High-Speed Cable Car System.

Aleksandar Zhelyazkov, Moritz Wenzel

With the transition of humanity towards a more environmentally friendly future, the demand for high-speed trains is increasing. The reason for this is the need for a comfortable, eco-friendly mode of transport that can compete with cars and airplanes. The market for high-speed ground transportation is currently dominated by high-speed rail. Maglev trains are also on the rise, and futuristic technologies like Hyperloop could hit the market in the coming years.

A hurdle for the wider use of high-speed trains are the substantial costs, which are largely caused by the construction of the tracks. Two main reasons make the route expensive: the weight of the train and the forces that occur at high speeds. The heavier the train is, the more building material is needed for the infrastructure. In addition, high-speed traffic requires wide turns to keep the centripetal acceleration for passengers within limits. Therefore, more tunnels and bridges are needed to cross the natural terrain. Finally, the combination of weight and high speed causes dynamic vibrations that need to be limited. The limitation of these vibrations is achieved by a more massive, stiffer permanent track, which in turn leads to a higher consumption of building material and CO_2 emissions.

The concept

The proposed concept is to create a high-speed cable car transportation system that combines air and ground transport by installing wings on a ground-vehicle. The system operates at high speed on a cost-effective ground infrastructure by means of electric cable cars with wings. The uplift from the air relieves the infrastructure from the gravitational force and thereby minimizes the requirements for a load bearing infrastructure. This promises a transport system that can compete with high-speed trains, at significantly lower construction costs, while at the same time offering advantages over conventional air traffic, such as lower noise pollution and the possibility of short commuting distances. By relieving the infrastructure, the use of wings allows high speeds combined with light weight ground infrastructure, so that difficult terrain can be navigated cost-effectively and the environmentally friendly public transport can be expanded.

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Utilization of the surrounding fluid called air

Airplanes have wings that generate lift when moving through the air. Once the airplane has taken off, no ground infrastructure is needed to support the weight of the airplane, as the entire weight is carried by the wings. So why not commute with airplanes all the time? For distances of less than 400-500 km, the airplane makes little sense, especially not for daily commuting. This is exactly where high-speed ground transportation comes into play. As already explained, one problem with ground transportation is the weight. A novel approach would be to connect the worlds of air and ground transportation by attaching wings to a ground vehicle. In this way, the weight is removed from the ground infrastructure, which could significantly reduce construction costs. For all ground vehicles currently known to the authors, the presence of air is a hindrance as it creates air resistance. The core of the proposed concept is to utilize the air. Such a concept might seem unusual, so we will present it in small steps.

The Track

One type of ground infrastructure that is an order of magnitude cheaper than high-speed rail, are cable cars. The reason for this is that cable cars need significantly less building material to cross natural terrain compared to high-speed railways. Cable cars can also transport large loads, but with the immediate disadvantage of large deformations. The large deformations of the cable under the load of a vehicle (gondola) passing over it limit the possible speed. One could imagine a small pedestrian cable bridge. Running over such a bridge may generate considerable dynamic vibrations, making the crossing uncomfortable and dangerous. To limit these vibrations, either the bridge has be very rigid, or the weight of the passing traffic has be low. A bridge that does not exhibit significant deformations would have to be made of steel or concrete and would therefore be much more expensive than a cable (rope) bridge. A relief of the infrastructure could therefore lead to enormous savings.

A schematic side view of the infrastructure can be seen in Figure 1, while a sketch of the rail attachment can be seen in Figure 2. All current high-speed ground transportation methods move on a fixed track. We will follow this approach and use a series of rails (1). The rails must have a solid geometry, which can be achieved by a cable support structure. We will therefore attach two tensioned steel cables (4) under each rail. Two cables per rail are needed to limit both transverse and torsional movements. The rails will then be attached to the cables with clamps and rail fastenings (2). In addition, steel plates (spacers, 3) are needed to compensate for the sagging of the cables and to keep the rails straight. The cables are laid on supports with a span of about 100 meters (based on preliminary calculations). The cables run continuously over the supports (6) and therefore only transmit vertical loads. The anchoring (5) of the cables should occur every 5-6 kilometers along the route.

