driven & Atmanirbhar

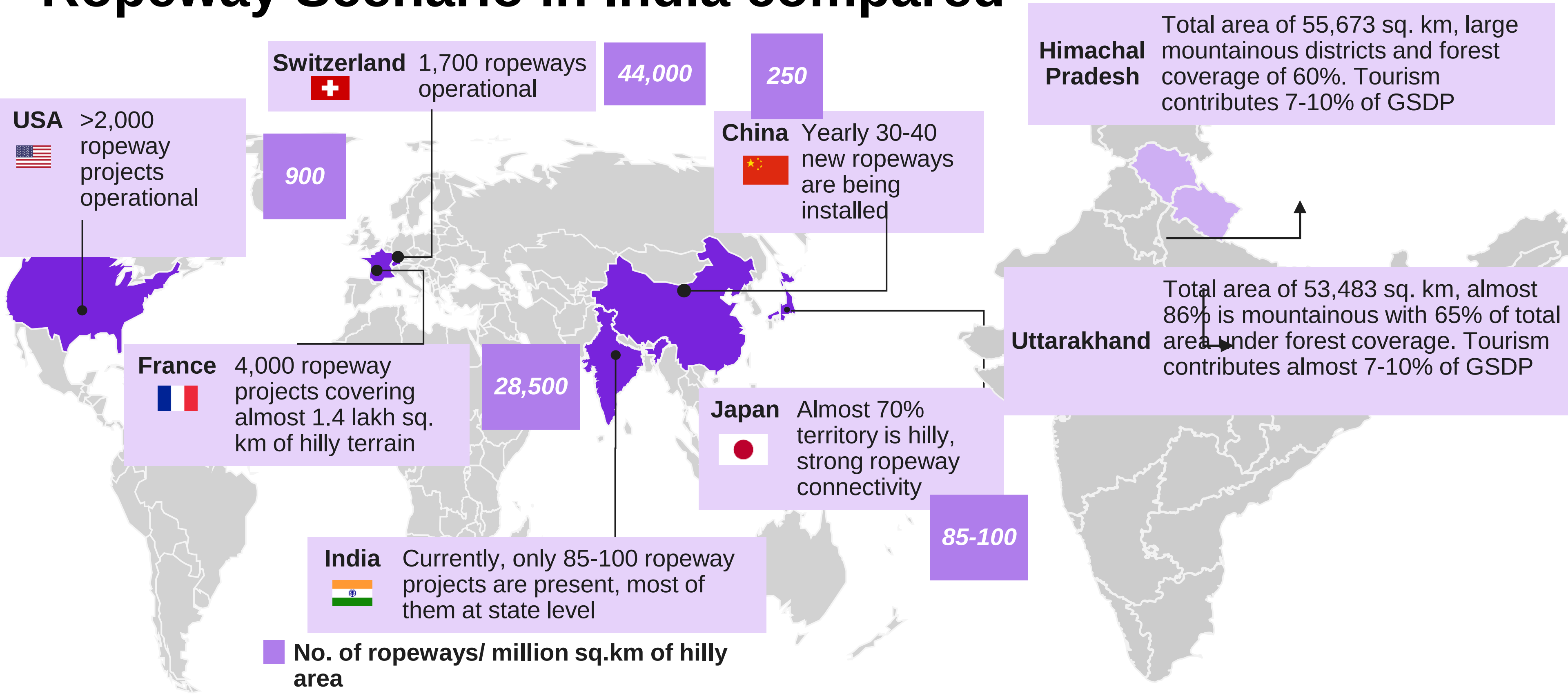
Collaboration between States & Centre

Scientific project structuring & contracting

Robust implementation monitoring & tracking

*“For the first time in the country, the '**Parvatmala scheme**' is being started for areas such as Himachal Pradesh, Uttarakhand, Jammu-Kashmir and the North-East. This scheme will create a modern system of transportation and connectivity on the mountains. It will also strengthen the border villages of our country, which need to be vibrant, and which is also necessary for the security of the country.”*

Ropeway Scenario in India compared



India is yet to significantly scale up ropeway development despite ~22% land area under hilly terrain, as well as rapid urbanization & congestion in city centers

India's hilly states are some of the least developed and remote despite having significant socio-economic potential for ropeway led development

Ropeway Cost Contributors & Revenue Drivers

ROPEWAY COST CONTRIBUTORS

Land Acquisition Cost
- Land for Stations
- Land for Terminal Facility
- Land for Ropeway ROW
- Land for Access Roads
- Allied Real Estate & Utilities
- Utility Shifting, rerouting

