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Title: Reimagining Transportation - Base Case Calculations on Flying Aerial Tram System

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ABSTRACT

Rapid and significant changes are emerging in the automobile industry including the prominence of electric cars, self-driving vehicles, and significant reductions in personal car ownership; for which current infrastructure and public transit are less than optimal. This paper presents base case calculations on a low-cost high-performance "flying train" infrastructure using a 1.5 inch (38 mm) zipline-type guideway offering a synergy with these emergences.

Base case calculations identify system viability, lane capacities exceeding four lanes of an interstate highway, and topics requiring further development. These topics include: a) airfoil-type vehicle shapes and modes of operation to attain lift-to-drag ratios of at least 4.0 and up to 12.0, b) operational logistics to attain capacities with spacing as low as two vehicle/train lengths, and c) a method to periodically relieve guideway (zipline) tension due to the additive nature of drag forces of sequential vehicles on the guideway. Base case approaches are presented to allow continuous guideway cables that are unobstructed for about 90% of their circumferences and zero-lead-time vehicle-controlled switching with linear motor guideways; these are fourth and fifth topics for advancement.

In an aerial-tram configuration with linear motors pulling the vehicle along a stationary zipline-type guideway, it is possible to convert a significant portion of the vehicle drag to lift. This "free" lift is proportional to velocity squared and suggests that flying train configurations are a natural/synergistic evolution of guideway transit systems operating at velocities greater than about 180 mph (290 km/h).

INTRODUCTION

A recent Wall Street Journal included a "Future of Transportation" section highlighting a number of disruptive technologies.[1, 2] Several of these technologies/concepts have passed critical milestones indicating the imminent gaining of significant market shares; of particular relevance herein are:

- The end of car ownership
- Self-Driving vehicles
- Cell phone app-enhanced ride sharing (alternatives to traditional taxis)

These advances will create demand for improved public transit access to city centers having automated taxi service; increased demand will be due to both the reduction of personal car ownership and lower-cost more-reliable taxi service. New approaches to public transit could provide non-stop service, velocities greater than 90 mph, and costs considerably less than taxi service for distances over a few miles. The demand for such public transit could be an order of magnitude greater than today's public transit. The same inter-connected system would provide both commuter and trans-continental service.

This base case study is on a transportation system using a 1.5 inch (38 mm) diameter zipline-type guideway that can be routed above existing streets, railway lines, and buildings. The zipline cable is supported by connections that leave 90% of the cable's circumference unobstructed, allowing free movement of a propulsion carriage along the cable. The cable functions as an overhead monorail for airfoil-shaped vehicles that attain full aerodynamic lift at speeds greater than 90 mph (145 km/h). The primary vehicular force on the guideway is longitudinal tensile (pulling) force that inherently straightens the guideway and dampens vertical or lateral guideway movement (see FIGURE 1).

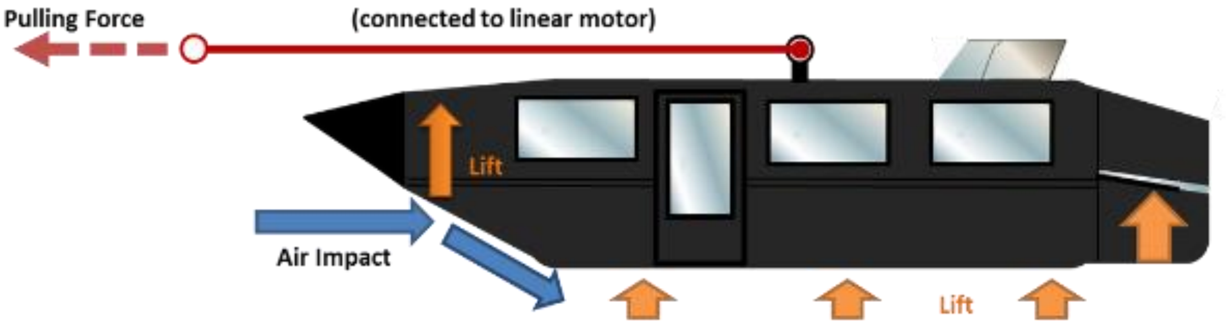


FIGURE 1. Illustration of Terreplane vehicle with linear motor to provide propulsion force.

BACKGROUND

A number of overhead-monorail mass transit systems have been disclosed that use vehicles providing aerodynamic lift. FIGURE 2 summarizes four of these systems. Two primary differences of these as compared toTerreplane[3] (the FIGURE 1 system) are:

1. Smyser,[4] Timperman,[5] and Lehl et al;[6] each have jet or turbine engines versus wheel or linear motor propulsion along a cable-type guideway and
2. Leibowitz,[7] Timperman, and Lehl et al; each have rigid overhead monorails versus tensile-straightened cables.