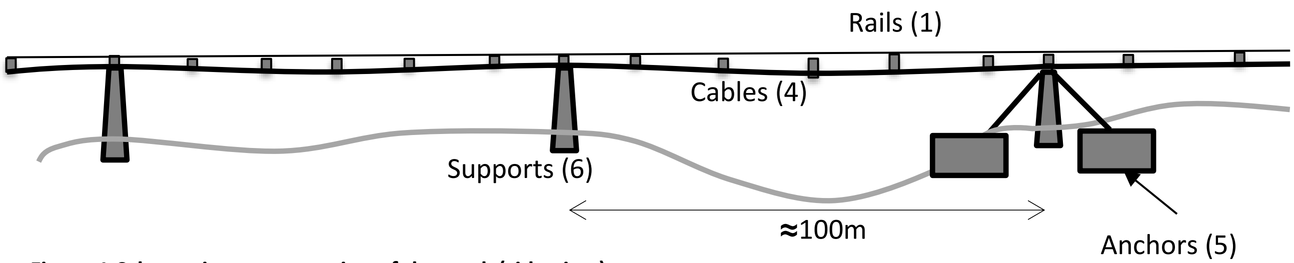

Figure 1 Schematic representation of the track (side view)

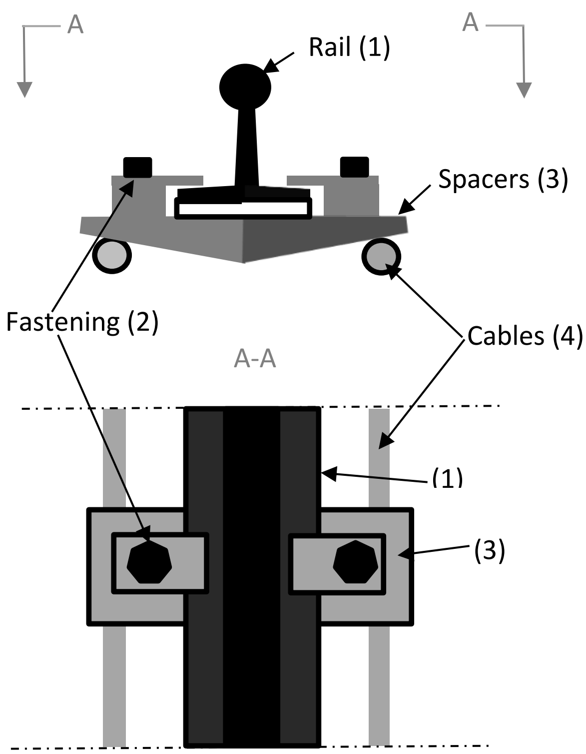

Figure 2 top: Schematic cross-section through the rail-cable attachment system; bottom: top view of the rail. Note: The rail-cable attachment system consists of two rails and four cables.

k that requires only a small amount of material compared to the material volume required for the construction of a typical high-speed track. Due to its slender design, the route can only accommodate a relatively light vehicle (maximum 6-8 tons) moving at low speeds over it. To increase the speed, we need to design a new type of vehicle.

The vehicle

Due to the easily deformable rail, the center of gravity of our vehicle should hang below the rail. This is the typical approach for cable cars, as it prevents instability of the vehicle through a rotational movement of the cables. The system always returns to a stable position, just like a pendulum does. So far, the design resembles a gondola. Gondolas can move at speeds of up to 40 km/h, but this is far from sufficient to compete with high-speed trains (200-400 km/h). The speed limit is due to the excessive vibrations that would occur at high speeds in the cable car. The vibrations are induced by the weight of the passing vehicle and are particularly pronounced when it drives over the rail supports. We need one more important change - the installation of wings on the sides of the vehicle, see Figure 3.

