THE ARTICULATED FUNICULATOR and the TUBED MEGA FRAME

By

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What happens if a funicular, such as the funicular to Victoria Peak...
Is turned vertical and placed inside a tall thin skyscrapers such as?

International Commerce Center

2 International Finance Center
The Articulated Funiculator is Born!

What is the Articulated Funiculator?

- A New and innovative solution to vertical transportation
- Connected system of vertical trains
- Moves people in masse
- Sustainable ”Sky Subway”
- The Way of the Future
In A Horizontal City

People ride buses and subways as transportation
In A Vertical City

If elevators are the buses
the Articulated Funiculator is the subway
In the words of noted philosopher and Kyoto Prize winner Sir Karl Popper 1963:

What Really Makes Science Grow Are New Ideas, Including False Ideas!
Vertical Transportation
In the Beginning

1854 Otis Mechanical Lift
1900 Otis Brothers & Co elevator
The Challenge

Tall and super tall buildings struggle with:

- Large number of elevators
- Large number of elevator shafts
- High electricity consumption
- Relatively slow elevator speeds
- Low floor area utilization ratios

Which costs ¥ $ €
Articulated Funiculator Basic Concepts

One train is made of several train cars

Trains in vertical legs

Trains parked at horizontal stations
Articulated Funiculator Basic Concepts

- A continuous, connected system of trains
- Moves people in masse
- Sustainable "Sky Subway"

- Prototype building
- Trains in vertical legs
Articulated Funiculator Basic Concepts

- Trains transition from horizontal alignments at the stations to vertical alignments between stations
- Passengers remain standing

- Prototype building
- Trains parked at horizontal stations
Articulated Funiculator Basic Concepts

• Prototype Building
• Cut away
• Trains in vertical legs
Train Development

- Articulated Funiculator is a series of trains
- One train is made of several train cars
- Passengers remain standing through vertical to horizontal alignment transitions
Acceleration and Velocity Strategies

- Ultra high speeds
- Short cycle times

Velocity Table

<table>
<thead>
<tr>
<th>Rise/Fall (m)</th>
<th>Time (s)</th>
<th>Max Velocity (km/h)</th>
</tr>
</thead>
<tbody>
<tr>
<td>200</td>
<td>9.03</td>
<td>159</td>
</tr>
<tr>
<td>225</td>
<td>9.58</td>
<td>169</td>
</tr>
<tr>
<td>250</td>
<td>10.10</td>
<td>178</td>
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<tr>
<td>275</td>
<td>10.59</td>
<td>187</td>
</tr>
<tr>
<td>300</td>
<td>11.06</td>
<td>195</td>
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<tr>
<td>350</td>
<td>11.95</td>
<td>211</td>
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<tr>
<td>400</td>
<td>12.77</td>
<td>225</td>
</tr>
<tr>
<td>450</td>
<td>13.55</td>
<td>239</td>
</tr>
<tr>
<td>500</td>
<td>14.28</td>
<td>252</td>
</tr>
</tbody>
</table>
Acceleration and Velocity Strategies

Ultra high speeds  ➡  Short cycle times

- Loading and un-loading: 10-15 seconds
- Horizontal to vertical transitions (2): 10 seconds
- Rises and falls (200m – 500m): 9-14 seconds

Total cycles times between trains: 29-39 seconds

Cycle times can be reduced during off peak times

For example: 1000 m building w/3 stations
time from bottom to top: 78 seconds!
In the words of Nobel Laureate Eugene O’Neill 1936:

Happiness Hates The Timid,
So Does Science!
Tubed Mega Frame Prototype Building

- Height: 620m
- 40 m x 45 m plan
- 4 vertical tubed legs
- Slenderness ratios:
  - 1:15.5
  - 1:13.8
Tubed Mega Frame Prototype Building

- 4 cross-tube stations
- 4 intermediate cross-tubes
- High strength concrete
- Gravity loads transferred to vertical legs at stations and intermediate cross-tubes
- Increased building stance
- Very efficient super structure
Tubed Mega Frame
Structural Performance

Vertical wall thicknesses:
  • 1.50 m at base
  • 0.30 m at top

83 mph (37.1 m/s) wind:
  • Strength
  • C60 – C70 concrete expected

77.5 mph (34.6 m/s) wind:
  • Deflections
  • H/400 drift, 40 m direction
  • H/580 drift, 45 m direction

Mode 1: 11.25 s
Mode 2: 9.80 s
Mode 3: 2.95 s
Mode 4: 2.77 s
Mode 5: 2.76 s
Power/Braking System

- Dynamic braking
- Energy storage and re-use
- Energy to brake the system = energy to power the system
- Sustainable

Power/Braking cogs
Power/Braking System

- When downbound payloads are heavier than the upbound
- The Articulated Funiculator captures energy from braking the trains and stores it
- The stored energy is used to accelerate the Articulated Funiculator when the upbound payloads are heavier than the downbound
- Capture are re-use of energy is sustainable

Trains parked at horizontal stations
Power/Braking System

- For example;
- Before lunch most passengers will travel down;
- The energy needed to brake the system will be stored;
- The stored energy will power passenger up after lunch.