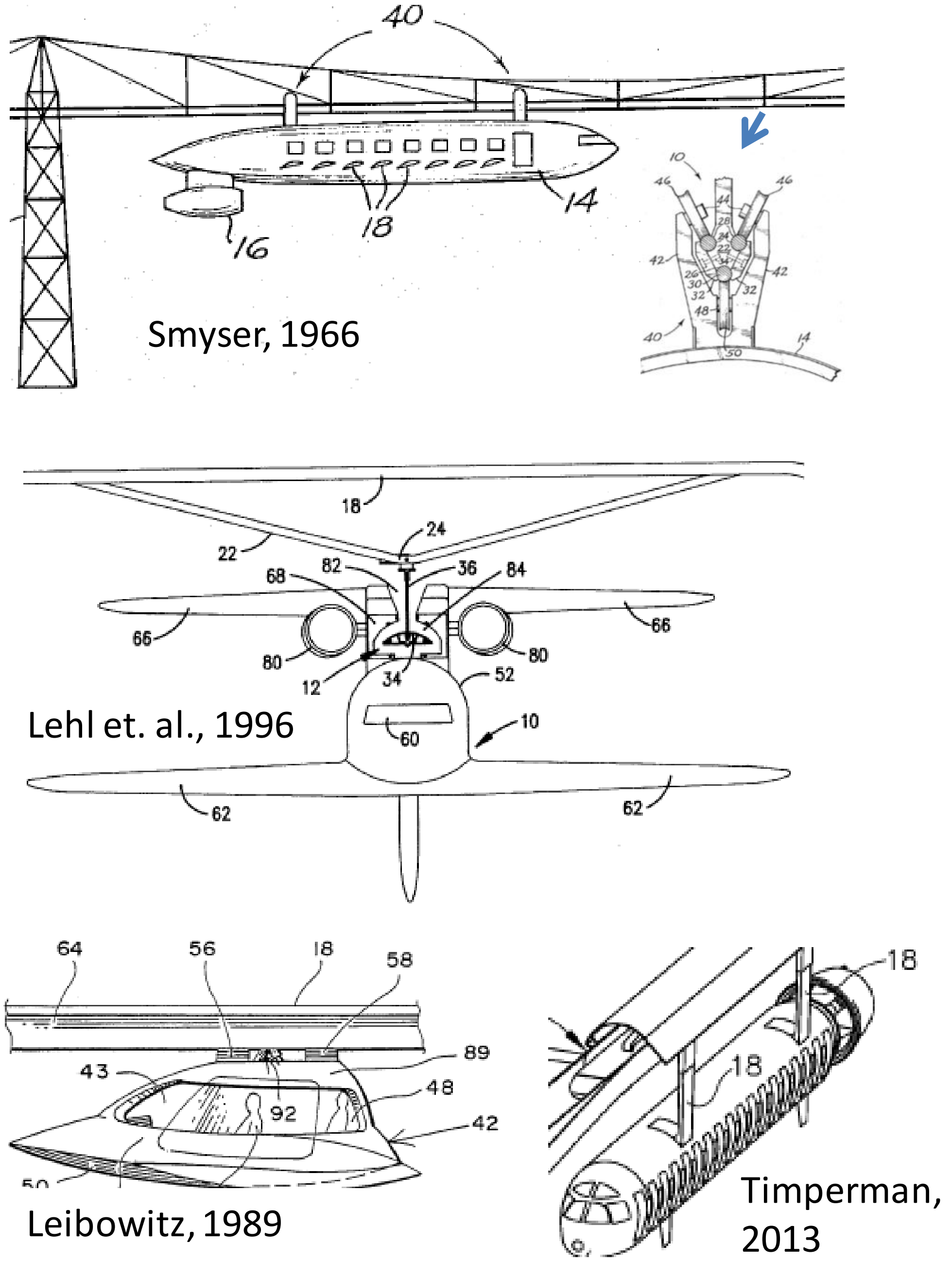
The roaring jets and turbine engines of Smyser, Timperman, and Lehl et. al. limit routing options and represents a fatal design flaw for ground-based systems seeking to interconnect metro with trans-continental service.

The rigid overhead monorails of Leibowitz, Timperman, and Lehl et. al. would have to be designed to handle the weight of stalled vehicles, and so, they would have similar costs as high speed rail systems. While Smyser illustrates a cable guideway, each cable of the cable triad would move laterally/vertically if the wheels press (apply radial forces) on the cable triad to attain traction/propulsion; induced traction force on the cables would be necessary when the vehicle weight is supported by aerodynamic lift. Alternatively, if the three wheels are spaced around a single cable, radial forces of the wheels would cancel with proper symmetry; no lateral movement would result, and traction would be attained.

An impacting and distinguishing factor of Terreplane is compatibility with low-cost zipline-type guideways. This compatibility is only possible for high-speed transit if downward and lateral forces from vehicles do not cause the same movement in the guideway cable. Compatibility with cable guideways is augmented when pulling tension generated by the propulsion carriage further damps any movement in the cable and reduces an drop/sag as the vehicle approaches.