Ropeway Plant Cost
- Soil tests & Foundations
- Statons & Towers
- Electro - Mechanical Components
- Controls & Automation
- Ropeway Line & Cabins
- Monitoring & Safety Systems
- Dedicated Power Supply

O&M Cost
- Fuel/ Power
- Routine maintenance
- Lubricants & spares
- Backup generator
- Parts Replacement
- Manpower

Miscellaneous Cost
- Rope change cost (periodical)
- Annual inspection charges

Revenue Drivers
- Tickets
- Advertisements
- Real estate lease rent
- Land Value Capture
- Commission from tourist activities
- Parking
- Indirect Benefits

Ropeway Feasibility Determinants

TECHNICAL FEASIBILITY DETERMINANTS

- Terrain Features
- Natural Elements
- Ecological Impact
- Ground Features
- Construction Footprint
- Maximum Angle of Climb

- Project Location
- Availability of Installation Technologies
- Capacity
- Passenger Characteristics

- Possible width between to and fro lines
- Power Supply Availability

- Accessibility
- Feasibility of Conducting Service & Maintenance
- Purpose
- Safety – Recovery & Rescue

- Height of Towers
- Position of Towers
- Number of Intermediate Station
- Constructability at Station and Tower Locations
- Ropeway System Length

Ropeway - Comparison with other modes

Mode of Transport	CAPEX (INR Cr/km)1	Avg. Speed (km/hr)	Advantages	Disadvantages	Average Capacity (PPH)	Suitability
Ropeway	45-75	25-30	Efficient in hilly & congested urban areas Eco-friendly Low capex Less land requirement Highly reliable	Technologically complex Limited speed Maintenance	12000 - 16000	Hilly Terrain Congested Urban Areas Large Campuses
BRT	10-20	25-45	Low Capex Easy Maintenance	Used Road Space Reliability	20000 - 30000	Planned cities Plains Where road width is available
Metro Rail	200-250	30-50	High Capacity Highly reliable Fast	Capex Cost Land Cost Hilly terrain not possible	8000 - 120000	Metro cities High capacity situations Non Hill conditions
Waterway	2-6	15	Cheapest mode of transport	More prone to closures, less reliable	10,000	Cities like Kochi network of waterways

Comparison - Cable Propelled Transit

Technical name	Speed limit	Max. capacity (PPH)	Max. distance	Max. Free Span
Ropeway/Gondola (specs depend on tech. used)	22-31 Km/h	4500-12000	No limit (with multiple sections)	3.3 Km + (3S) 1 Km (mono/bi-cable)
Aerial Tramway	43 Km/h	Practically Varies (500 - 2400+)	4-5 Km	3.3 Km +
Funitel (Detachable)	22-25 Km/h	8000	5 Km	1 Km
Funicular	50 Km/h	4000	2 Km + (Depends on Rope, Climb)	-
Inclined Lift	10 Km/h	600	0.3 Km	-

Comparison Of Top Suspended Ropeway Technologies

Factor/ Type of Gondola	Mono-cable Detachable Gondolas	Bi-cable Detachable Gondolas	Tri-cable Detachable Gondolas	Dual-Track Aerial Tramway	Funitel (Detach.)	Pulsed gondolas
System & Rope type	Endless continuous moving rope	Endless continuous moving Haulage rope & fixed carriage rope	3 cable system (2 carriage fixed & 1 haulage moving)	3 cable arrangement (2 Track rope & 1 Haul rope)	Single dual-loop cable arrangement	Single cable, fixed grip/ Non-detachable
System characteristics	Short span	Medium span	High speed, High pax capacity, Can operate even at 100 km/hr wind speed, Longest Spans	Non-Detachable Cabins, Long Spans possible, Higher wait times	Short trips, Low pax. Capacity, Short spans, Can operate at 90-100 km/hr wind speed	Low capacity, Multiple cabin can be put together
Max. Line speed (m/s)	7	7	8.5	12	7.5	6
Max dist. Between towers (Free span)	900 m	900 m – 1200 m	3000 m	3200 m	1000 m	900 m (total system)
No of stations	Multiple	Multiple	Multiple	3 (2 Terminal + int. station)	Multiple	2 (Terminals)
Max System capacity (PPHPD)	4500	4500	6000	2000	4000	2000
Cabins/line	No restriction	No restriction	No restriction	2	No restriction	2+ system specific (evenly spaced)
Cost Comparison	Low Cost	Medium Cost	High Cost	Medium Cost	Low- medium cost	Low Cost