The uplift force in the wings should compensate for the weight of the vehicle. In this way, only an insignificant load is transferred to the cables, and the travel speed could approach that of a high-speed train.

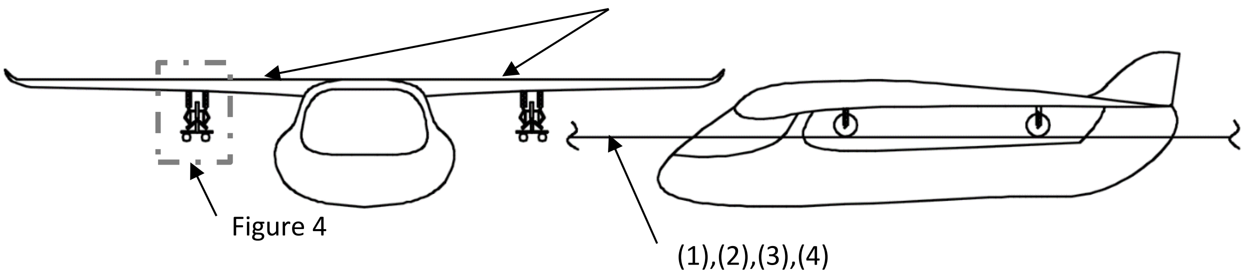

Figure 3 Schematic representation of the vehicle

The vehicle is essentially an airplane that, however, does not move forward with the help of jet engines or propellers, but rather moves along a rail self-propelled through electric motors. In this way, the significant noise and vibrations caused by typical airplane engines are avoided, while efficiency is greatly improved due to the hard contact with the rail. Furthermore, the electric drive allows for an emission-free infrastructure. Last but not least, this form of transportation can move close to the ground (unlike airplanes) because, first, the vehicle is bound to a fixed route, which can ensure the safety of the surrounding population; and second, the noise pollution can be kept very low.

The propulsion

Since the weight of the vehicle is carried by the wings, the friction between wheels (9) and rail (1) must be introduced 'artificially'. By pressing the wheels against the rails, either by a second set of wheels (8) mounted under the rails, or by a set of magnets pulling at the rails, continuous contact may be achieved. This mechanism also ensures that the vehicle remains attached to the rail. A schematic representation can be seen in Figure 4.