A third distinguishing factor is related to passive increases in vehicle stability and reductions in aerodynamic drag. FIGURE 3 illustrates a Terreplane **Propulsion Carriage** on the **Guideway Cable** connected to the **Vehicle** via a connection arm having a joint on both the carriage and vehicle. As velocity increases, the vehicle swings back on the arm, closer to the Propulsion Carriage. This passive adjustment allows the vehicle to be located further below the carriage when parked allowing a lowered center of gravity to minimizes how movement of passengers in the vehicle translates to tilting of the vehicle. The closer approach of the Vehicle to the Propulsion Carriage during travel reduces the adverse effects of vehicle-drag-generated torque on the guideway. For Smyser's system, vehicle drag would pull down on the front truck (arm connecting vehicle to guideway) and push up on the back truck. Timperman has adjustable arms/trucks that would reduce this torque, but these are actively adjusted rather than substantially passively adjusted. Flaps on the propulsion carriage (truck) can compensate for vehicle-drag-generated torque; but these flaps would increase drag and energy consumption.

A fourth distinguishing factor is a designed guideway-carriage-vehicle alignment that generates purely longitudinal forces on the guideway without systematic compensation by flaps on the carriage. A further inspection of FIGURE 1 (in view of FIGURE 3) reveals this quality. The guideway, arm joint on the propulsion carriage, and arm joint on the vehicle are all aligned in a horizontal plane at the full aerodynamic lift position. This in-flight configuration produces a purely longitudinal force on the guideway cable with minimal drag and energy consumption.



Smyser, 1966

Lehl et. al., 1996

Leibowitz, 1989

Timperman, 2013

FIGURE 2. Summary of patent literature on overhead monorail-type systems using vehicles having aerodynamic lift.

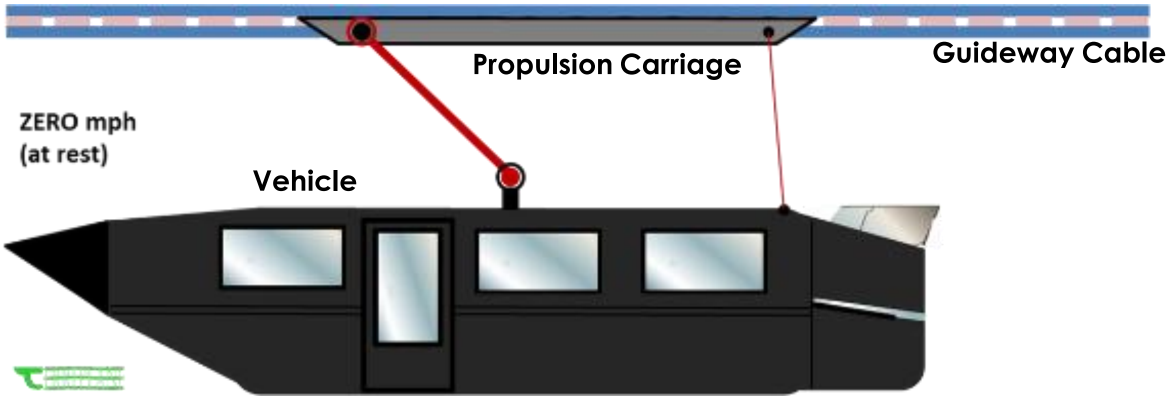


FIGURE 3. Airfoil vehicle showing propulsion carriage on guideway cable connected to vehicle by arm and back cable.

An example force and torque balance providing a purely longitudinal force is illustrated by the vehicle-arm combination of FIGURE 4. The prior art does not suggest the beneficial torque balance of FIGURE 4. An optimally controlled and designed vehicle would both only provide longitudinal force on the cable and would convert the impact momentum on the front of the vehicle (a part of total vehicle drag) into a lift by downward-sloping surfaces. This "free" lift is proportional to velocity squared.

The momentum theory of lift[8] correlates lift with the velocity of air pushed downward by the front surface of the vehicle according to Equation 1. Typical Terreplane vehicles would operate at 1.225 kg/m^3, $3m^2$, and 40.3 m/s; a lift force of 6,000 $kg\ m / s^2$ (weight of 4 passengers plus vehicle). At 180 mph this is enough lift for 16 passengers (at 360 mph, 64 passengers). Vehicles of this system do not need wings; this approach is a "natural/synergistic evolution" of guideway transit systems.

$$L = \omega\, \rho_{air}\, A\, v^2 \qquad \textbf{Equation 1}$$

L is lift ($kg\ m / s^2$).
ρ_{air} is air's density (kg / m^3)
A is cross-sectional area (m^2)
v is velocity (m/s)
ω is related to the impact angle and has a value less than 1.0

Wings in the form of spoilers could supplement the vehicle body to provide lift. Commercial passenger jets attain about 1500 kg of takeoff load per ft of wingspan; takeoff velocity is about 180 mph (290 km/hr). At 150 kg per passenger (including Terreplane vehicle weight), this translates to about 10 passengers per foot of spoiler wing as an upper end capacity indicating possibilities.