Global Safety Standards & Regulations Of Ropeway

	CEN - 2000/9/EC	ANSI B77.1	OITAF Recommendations
Country/ Organization	European Union	U.S.A	International Organization for transportation by Rope
Aspects covered	Safety standards for the construction and operation of passenger transportation by rope	Specifications & guidelines for design and installation, electrical design and installation, and operation and maintenance of passenger ropeways	Technical Recommendations, Studies and Statistics for Aerial Ropeways
Modes of transport covered	Aerial ropeways Funicular ropeways Surface lifts	Aerial tramways (single & double reversible) Aerial lifts (detachable lifts, chair lifts, & similar equipment) Surface lifts (T-bars, J-bars, platter lifts, & similar equipment) Tows (wire rope and fiber rope tows) Conveyors	Aerial Ropeways
Structure	28 individual standards including 10 standards on rope specifications	7 main parts & 7 normative annexes, on wire rope and strand requirements	30 Books on technical recommendations & various studies & statistics

Comparison BIS Vs CEN

Point of differentiation	CEN (Europe)	BIS (India)
Certification criteria	Approval required after completion of every step in the value chain starting with design to installation	BIS only specifies general norms to be followed across the value chain. Approval at each step is not mandatory
Testing methodology	More stringent and detailed: CEN standards specify the test to be conducted along with equipment details, procedures, performance requirements, qualification of personnel etc. CEN specifies that after installation, the detachable system should be tested for 50 h with main drive, at least 5 h of which shall be at full load.	Less stringent: BIS standards have similar specifications for components as CEN but have fewer requirements for testing BIS specifies only the test to be conducted without mentioning other details BIS does not mention any test to be conducted after installation to assess the operations of ropeway system
Inspection procedures	Testing is done for every sub-component mandatorily at specified intervals Testing to be done by a CEN certified professional only TUV, Bureau veritas Italia S.P.A. are the certifying agencies approved by CEN for ropeway components These agencies are approved by respective ministries of the countries	Testing is done at request and there is no mandatory frequency for tests The person conducting tests may or may not be a certified professional BIS does not have any certifying agencies for ropeway components
Specifications	Component, system specs & eng. design guidelines updated as per latest technological advancement	Relatively less updated

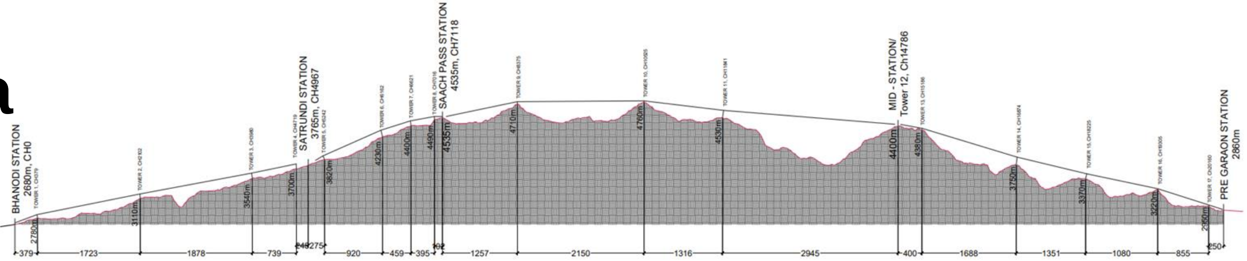
Comparison of Best Examples of Cable Car Systems