Trains in transition from horizontal to vertical alignments
Passengers remain standing
Train Station Concepts

• 3-story cross tubes
• Load and unload from center story
• Transfers to the opposite sides of the building
• Transfers to conventional elevators
Train Station Concepts

- Power/Braking systems housed inside the stations
- Passengers transition up to take conventional elevators up
- Passengers transition down to take conventional elevators down
Train Station Concepts
Floor Utilization Ratios

The central core in tall buildings consumes floor space, leading to low floor space utilization ratios.

Floor utilization ratios for a building with a central core:
0.596 – 0.745 (0.6705 average)
Floor Utilization Ratios
Floor utilization ratios for building with the Articulated Funiculator and the Tubed Mega Frame: 0.808 – 0.914
Approximate percentage increase in floor utilization:
0.861/0.6705 = 1.28
to
28% increase in rentable / sellable floor space
Vertical Transportation Plan

- 4 articulated funicular train stations
- 6 articulated funicular trains
- Conventional elevators between train stations
- 22 conventional elevators
- Movement options:
  - Funiculator up then elevators up
  - Funiculator up then elevators down
  - Elevators all the way up

High passenger flow and reduced congestion
Architectural Programs
Articulated Funiculator and the Tubed Mega Frame
• Can support many architectural forms and shapes
• Slants, curves and stepbacks are supported
Architectural Programs
Articulated Funiculator and the Tubed Mega Frame

No central core \rightarrow open floor plates and allows:
- Concert halls
- Large conference rooms
- Theaters
- Swimming pools
- Hospitals
- Schools

To be incorporated into tall thin skyscrapers
## Comparison with Ten High-Rise Buildings

<table>
<thead>
<tr>
<th>Name</th>
<th>City</th>
<th>Height (meter)</th>
<th>floors</th>
<th>completed</th>
<th>Total number of elevators</th>
<th>Top Elevator Speed (m/s)</th>
<th>Building width (m)</th>
<th>Core width (m)</th>
<th>Floor plate (m²)</th>
<th>Core Area (m²)</th>
<th>Useable Floor Area Ratio</th>
<th>Building Slenderness Factor</th>
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<tbody>
<tr>
<td>Ping An IFC</td>
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<td>115</td>
<td>2015</td>
<td>76</td>
<td>10</td>
<td>56</td>
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<td>2925</td>
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<td>121</td>
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<td>18</td>
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<td>150</td>
<td></td>
<td></td>
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<td>2400</td>
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<td>Taipei 101</td>
<td>Taipei</td>
<td>508</td>
<td>101</td>
<td>2004</td>
<td>61</td>
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<td>56</td>
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<td>1800</td>
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</table>
Conclusion
Articulated Funiculator

- Reduced number of conventional elevators
- Reduced number of elevator shafts
- Increased rentable / sellable floor area ratios
- Dynamic braking $\rightarrow$ Energy storage and re-use
  $\rightarrow$ Sustainable system
- Ultra fast speeds
- Short cycle times
Conclusion

Tubed Mega Frame

• Only 4 vertical tubed mega columns
• No outriggers or outrigger connections
• No belt trusses
• No central core
• Smaller floor plates
• All loads at building perimeter
  – Sleek, very efficient super structure
In the words of Nobel Laureate Albert Einstein:

We cannot solve our problems with the same thinking we used when we created them!
The sky’s the limit!
Tyréns presented
The Articulated funicularator and the Tubed Mega Frame
at the council on Tall Buildings and Urban Habitat
9th World Congress September 19-21, 2012 Shanghai

"Why haven´t we seen this before?!"

"Outstanding!"
"Blown away!"
"Brilliant!"
"Excellent!"
"Visionary!"

As hailed by international high-rise experts:

KPF Architects
Adrian Smith + Gordon Gill Architecture
Skidmore Ownings & Merrill
Arup

Thorton Tomasetti
WSP
Schindler
Samsung