This paper is on base case calculations for a zipline-type guideway that would provide travel at velocities greater than 90 mph; velocities targeting full aerodynamic lift. The cable guideways must provide a continuous path that is sufficiently straight to minimize g-force passenger discomfort. These guideway characteristics are inherent features of a high-tension 1.5 inch diameter cable where support towers primarily support the weight of the guideway and support cables. Tension is transferred through, to, and between cables rather than to the towers

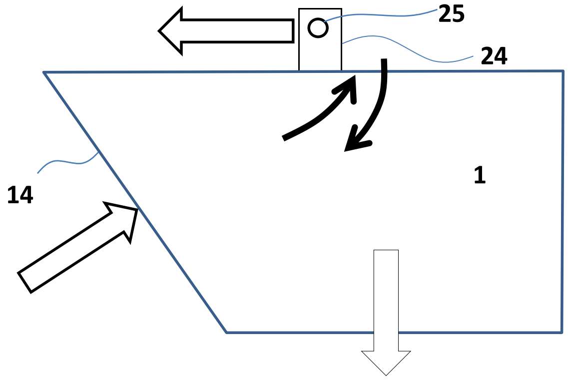


FIGURE 4. Force (propulsion, lift/drag, weight) and torque (lift/drag and weight) balance on vehicle allowing travel with only a longitudinal force on the guideway (propulsion line).

BASE CASE CALCULATIONS

Base case design degrees of freedom are specified in TABLE 1. The purpose of base case specifications are to specify and identify process viability. They may or may not be optimal. They are intended to assist in identifying the best opportunities for optimization.

TABLE 1. Base case specification of design degrees of freedom.

Base Case Specification	Design Parameter
3 mm	Maximum drop/sag of cable between supports
200 lb/ft, 298 kg/m	Maximum load on guideway cable
0.2 g-force	Longitudinal acceleration braking/acceleration
1.5" (38 mm) D	Cable specification
10%	Static tension applied to guideway (% nominal strength)
90 mph, 145 km/hr	Base case operating speed (40.3 m/s).

Cable Support Spacing

Cables are approximated as providing only tensile force, and so, a control volume on a freely hanging cable has three forces: two tensile end forces on the cable and the cable weight. This leads to the Equation 2 differential equation of the force vector:

$$dh / dl = W/T \qquad \textbf{Equation 2}$$

h is change in height of the cable due to drop (m)
l is horizontal distance (m)
W is weight supported by the vertical component of the cable tension (kg * 9.81, N)
T is the horizontal component of tension (N)

A solution was prepared using Newton's method in a spreadsheet with numeric integration starting at the middle of the cable with h=0, l=0, T is specified, and W starts at zero and is the cumulative weight over the integration. T was specified at 10% of the cable's nominal strength. The cable was specified as a 6 X 19 Classification/Bright wire rope at 38 mm (1.5 inch) diameter, at 89.7 metric tons (98.9 tons) nominal tensile strength, and a mass of 6.19 kg/m (4.22 lb/ft).

Results of the integration identified that 6 meters between supports leads to a drop of 3 mm. A tower spacing of 300 meters results in a drop of 7.8 meters. In a suspension arrangement (neglecting weight of connecting cables) where the support cable is the same diameter as the guideway cable, the suspension cable would support twice its weight and would have a drop of 15.6 m (twice the drop) between towers. At the towers, the horizontal component of the tension is 88 kN as compared to the vertical component of the support cable which is 18.4 kN.

Large electrical power transmission lines (versus smaller local distribution lines) are substantially comprised of 500 kV Lattice towers at heights of 37.6 m (123.5 ft). A 7.8 m calculated drop over a 300 m spacing of towers is consistent with observations in the electrical power industry; lower drops are possible by increasing the tension. As an additional industrial benchmark, the wind turbine industry routinely installs 100 m towers, as compared to 37.6 m towers for electrical power transmission. [9]

Support of Stalled Vehicles and System Capacity

A 300 m spacing of towers has about 1860 kg of guideway cable. At a load specification of 298 kg per longitudinal meter, that same expanse has could potentially have 89,400 kg (877 kN) of vehicle/passenger/carriage. The nominal rating of the cable is 880 kN, which is multiplied times two since both ends of the 300 M spacing provide support at the towers (i.e. 1760 kN). Two cables at an average of a 45 degree angle at the towers would have a vertical load of 1760 X 2 X 0.707, or 2490 kN.

These calculations reveal that the cables could support a full load of carriages/vehicles on the guideway, depending on:

- how the guideway cable transforms from being a load supported by the support cable to assisting the support cable with the load of stalled vehicles and
- the ability of cables that are normally at 0° (guideway) and 7° at the tower are able to stretch sufficiently to attain better angles to support load (e.g. 45°).

On system passenger capacity, at 145,000 m/hr (90 mph) and 1.5 passenger per m (per 248/1.5 = 165 kg load per passenger, including vehicle), a guideway capacity is 217,000 passengers/hr.