Name of Ropeway	System	Length	Capacity (PPHPD)	No of Stations, No of Lines	Learnings/Takeaways
Medellin Ropeway, Columbia	MDG (Mono Cable Detachable Gondola)	14.7 Kms	1800 - 2500 PPHPD	20 Stations across 6 lines	One of the most extensive urban cable car system
La Paz Ropeway, Bolivia	MDG (Mono Cable Detachable Gondola)	32.7 Kms	Up to 3000 PPHPD	26 Stations, 10 lines	Continuous development of System network similar to Delhi Metro
Caracas Metro Cable, Venezuela	MDG (Mono Cable Detachable Gondola)	6.6 Kms	Up to 3000 PPHPD	7 Stations, 2 Lines	Neighborhood Ropeway system complementing the Metro rail. Innovative urban Design by UTT Zurich.
Sentosa Ropeway, Singapore	MDG (Mono Cable Detachable Gondola)	2.5 kms	2000 PPHPD	6 Stations, 2 Lines	Spans across sea
Emirates Air Line Cable Car, London	MDG (Mono Cable Detachable Gondola)	1.1 Km	2500 PPHPD	2 Stations, 1 Line	across the River Thames in London
Constantine Gondola, Algeria	BDG (Bi- Cable Detachable Gondola	1.55 km	1000 PPHPD	3 Stations, 1 line	Ropeway city in a very challenging hill city terrain
Ankara Cable Car, Turkey	MDG (Mono Cable Detachable Gondola)	3.2 Kms	2400 PPHPD	4 Stations, 1 line	combating the high traffic volume experienced in dense neighborhoods, integrated with the metro

Key Features - unique cable car systems across the world

Project	Key Features & takeaways
Mi Teleferico, Bolivia (Urban)	10 lines, 30+ kms – one of the world's most extensive (& highest-elevation) aerial urban cable car system Aimed at improving mobility in hilly terrain & poverty reduction
Kuélap Cable Car System, Peru (Hilly)	1st cable car in Peru, connects to Kuélap Fortress, an important pre-Incan archaeological site Has reduced transit time from 90 to 20 minutes, increasing tourism
Mexicable, Mexico (Urban)	Mexico's first urban cable car, Conceived as a catalyst for economic & social development of the area
Mérida Cable Car, Venezuela (Hilly)	One of the world's highest & longest cable system, terminating at 4,765m Improved accessibility to the Sierra Nevada de Mérida
Capucins Cable Car, France (Urban)	France's first entirely urban cable-propelled transit system Gondola system built to provide a rapid & direct link at less cost, without interfering with traffic
Sentosa Island Ropeways, Singapore (Urban Sea)	0.88km long connection from Mount Faber on the main island of Singapore to the resort island of Sentosa across the Keppel Harbour USD 45M , Mono cable Detachable Gondola System, 4.0 m/s speed, 2200 PPHPD
Grindelwald-First, Switzerland (Hilly, ski resort)	Consists of a high-speed, slim-profile turning station, which is quite unique It will have dramatic implications for the technology in urban environments
Norsjö Aerial Ropeway, Sweden (Hilly, Marshes & Waterbody)	13.2 kilometers long, Over 3,000 meters of the Norsjö passenger ropeway is built over marshes and lakes and the system is but one small part of an even longer system. In 1989 this 13.2 km section was converted from mining and industrial purposes to tourism usage. The system as a whole, however, is a whopping 96 km long. By far the longest cable system in the world. That it was built in 1943 and is still operational
The Peak to Peak, Whistler, BC, Canada (Mountainous)	At its highest point, the cable is 436 m above the valley floor, longest unsupported cable span in the world Capacity of the Peak 2 Peak is 2,500 pphpd with 28-person vehicle headways of 49 seconds
Volkswagen Funitel, Slovakia (Factory premises)	An example of Heavy weight goods/freight transportation by cable cars 450 meters long over the factory premises from the assembly line to the in-house testing area and back

