Abstract

This paper “Driving without wheels, Flying without wings” deals with the present
scenario of magnetic levitation (maglev) with Linear induction motor (LIM). The magnetically levitated train has no wheels, but floats-- or surfs-- on an electromagnetic wave, enabling rides at 330 miles per hour. By employing no wheels, maglev eliminates the friction, and concomitant heat, associated with conventional wheel-on-rail train configurations. There are two basic types of non-contact Maglev systems Electro Dynamic Suspension (EDS), and Electro Magnetic Suspension (EMS). EDS is commonly known as "Repulsive Levitation," and EMS is commonly known as "Attractive Levitation." Each type of Maglev system requires propulsion as well as "levitation." The various projects above use different techniques for propulsion, but they are all variations of the Linear Induction Motor (LIM) or Linear Synchronous Motor (LSM). The conversion to a linear geometry has a far greater effect on induction motor performance than on that of synchronous motors. The cost of making the guideway is a high percentage of the total investment for a maglev system. The comparison looks even better for maglev when the terrain becomes difficult. Many of the tunnels, embankments, and cuttings necessary for roads and railroads are avoided because maglev guideways can be easily adapted to the topography. The Maglev system requires a slightly larger start-up capital construction cost, its operating cost-- because it deploys electricity in electromagnets in an extraordinarily efficient manner, rather than using as a fuel source coal, gas or oil-- can be one-half that of conventional rail. The crucial point is that maglev will set off a transportation and broader scientific explosion.

Key words: Magnetic levitation , Levitation , Propulsion , Linear induction motor(LIM).

Introduction:

Air flights are and will remain beyond the reach of a major section of society, particularly in India. Moreover there are problems of wastage of time in air traffic delays and
growing safety concerns. Trends in increased mobility of large masses with changing lifestyle for more comfort are leading to congestion on roads with automobiles. Besides, increasing pollution levels from automobiles, depleting fuel resources, critical dependence on the fuel import and due to a limited range of mobility of buses and cars the need for fast and reliable transportation is increasing throughout the world. High-speed rail has been the solution for many countries. Trains are fast, comfortable, and energy-efficient and magnetic levitation may be an even better solution.

Development of magnetic levitated transport systems is under progress in developed countries and it is just a matter of time they make inroads to India as well. Therefore, it will be interesting to know about the science and technology behind mass ground transport system known as "magnetic flight".

A LITTLE HISTORY

In 1922 a German engineer named Hermann Kemper recorded his first ideas for an electromagnetic levitation train. He received a patent in 1934 and one year later demonstrated the first functioning model. It wasn't until 1969, however, that a government-sponsored research project built the first full scale functioning Transrapid 01. The first passenger Maglev followed a few years later and carried people a few thousand feet at speeds up to 50 mph. The company, Munich's KraussMaffei, which built the first Transrapid, continued to build improved versions in a combined public-private research effort and completed Transrapid 02 in 1971, TR 03 in 1972 and TR 04 in 1973. The Transrapid 04 Transrapid 05 carried 50,000 visitors between parking and exhibition halls for six months.

A test center, including a 19-mile figure "eight" test track, was erected between the years of 1979 and 1987 in North Germany. Going into service with the new test facility in 1979 was the vehicle Transrapid 06. This vehicle reached a speed of 221mph shortly after the completion of the first 13-mile section of track. With the completion of the track, the TR 06 eventually achieved a speed of 256 mph, traveling some 40,000 miles before being retired in 1990. Through the continuous testing and refinements on the TR 06, it became possible to build the next generation vehicle Transrapid 07, built by the Thyssen Co. in Kassel. Since 1989, the Transrapid 07 has been the workhorse reaching the record speed of 280 mph and traveling some 248,000 miles by the end of 1996. The most significant milestone was reached in 1991 when the Transrapid system received its certification of commercial worthiness.

Principle Of Operation:

Imagine that two bar magnets are suspended one above the other with like poles (two north poles or
two south poles) directly above and below each other. Any effort to bring these two magnets into contact with each other will have to overcome the force of repulsion that exists between two like magnetic poles. The strength of that force of repulsion depends, among other things, on the strength of the magnetic field between the two bar magnets. The stronger the magnet field, the stronger the force of repulsion.

If one were to repeat this experiment using a very small, very light bar magnet as the upper member of the pair, one could imagine that the force of repulsion would be sufficient to hold the smaller magnet suspended—levitated—in air. This example illustrates the principle that the force of repulsion between the two magnets is able to keep the upper object suspended in air.