For comparison purposes, a lane of interstate traveling at 120 km/h, two passengers per vehicle, and following at a 2-second rule (120,000 m / 3600 s X 2 s / 2 passengers ~ 35 m / passenger) has a capacity of 120,000 / 35= 3,428 passengers per hour (about 1 passenger per second, consistent with two passengers every 2 seconds).

The conclusions of these calculations are that the base case system can handle the weight of a full length of stalled vehicles and that the passenger capacity of a single lane is quite large in comparison to a lane of a highway (assuming not highway traffic congestion).

Tension Load from Vehicle Propulsion

During transit, the pulling force on the guideway cable is equal and opposite the drag force on the moving vehicle and carriage. The force is highly dependent on vehicle design and operational parameters. For aircraft, lift:drag (L/D) ratios vary from 4.0 for a Concord aircraft taking off to 18 for a cruising Boeing 747. Due to a prominence of surfaces of the airfoil vehicles that do not contribute to lift(e.g. sides), and upper L/D ratio will likely not exceed 12. A L/D ratio of 4.0 should be attainable.

The calculations for stalled vehicles can be transformed to propulsion tension using a L/D ratio of 4.0, resulting in a propulsion tension load equal to 25% of the stalled vehicle load (stalled vehicle weights are the same as the lift needed for flight). Hence, a 38 mm cable can handle the propulsion load.

To a first approximation, only the guideway contributes to supporting propulsion forces. Furthermore, these forces are not transferred to the towers; rather, these forces would accumulate over the expanse of the propulsion line unless they are transferred to something other than an additive force on the guideway. This is a major problem and requires a solution. Ideally, these tension forces would be transferred to guideways for vehicles of opposite travel directions, leading to cancelation of the forces versus accumulation of the forces.

This base case calculation reveals that design considerations should transfer tension forces between guideways of opposite travel direction. This calculation also reveals that the added tension to the cables from propulsion needs is significant compared to the 10% of nominal strength used to estimate the drop between supports, and that actual cable drop will be less than calculated due to this.

A vehicle-full guideway capacity of 217,000 passengers per lane per hour would reach cable capacity in 300 meters of vehicles. A starting point on limits of operation is having vehicles/trains travel with at least two vehicle/train lengths spacing, limiting train lengths to 50 m, and having transfer of tension between guideways of opposite travel at least every 300 m.

Tension Load from Vehicle Acceleration

An acceleration of 0.2 g-forces would have a similar force on a cable as a L/D ratio of 4.0. The vehicle drag during this acceleration would be additive to drag-induced tension. An analogy to the calculations of the previous section on Tension Load from Vehicle Propulsion suggests that these combined forces for a 150 m train could break a 1.5 inch diameter cable. The answer is to reinforce cables at locations near stations to accommodate loads from both acceleration/braking and vehicle weight.

Station specifications will need to include a maximum length for a train, both due to acceleration concerns and lengths of platforms.

Tower Spacing Options

An expansion of the previous Newton's method yields:

- 7.8 m Drop for 300 m spacing at10% (of maximum tension at midpoint)
- 31.8 m Drop for 600 m spacing at 10%
- 70.4 m Drop for 900 m spacing at 10%
- 126 m Drop for 1200 m spacing at 10%
- 63 m Drop for 1200 m spacing at 20%
- 252 m Drop for 2400 m spacing at 20% (29% at tower connection)
- 124 m Drop for 2400 m spacing at 40% (49% at tower connection)

The mid-point tension does not have much of an impact on drop at smaller tower spacing, but has a significant impact at greater tower spacing. The drops are doubled for a support cable that supports the weight of a guideway cable. Methods to reduce the drop include: 1) use a larger diameter support cable than guidway cable, 2) use lighter weight materials such as carbon fibers for cables, and 3) use variable diameter support cable.

DISCUSSION

Operational Logistics and Capacity

The largest 10-lane highways only have capacities of about 18,000 passengers/hr per direction (5 lanes per direction, 2 passengers per vehicle, 2-second rule following distance). The 2-second rule does not apply to cars connected in train units. And the 2-second rule does not apply to centrally-controlled vehicles on a propulsion line guideway. A single lane of a propulsion line guideway (217,000 ÷ 3) can readily exceed the capacity of 5 lanes of interstate highway (18,000 passengers/hr).

The base case conditions of TABLE 1are able to fully meet reasonable capacity demands within the following constraints:

- Use of guideway tension release mechanisms to prevent the accumulation of drag-induced tension forces, a preferred method of release is through tension-relieving connections every 300 m between guideways of opposite travel directions.
- A 50 m (75 passengers) length limit on trains emerges from handling propulsion forces and dead load support of stalled vehicles.
- Guideway occupancy limits based on vehicle/train spacing of at least two vehicle/train lengths is needed to handle vehicle drag as translated to guideway tension.
- Use of operational logistics and switching methods[10] to allow vehicles to merge onto lanes at high speed and low vehicle spacing.
- Use of reinforced guideways at stations capable of handling acceleration/braking needs as well as supporting vehicles that are not flying.