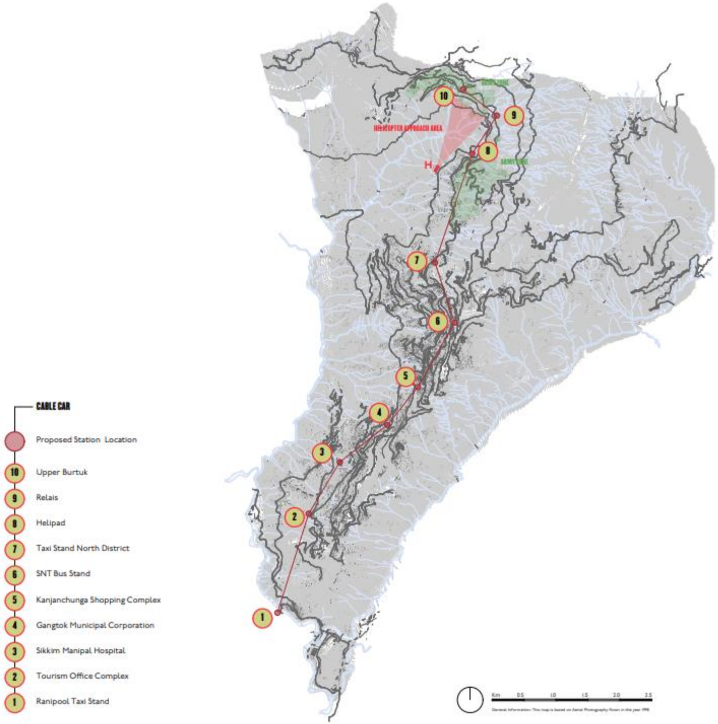
Case Studies - India

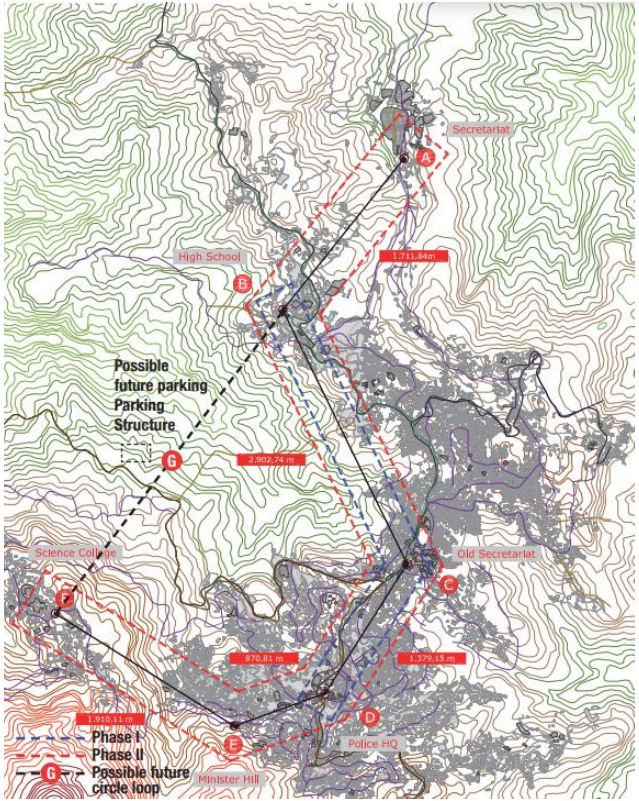


Gangtok, Sikkim
Urban Ropeway
10 Statons
Monocable Detachable Gondola system
2000-5000 PPHPD

Saach Pass, HP
Rural COnnectivity Ropeway
22 Kms, Crossing 4500 m altitude
Longest Span: 2.9 kms
Tr Cable Detachable System (3S)
250-500 PPHPD
INR 1400 Cr (2022)

Kohima, Nagaland
4 kms
6 Stations (Phase 1)
1000 - 2000 PPHPD
124 carriages capable of carrying 8 passengers each
Monocable Detachable Gondola system
INR 400 Cr (2011)





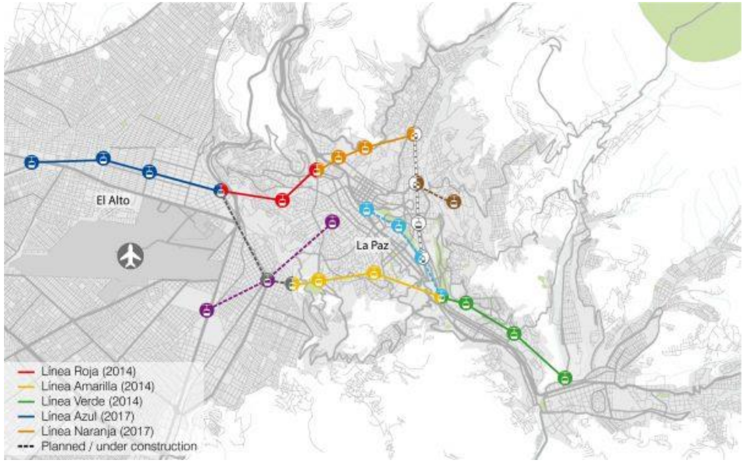
Case Studies - International (La Paz & Caracas)