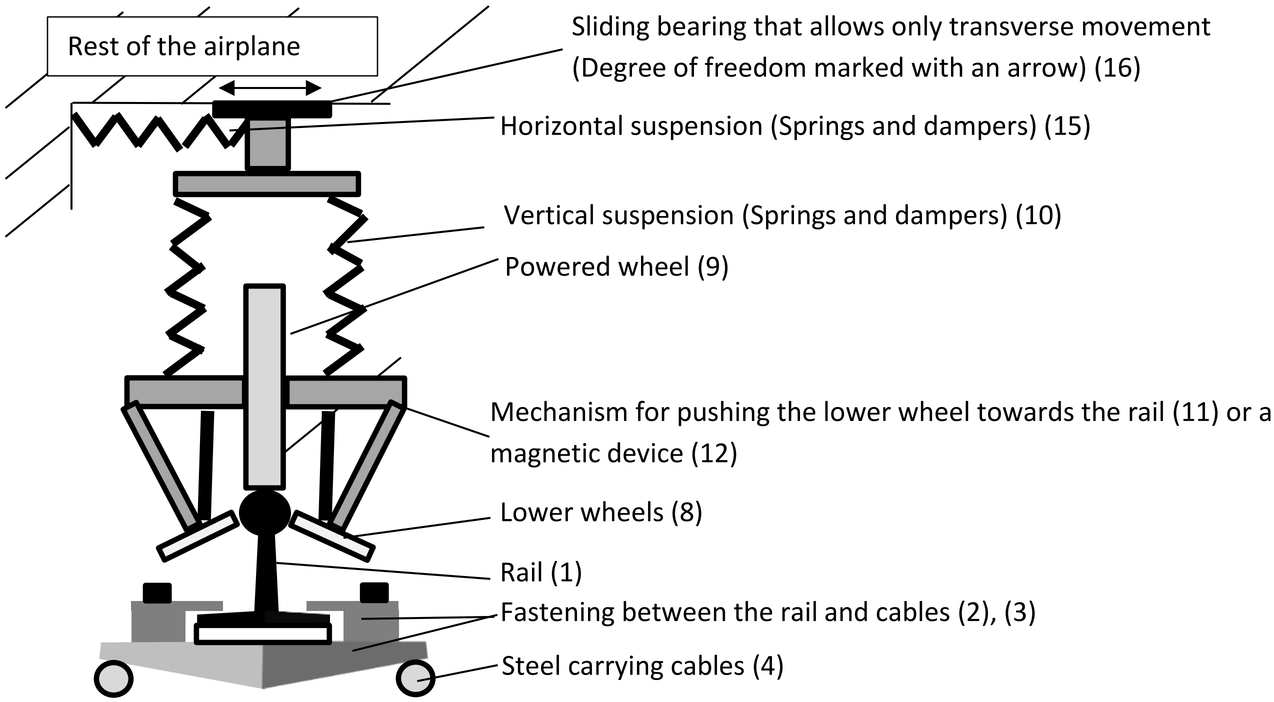

Figure 4 Schematic view of the wheel-rail contact

Another important point is that a certain travel speed must be reached for the uplift force on the wings to equalize the self-weight of the vehicle. This means the vehicle must accelerate and decelerate on a designated "runway," which can be constructed as a conventional track, either resting directly on the ground or on a rigid, elevated structure (Estacade).

This innovative cable car system features self-propelled cars that draw energy directly from the track, eliminating the need for separate power sources for individual vehicles.

Further details can be found in the Operation chapter and Figure 5.

Main challenges

Wind-induced forces on the vehicle can act in all directions and need to be compensated for. If these forces are not compensated, they will be transferred to the cable car system and may potentially generate unwanted vibrations. Therefore, the vehicle must follow an exact path. One way to achieve this is through constant corrections of the control surfaces (flaps, ailerons, rudders, stabilizers, etc.) based on the inputs of an aircraft autopilot system. The cable car system would then only have to bear the uncompensated part of the forces that result from path correction error.

The challenges here lie in understanding the combined actions of the vehicle controlled by the autopilot and the cable car system. Depending on the autopilot's ability to follow the given path, different forces will be introduced into the cable system. Environmental factors, such as wind speeds, also set operational limits that need to be taken into account. Last but not least, the stiffness of the vehicle's suspension will play an important role.

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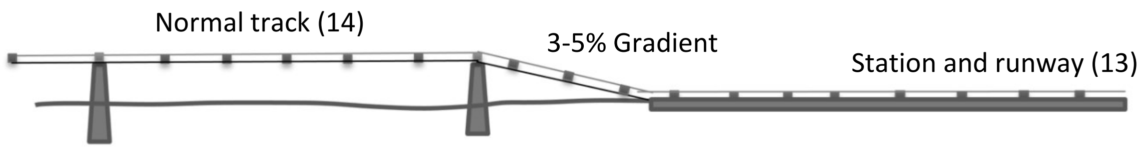

Figure 5 Station and runway

Operation

This mode of transportation is currently designed for a capacity of about 15-20 passengers. With short departure times between vehicles, it can compete with high-speed trains in connecting cities of medium size. Particularly in difficult terrains, the construction costs could be an order of magnitude lower than for high-speed trains. This means that public high-speed connections could become economically feasible for larger parts of the population. Integration into the existing rail infrastructure could be achieved by placing stations along the rail lines and/or by integrating into existing stations.