It is common for trains and aircraft to have seating of 4 seats (or more) across the cabin at intervals of less than three feet along the length of the cabin. The base case specifications are for 2 seats across at intervals of about 1.33 meters (4 feet) with the option of a walkway between the two seats. This is a manifestation of a load specification of 298 kg per meter on the propulsion line. For designs with propulsion carriages twice as long as the vehicle lengths, cabins consistent with train cars are possible.

Tower Spacing

At 33% guideway occupancy, a 38 mm D cable would provide needed tensile capacities at distances up to a km. The issue that emerges with greater spacing of towers is the drop in the support cable that occurs between posts.

For example, the drop in a support cable (supporting both its weight and the weight of a guideway cable) is about 63 meters at 600 meter spacing of towers. Figure 5 illustrates how a post suspended by a support cable can be used to support the guideway. A benefit of such a system includes allowing the use of shorter towers. More importantly, this design allows the crossing of mountain hollows or bodies of water where the nadir between the tower foundations is lower than the tower foundations. The current record for an expanse between towers is 1.88 miles (3 km) for the Peak2Peak gondola at Whistler-Blackcomb, which is consistent with the calculated drop of 124m drop at 2.4 km (support cable larger than guideway cable).

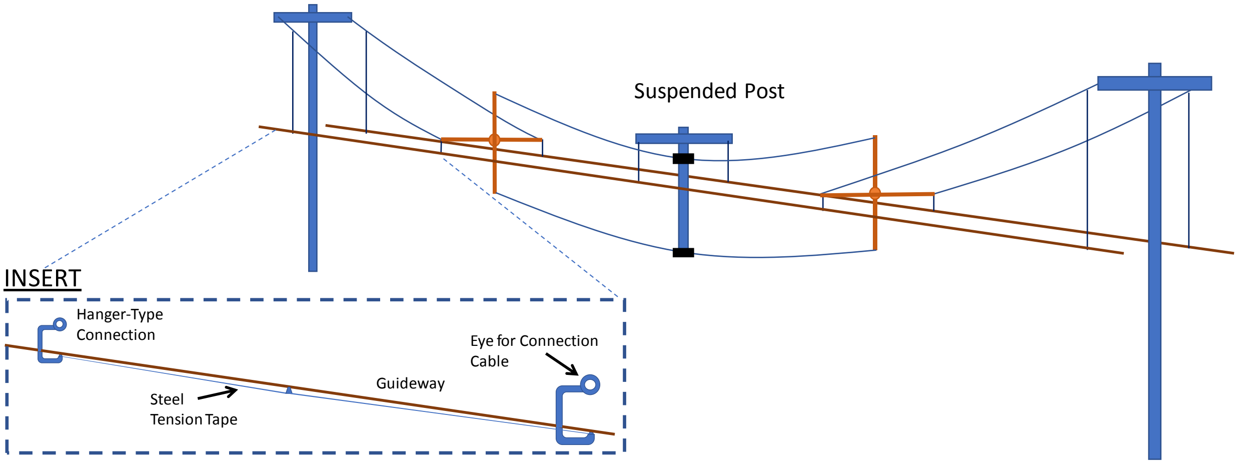


Figure 5. Illustration of a suspended post and hanger-type connection that connects to bottom of guideway cable [insert] with use of steel tension tape on middle support.

Benchmark calculations suggest that 2.4 km spacing (1.5 mile) of towers is possible with 130 m towers. At an acceleration/braking of 0.2 g (0.2 * 9.81 m^2/s), a velocity of 145 km/h can be attained in 20.5 seconds at a distance of 413 meters. About two thirds of this 2.4 km distance would be at the 145 km/h velocity; which is acceptable. The conclusion is that this approach is acceptable for metro service at station spacing of 2.4 km, and that such a system in a city could be built with the only ground structures (towers) being at the stations. The towers could be incorporated into station buildings at these intervals where the station buildings could emerge as local store, shop, and office centers.

In cities, the cable infrastructure could be used to mount lighting, stoplights, and signs for streets and walkways below the cables. The vehicles would be aerodynamically quiet. Ample opportunities exist to minimize impact in cities while creating an overall improvement in aesthetics.

Benchmark Capital Costs

Towers of 100 m height for wind turbines are documented at costing about $240k per tower, installed.[9] A 38 mm cable is about $8 /ft ($42k/mile, $26k/km). At 2.5 towers per mile (installed), four cables per two-lane section, and a Lange factor of 4 for installation, the cost is $1275k/mile ($600k + $675k) or $792k/km. These costs are consistent with reported costs of electrical power transmission lines of $960k/mile and $2,350k/mile.[11]

A low number for the cost of high speed rail is $30M per mile.[12] If the bench mark costs are doubled ($4M/mile), the costs are still less than one fifth the cost of high speed rail. The low costs are well-founded because the system is based around ultra-light vehicles and an innovative design based on tensile properties of cables which are relative inexpensive compared to concrete beam/truss construction.

The base case approach is well-suited for expanses across bodies of water and mountain hollows with little increase in the $4M/mile cost. Railway lines and highways readily cost a factor of 100X more ($400M/mile) across rivers and through mountains.