In fact, the force of repulsion between two bar magnets would be too small to produce the effect described here. In actual experiments with magnetic levitation, the phenomenon is produced by magnetic fields obtained from electromagnets. For example, imagine that a metal ring is fitted loosely around a cylindrical metal core attached to an external source of electrical current. When current flows through the core, it sets up a magnetic field within the core. That magnetic field, in turn, sets up a current in the metal ring which produces its own magnetic field. According to Lenz's law, the two magnetic fields thus produced—one in the metal core and one in the metal ring—have opposing polarities. The effect one observes in such an experiment is that the metal ring rises upward along the metal core as the two parts of the system are repelled by each other. If the current is increased to a sufficient level, the ring can actually be caused to fly upward off the core. Alternatively, the current can be adjusted so that the ring can be held in suspension at any given height with relation to the core.

**MAGNETIC LEVIATION:**

Magnetic levitation transport, or maglev, is a form of transportation that suspends, guides and propels vehicles via electromagnetic force. This method can be faster and more comfortable than wheeled mass transit systems. Maglevs could potentially reach velocities comparable to turboprop and jet aircraft (500 to 580 km/h). Since much of a Maglev's propulsion system is in the track rather than the vehicle, Maglev trains are lighter and can ascend steeper slopes than conventional trains. They can be supported on lightweight elevated tracks. Maglevs have operated commercially since 1984. However, scientific and economic limitations have hindered the proliferation of the technology.

Magnetic levitation is the use of magnetic fields to levitate a (usually) metallic object. Manipulating magnetic fields and controlling their forces can levitate an object. In this process an object is suspended above another with no other support but magnetic fields. The electromagnetic force is
used to counteract the effects of gravitation. The forces acting on an object in any combination of gravitational, electrostatic, and magnetostatic fields will make the object's position unstable. The reason a permanent magnet suspended above another magnet is unstable is because the levitated magnet will easily overturn and the force will become attractive. If the levitated magnet is rotated, the gyroscopic forces can prevent the magnet from overturning. Several possibilities exist to make levitation viable.

It is possible to levitate superconductors and other diamagnetic materials, which magnetize in the opposite sense to a magnetic field in which they are placed. A superconductor is perfectly diamagnetic which means it expels a magnetic field (Meissner-Ochsenfeld effect). Other diamagnetic materials are common place and can also be levitated in a magnetic field if it is strong enough. Diamagnetism is a very weak form of magnetism that is only exhibited in the presence of an external magnetic field. The induced magnetic moment is very small and in a direction opposite to that of the applied field. When placed between the poles of a strong electromagnet, diamagnetic materials are attracted towards regions where the magnetic field is weak. Diamagnetism can be used to levitate light pieces of pyrolytic graphite or bismuth above a moderately strong permanent magnet. As Superconductors are perfect diamagnets and when placed in an external magnetic field expel the field lines from their interiors (better than a diamagnet). The magnet is held at a fixed distance from the superconductor or vice versa. This is the principle in place behind EDS (electrodynamic suspension) maglev trains. The EDS system relies on superconducting magnets.

A maglev is a train, which is suspended in air above the track, and propelled forward using magnetism. Because of the lack of physical contact between the track and vehicle, the only friction is that between the carriages and air. So maglev trains can travel at very high speeds (650 km/h) with reasonable energy consumption and noise levels.

Due to the lack of physical contact between the track and the vehicle, the only friction exerted is that between the vehicles and the air. If it were the case that air-resistance were only a minor form of friction, it would be appropriate to say "Consequently maglevs can potentially travel at very high speeds with reasonable energy consumption and noise levels. Systems have been proposed that
operate at up to 650 km/h (404 mph), which is far faster than is practical with conventional rail transport. But this is not true. In an ordinary high speed train, most of the friction is air resistance. The power consumption per passenger-km of the Transrapid Maglev train at 200 km/h is only 24% less than the ICE at 200 km/h (22 W per seat-km, compared to 29 W per seat-km). The very high maximum speed potential of maglevs make them competitors to airline routes of 1,000 kilometers (600 miles) or less

**levitation**

Each type of Maglev system requires propulsion as well as "levitation." The various projects below use different techniques for propulsion. The first thing a maglev system must do is get off the ground, and then stay suspended off the ground. This is achieved by the electromagnetic levitation system.

Another experimental technology, which was designed, proven mathematically, peer reviewed, and patented, but is yet to be built, is the magnetodynamic suspension (MDS), which uses the attractive magnetic force of a permanent magnet array near a steel track to lift the train and hold it in place. Other technologies such as repulsive permanent magnets and superconducting magnets have seen some research.

**Electromagnetic suspension:**

In current electromagnetic suspension (EMS) systems, the train levitates above a steel rail while electromagnets, attached to the train, are oriented toward the rail from below. The system is typically arranged on a series of C-shaped arms, with the upper portion of the arm attached to the vehicle, and the lower inside edge containing the magnets. The rail is situated between the upper and lower edges.