Before and after the stations, the vehicles would have to be guided on a stiff track during the acceleration and deceleration phase. These could be bridges or embankments (11) designed to carry the vehicle until the speed necessary for sufficient lift of the wings is reached. Afterwards, the transition to the "soft" track (14) takes place, i.e., to the part of the track whose rails are supported by tensioned cables. The "stiff" part (13) of the track is necessary because otherwise the vehicle cannot reach the speed at which the lift force and vehicle weight balance each other without causing strong vibrations in the cables. It is assumed that an appropriate height of the cable car above the ground is about 15-20 meters. By introducing a longitudinal gradient into the track layout, the height can be reduced in the stations, so that the runway can lie directly on the ground.

The track must be robust enough to ensure emergency braking and that the vehicles can travel along the track at low speeds. Of course, emergency braking must be limited as much as possible.

Next Steps

Significant effort is required for the construction of the vehicle, which could be referred to as a flying train. The vehicle, the drive, and the autopilot need to be developed. These items represent an important prerequisite for the feasibility of the idea. However, the real benefit comes from the significantly cheaper design of the route.

When designing the route, several load cases must be considered. The first is the stochastic load on the route, which is caused by autopilot errors. To obtain a reliable estimate of this load, extensive numerical simulations as well as experimental work on a scaled model (e.g., 1:50) would be required. Another load is the traction force of the wheels, a load moving longitudinally, the value of which roughly corresponds to the force of air resistance. The load on the cables during emergency braking must also be analysed. Wind-induced vibrations and temperature loads must also be taken into account. All these loads determine the cable diameter, the prestressing force, and the span between the supports.

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Claims

A high-speed cable car transport system is proposed combining air and ground transport by installing wings (7) on the cable cars. The system operates at high speed on a cost-effective ground infrastructure (1, 2, 3, 4). It consists of rails (1), which are carried by cables (4) at a certain height above the ground. The cables, in turn, are guided over supports (6) and anchored to the ground with cable anchors (5). This allows a slender infrastructure, that can easily transverse difficult terrain. Furthermore, it must be ensured that the rails are kept as level as possible. For this purpose, spacers (3) are used, which can compensate for the sag of the cables. The slender infrastructure is made possible by the wings (7), which are attached to the vehicles. These transfer the vertical loads due to gravity onto the surrounding air. Since there is not enough downwards load at the wheel-rail interface, the drive wheels (9) must be pressed against the rail (1) either by guide wheels (8) and a holding mechanism (11), or by a magnetic securing device (12). In this way the required traction force for the forwards movement of the cable cars can be reached. Since the 'soft' track (14) should be transversed only at high speed, there must be a runway (13) in the station area in order to reach the required speed.

Summary

The proposed concept for high-speed travel between cities leverages the surrounding air. Lift forces reduce the burden on ground infrastructure, promising significant cost savings and lower CO2 emissions compared to high-speed trains. Additionally, reducing the dynamic load on the ground infrastructure can significantly lower maintenance costs, as dynamic load is a primary factor in track wear.

This system also allows for routine travel over short distances (10-50 km), which is often not feasible with airplanes. It would be ideal for connecting medium-sized cities and traversing challenging terrain, where high-speed trains may not be economically viable or where passenger demand does not justify the high costs of train infrastructure.

By essentially coupling an airplane to a cableway system, the technological advantages are as follows:

1. **Significant cost savings in construction** – Heavy infrastructure is avoided by effectively transferring the weight of the vehicles to the surrounding fluid, commonly known as air.

2. **Energy efficiency and zero emissions** – The vehicle is powered through the track and does not need to carry its own energy source (e.g., a battery). This allows for zero-emission transport with a capacity significantly higher than some competitors, such as eVTOLs and short-haul electric airplanes.

3. **Enhanced safety and efficiency** – The cables guide the vehicle, preventing it from colliding with nearby obstacles. This enables it to "fly" at low altitudes without the need for ascents and descents, which is a significant advantage for the relatively short regional routes envisioned.

4. **Reduced noise pollution** – The presence of cables and rails enables propulsion via steel wheels, which are much quieter than propellers. As a result, this mode of transport could operate in close proximity to residential areas without causing significant noise disturbances.

Patent

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