What is needed for the technology to advance are initial applications that would allow visual exposure. Those initial routes could then be expanded and the technology incrementally improved. The next sections are on initial applications and topics for system evolution.

System Evolution and Critical Technologies

The base case analysis reveals critical topics where performance is needed and continuous improvement would yield reward. These topics include:

- L/D ratios of airfoil-type vehicles (no wings) limit guideway capacity because of the additive tensions on a guideway. A base case estimate of 4.0 was provided and an upper limit of about 12.0 is expected.
- While batteries could be used to power the vehicle and propulsion, direct transfer of grid electricity to the vehicle from a catenary wire (overhead line) suspended a couple inches above the guideway cable with a conductive strip being pushed against this wire (the guideway cable can be the return).
- Base case propulsion carriages consists of sets of triads of wheels pressing against the guideway cable to provide propulsion traction. Additional wheels above the cable would distribute the weight for stalled and parked vehicles. Advanced options include use linear motors where the magnetic forces both center the carriage around the cable and provide propulsion forces.
- Base case calculations on stalled vehicles did not account for longer cable lengths necessary to provide favorable angles to provide vertical support; however, this is less of an issue at a maximum of 33% loading. Further details are needed.
- Base case calculations indicate that spacing of 6 m between support locations on the cable is adequate to keep drop less than 3 mm. This spacing can be increased, reducing the number of connection cables between the support cable and the. This is a topic of further discussion in the next section.

Cable, Connection, and Support Designs

In a suspension guideway configuration, an overhead support cable is connected to the guideway with vertical connection cables. The cables can connect on the top of the guideway or on the bottom of the guideway. Figure 5 (insert) illustrates a connection on the bottom of the cable with use of steel tension tape/band to support the cable weight at a middle section.

For the based case 3mm drop specification, the 6 meter distance between vertical connection cables can be doubled with the use of tension bands. The band and middle support must support half the cable weight for this expanse, which is 37.2 kg. If the connection cables and hangers are to support half of the load specifications on the cable, each must support about 3.6 metric tons. This load is half the nominal tensile strength of a 10 mm steel cable.

In this configuration, the propulsion carriage travels above the guideway, and a series of wheels on the top of the propulsion carriage are able to distribute the weight on the cable if the vehicle is stalled. Aerial trams routinely use wheel suspension above cables with good safety records.

Redefining the Metal Cable

Connections on steel cables are needed for intermediate support and cable-to-cable connections. The connection must leave 90% of the circumference unobstructed, which leaves 11.9 mm (38 mm X 0.1 * 3.14) of width and unspecified lengths for these connections/supports. The strength of the connection would increase with the length of the brazing weld connection, this is a base case approach.

Once sufficiently removed from the cable circumference (e.g. 40 mm), the 11.9 mm thickness of these connections can increase. Base case specifications are prudently augmented to allow the full dead load (298 kg/m) to be transferred from the guideway cable to support cable. Example connections would be 3 metric ton capacity connections at 10 m spacing.

For cable-to-cable connections, the connections would require connection brazing/welding lengths adequate to transfer the full tension load of the cables. Increasing the length of the brazing/welding is the ultimate degree of freedom that allows the base case system to meet these requirements.

The base case approach would be adequate; however, four areas of advancement (i.e. cable materials development) would reduce costs, improve aesthetics, and expand capabilities; these advancements include:

- oriented cables with factory-installed connections,
- sacrificial core cables that enable alternative methods to attach connections,
- weight-straightening designs (enhanced tension straightening cables) , and
- conductive shell cables for linear motor designs.

Wire rope is classified by its cross section where more-robust designs are actually windings of multiple strands. For example, a 7 X 19 aircraft cable consists of seven 19-wire strands (smaller diameter cables) where six of these strand are wrapped around the seventh cable. An example of an oriented design is a 8 X 19 cable where two strands from the core which is wrapped by six of the strands; rather than round, the resulting cable would be oval in shape. The flatter surfaces of the oval cross-section define the orientation.

Connections could be installed factory-controlled settings with the cable and low-profile connections wound on reels/spools. Factory-manufactured connections would reduce standard deviations in joint properties and allow rapid installation (including replacement) of guideway cables.

Sacrificial core cable technology would use space-filling polymer cores in wire rope that could be removed at connection points to reduce the cable diameter and allow traditional connectors to be used. At the smaller diameter locations, the overall diameter at the cable/connections would be the same as the cable's overall diameter with the sacrificial core. Factory-installed connections would enhance quality and literally allow a mile of guideway to be rolled from a reel, ready to clip onto support structures. The upgrading of large sections of guideway could be performed overnight with easy recovery and recycle of the old guideway.

While thermoplastic cores in cables could be used to facilitate attaching connections without changing overall diameter, other types of cores (e.g. metal strips) can be used to assist in supporting the cable weight and reduce sag (i.e., weight-straightening designs). Also use aluminum coating on ferromagnetic steal could be used to provide superior propulsion capabilities where the cable is the armature of a linear motor. Terreplane systems would push cable technology past it current infancy, with great potential for cable innovations and advancement.