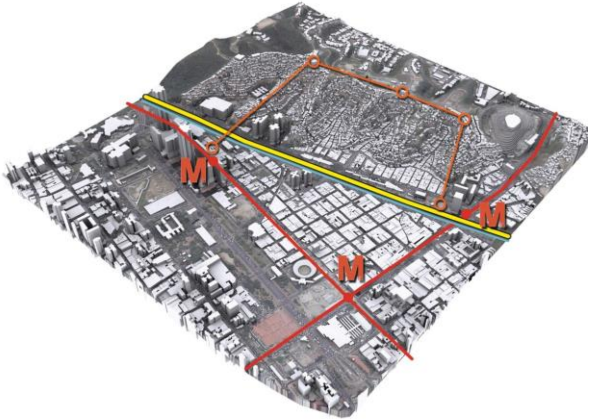
Mi Teleférico Urbano Cable Cars, La Paz, Bolivia

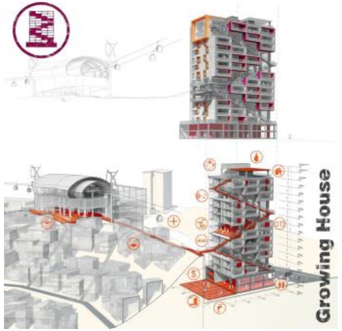
- Limited road capacity due to narrow roads and rising vehicle ownership; registered cars tripled between 2003-12
- Poor public transport, characterized by old, informal buses providing low-quality service
- Cumbersome travel between La Paz & its twin city El Alto due to large disparities in elevation; travel was limited to a single congested highway
- 2012 - 3 lines to 2022 - 10 lines
- 3000- 4000 PPHPD
- 30+ kms & growing
- Record-high ridership for public transport, transporting more than 1 lakh people a day

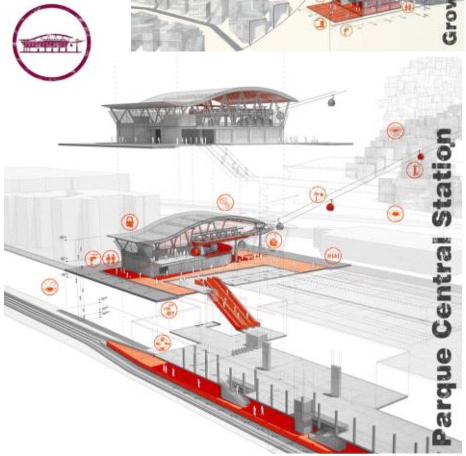
Metro Cable, San Augustine, Caracas

- Connect low income settlements in the hills to the cities main transit system
- 5 Stations (2 in valley & 3 along mountain ridge)
- Complements existing metro & other transport modes
- 1200 PPHPD
- Number of cabins 52+1 (Rescue cabin)
- 15000 passengers per day
- Interval - 27 sec
- 1.8+ kms & growing
- Population served 40,000 people
- Monocable Detachable System
- Execution time 2007-2010









Urban Scenario Study - Shillong

- Rapidly-growing mobility demand has outgrown the capacity of the city's existing mobility systems
- Intra-city trips in Shillong have increased 40% in the last decade to reach an estimated ~8.81 lakh trips daily. Shillong's mobility systems have not kept up. Daily commutes time-consuming, expensive, and inconvenient
- Average 70 minutes spent in traffic snarls daily to cross the city's major traffic junctions, leading to expensive commutes and lost productivity
- Public bus system has spotty coverage and poor reliability; decline in bus (40%) and maxi-cab (50%) fleet size has impacted frequency
- Three out of five common daily commutes for all major trip types are undertaken via cars and taxis
- Road expansion is difficult due to topographical constraints and to local land laws
- Estimated 150% increase in vehicular emissions since 2010 leading to hotspots with worst air quality in NER and deep impact on residents' health
- Aggregate INR 500 crores in annual opportunity cost to workers and businesspersons due to congestion in Municipal area alone
- The environmental and economic consequences of poor mobility threaten to limit the aspirations of Shillong's residents
- Users in Shillong aspire to get around in a manner that is affordable, reliable, and time-effective

Car Dominated Mobility

Nearly **3 in 4 trips** in the city happen by car. Share of trips on public transport and by walking is around **10%** each.

Limited Road Capacity

Roads comprise <1% of Shillong's total land area (6% in Dehradun). More than 70% of roads are single lane. Illegal parking further reduces road capacity by 30-40% in areas.

Immense Congestion

Major junctions in the city witness speeds of less than **5 km/h** throughout the day.[3] Average speed in the city is less than **15 km/h** against a benchmark of **25 km/h.**[4]

High Vehicle Ownership Rates

70% of households in the SUA area own a vehicle (compared to 50% for Delhi). New registrations for cars are rising at 8% annually, while road capacity remains limited.