Switching Technology

To allow Terreplane vehicles to travel and switch lanes in close proximity, a vehicle-controlled switching technology is needed. Such switching methods would be based on the propulsion carriage having the capability to selectively engage a switching guideway while disengaging the main guideway to perform the switching maneuver.

A base case switching guideway would appear above the main guideway with the switching guideway supported from upper support connections and the main guideway supported by lower connections. As an upper limit of complexity, a second propulsion carriage on the Terreplane vehicle would have the capability of engaging the switching guideway while the main propulsion carriage would disengage the main guidway to perform the switch. Variations of this reduce the redundancy of propulsion carriage components and reduce or eliminate the need for moving parts. A strategic advantage of having a small guideway (38 mm diameter cables versus tracks that are 1200 mm apart) is that the propulsion carriage has a shorter distance to move to complete the switching process.

Initial Applications

The Wall Street Journal's highlighting of "The End of Car Ownership" and "On Demand Transportation" service indicates a decreasing market for corridors to drive cars to downtown areas of cities. The Terreplane system is a natural fit with people and parcel transport, but propulsion carriages greater than 20 meters in length could ferry vehicles. This suggests that locations in need of new bridges, which can readily cost in excess of $200M, could meet their needs with a Terreplane bridge corridor. Such applications would result in savings of over $100M (>50%) per application while providing needed traffic relief.

Base case estimates show that two land-based towers can readily traverse a body of water that is a mile wide. The system would provide access to multiple downtown locations from several stations on the opposite side of the body of water and would include ferry service for vehicles.

Bridges, Mount Hollows, and Under-Developed Countries

Of the world's most expensive bridges, the four completed since 1997 have costs from 700 to 2,900 million $/mile (437 to 1807 million $/km) and took 5 to 10 years to build. Total lengths were from 0.85 to 4.2 miles (1.38 to 6.8 km).

As discussed earlier, cities could use standard layouts of 1.5 miles (2.4 km) between towers/stations. This distance can be easily extended through water by using support cables that go below the surface of the water where regularly-spaced fully-submerged floats along the support cable would support the weight of the cable and allow extending expanses between towers, spacing of up to a few miles. The support cable would be along the bottom of the water channel, and intermittent suspended towers would be attached to this suspension cable. Depending upon the application and obstacles (e.g. ice flows), the bridges could be installed in days.

To date, large sections of the world have little to no road and electrical power infrastructure. Characteristic of these sections are mountains, large rivers, mud flows, and jungle canopies. All of these are readily overcome with the tower-cable infrastructure discussed in the previous paragraphs. Furthermore, it is possible to use suspension cables for electrical power transmission; or at least, use the infrastructure to support transmission lines. Designs are also available for installation of wind turbines at a fraction of the cost of isolated wind farms.[13]

Near-Sonic Land Corridors and Superports

The topic of near-sonic transit has again emerged in tech circles, presently under the name Hyperloop. Since the 1970's,[14, 15] the barrier to these near-sonic transit corridors has been low to negative returns on investment due to the combination of high costs and long construction times.[16, 17] With Terreplane technology, the market for transit corridors at travel speed greater than 300 mph could naturally evolve from the most basic initial systems.

When demand reaches a level of justification, these 300 mph open-air system could be placed in tunnels where vehicles push and maintain air speeds of 50 to 100 mph in both directions leading to 400 mph tunnel corridors. As these tunnel corridors become long enough to justify the time for entering/exiting vehicle air "locks", near-sonic travel at speeds near 700 mph would be attainable. The tensile-straightening guideway is highly compatible with these near-sonic speeds. The pressure in these corridors would be near 0.2 atm and would be determined by engineering calculations to optimize the appropriate objective functions. Air in the tunnels would travel at 100 to 150 mph; making travel faster than optimal with aircraft. Vehicles would have lighter specific (per passenger) weights due to the absence of stored fuel, which when combined with constant tailwinds of 100 to 150 mph, would allow improved energy efficient from non-fossil fuel energy sources.

Air travel could be enhanced by Terreplane networks. Highly reliable, non-stop, and on-demand transit at 90 to 200 mph (in cities) would allow transit in secured vehicles directly to jet gateways from locations tens of miles distant from the gateway. Just-in-time arrival to jet departures would be possible for downtown security stations with as little as 30 minutes notice before the closure of the aircraft door. Likewise, the time from the jet door to a downtown destination could be less than 20 minutes. All airports in a 50 mile radius could functionally perform as a single superport. This would transform air travel.

Twentieth Century Perspective

Since World War II, with the advent of the jet engine and mass production of aircraft, transportation technology has advanced substantially through incremental improvements of systems in place. Incremental improvement is better than no improvement, but society periodically needs disruptive technologies that make major advances and set technologies on new paths of incremental improvements. Base case calculations suggest that transportation systems based on flying aerial trams with guideways comprised substantially of cables can provide these new paths.

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