"There is congestion throughout the week, Monday to Friday – the day does not matter. Even if we leave earlier it does not help avoid the traffic. It is always there."

- Female, 35, Shop owner, Lawsohtun

- **Loss of income due to long commute times, significant productive time**
- **Lack of public transport options makes it expensive to travel**
- **Cars becoming normalized as a necessary 'part of living'**
- **Financial hardship to attain car dominated "mobility dream"**
- **Compromising mobility choices, especially for low-income groups**
- **Mobility challenges force users to make hard choices**

Challenges and potential solutions

Challenges	Solutions
Multiple standards - CEN vs BIS	Compare both and adopt the best suited one that is constantly updated
Lack of Made in India Components	Start manufacturing in India
Technical Knowhow, Experienced workforce	Training, Capacity Development
Transport of Ropeway components from Ports to execution site	Identifying bottlenecks, Foolproof planning & scheduling
Aerial right of way	Policy intervention
Construction in tough terrains, Cable mounting technologies	Accurate scheduling, Use of modern technologies for fast and safe construction
Clearances, NOCs, Permissions	Policy intervention & uniform process across the country
Funding	Exploring PPP options with VGF
O&M	Strict O&M practices and laid down SOP

Potential Outcomes

Livability: Users enjoy congestion free and affordable mobility that allows them to pursue their social and economic aspirations
Sustainability: Emissions from urban transport are progressively reduced in line with the country's SDG goals
Economic Growth: Businesses enjoy seamless movement and tourists experience the city's rich tourism offerings through a mobility systems that aligns with the city's cultural ethos
Land value unlocking: overall growth and socio-economic development in urban centers provides a new opportunity and unlocks land value around the modern transport infrastructure
Green Mobility: Adopt solutions that minimize emissions related stress on climate and residents' health
Inclusivity: Cater to travel needs of all users including children, women, elderly, and persons with disabilities
Human-Centricity: Make users co-designers and co-owners of mobility solutions and infrastructure in the city
Unique Identity: Build mobility systems that become ambassadors of the city's cultural and natural endowments
Integration: An integrated transport network that seamlessly connect with the existing modes of transport and the ruban fabric

Suitability of various types of Cable propelled transport

Aerial Tramway	When the ropeway is just connecting two stations linearly, with carriers of large capacity across long unsupported spans
Funitel	When high wind resistance and stability is required in low capacity situations in tough mountainous terrains
Funicular, Inclined Lifts	Short distance, low capacity cable propelled systems moving on ground in steep terrain.
Pulsated Gondola	In nonral hilly conditions for low capacity tourism requirements
Mono Cable Gondola	Most commonly and effectively used as a mode of urban transport system in hilly and mountainous terrains where the unsupported spans doesn't exceed 900m and the wind speeds does not cross 50km/hr very often
Bi-cable Gondola	Used in hilly and mountainous terrains where the unsupported spans exceed 900m and the wind speeds are higher.
Tri-Cable Gondola (3S)	Used in the toughest terrains and climatic conditions as it offers the best in class safety and capabilities, such as ability to cross unsupported spans over 3 kms, operate in wind conditions up to 100 km/hr, and capacity above 6000 PPHPD.

Conclusions

- Cable Car Systems are best suited for undulating terrain, hill cities, congested urban areas, landslide-prone terrain, areas with minimum land availability/ high land acquisition costs, density populated urban areas, snow-bound areas, across valleys to connect hill settlements on hilltops, etc.

- India is yet to significantly scale up ropeway development, but expects to do that with Parvatmala Scheme

- Cable Car transport is one of the greenest modes of transport

- Ropeways are one of the safest, smoothest and most reliable modes of transport

- Mono Cable Detachable Gondolas (MDG) are the most commonly used systems when ropeways are used as a mode of public transport. Bi Cable Detachable (BDG) and Tri Cable Detachable (TDG or 3S) are used in conditions that require longer spans, higher capacity and more stability against climatic factors.

- tri-cable detachable system allows for capacity over 12000 PPH, with operational wind speeds above 100 km/hr in toughest of the terrains, and unsupported spans over 3000 meters, the mono-cable detachable system allows more cheaper solution with capacity upto 4500 PPH using unsupported spans upto 900 meters, and capable to operate in wind conditions upto 35-40 km/hr.

- It is seen that cable car systems can be a cost effective mode of public transport for tier 2 and tier 3 cities which don't require transport capacity over 6000 PPHPD