Magnetic attraction varies with the cube of distance, so minor changes in distance between the magnets and the rail produce greatly varying forces. These changes in force are dynamically unstable - if there is a slight divergence from the optimum position, the tendency will be to exacerbate this, and complex systems of feedback control are required to maintain a train at a constant distance from the track, (approximately 15 millimeters (0.6 in)).[21][22]

The major advantage to suspended maglev systems is that they work at all speeds, unlike electrodynamic systems (see below) which only work at a minimum speed of about 30 km/h. This eliminates the need for a separate low-speed suspension system, and can simplify the track layout as a result. On the downside, the dynamic instability of the system demands high tolerances of the track, which can offset, or eliminate this advantage. Laithwaite, highly skeptical of the concept, was
concerned that in order to make a track with the required tolerances, the gap between the magnets and rail would have to be increased to the point where the magnets would be unreasonably large.

In practice, this problem was addressed through increased performance of the feedback systems, which allow the system to run with close tolerances.

The principal two systems: EMS- attractive and EDS-repulsive, respectively.

In the EMS-attractive system, the electromagnets which do the work of levitation are attached on the top side of a casing that extends below and then curves back up to the rail that is in the center of the track. The rail, which is in the shape of an inverted T, is a ferromagnetic rail. When a current is passed through it, and the electromagnet switched on, there is attraction, and the levitation electromagnets, which are below the rail, raise up to meet the rail. The car levitates. The gap between the bottom of the vehicle and the rail is only 3/8" and an electronic monitoring system, by controlling the amount of attractive force, must closely control the size of the gap.

Electrodynamic suspension

EDS Maglev Propulsion via propulsion coils
In electrodynamic suspension (EDS), both the rail and the train exert a magnetic field, and the train is levitated by the repulsive force between these magnetic fields. The magnetic field in the train is produced by either electromagnets (as in JR-Maglev) or by an array of permanent magnets (as in Inductrack). The repulsive force in the track is created by an induced magnetic field in wires or other conducting strips in the track. A major advantage of the repulsive maglev systems is that they are naturally stable - minor narrowing in distance between the track and the magnets create strong forces to repel the magnets back to their original position, while a slight increase in distance greatly reduced the force and again returns the vehicle to the right separation. No feedback control is needed.

Repulsive systems have a major downside as well. At slow speeds, the current induced in these coils and the resultant magnetic flux is not large enough to support the weight of the train. For this reason the train must have wheels or some other form of landing gear to support the train until it reaches a speed that can sustain levitation. Since a train may stop at any location, due to equipment problems for instance, the entire track must be able to support both low-speed and high-speed operation. Another downside is that the repulsive system naturally creates a field in the track in front and to the rear of the lift magnets, which act against the magnets and create a form of drag. This is generally only a concern at low speeds, at higher speeds the effect does not have time to build to its full potential and other forms of drag dominate.

The drag force can be used to the electrodynamic system's advantage, however, as it creates a varying force in the rails that can be used as a reactionary system to drive the train, without the need for a separate reaction plate, as in most linear motor systems. Laithwaite led development of such "traverse-flux" systems at his Imperial College lab. Alternately, propulsion coils on the guideway are used to exert a force on the magnets in the train and make the train move forward. The propulsion coils that exert a force on the train are effectively a linear motor: an alternating current flowing through the coils generates a continuously varying magnetic field that moves forward along the track. The frequency of the alternating current is synchronized to match the speed of the train. The offset between the field exerted by magnets on the train and the applied field creates a force moving the train forward.

In the EDS-repulsive system, the superconducting magnets (SCMs), which do the levitating of the vehicle, are at the bottom of the vehicle, but above the track. The track or roadway is either an aluminum guideway or a set of conductive coils. The magnetic field of the superconducting magnets aboard the maglev vehicle induces an eddy current in the guideway. The polarity of the eddy current is same as the polarity of the SCMs onboard the vehicle. Repulsion results, "pushing"
the vehicle away and thus up from the track. The gap between vehicle and guideway in the EDS-
system is considerably wider, at 1 to 7 inches, and is also regulated (by a null-flux system). Thus,
the guideway is not below, but out to the sides. Now the repulsion goes perpendicularly outward
from the vehicle to the coils in the guidewalls. The perpendicular repulsion still provides lift.

they are all variations of the Linear Induction Motor (LIM) or Linear Synchronous Motor (LSM).

**Choice of linear electric motor**

A linear electric motor (LEM) is a mechanism which converts electrical energy directly into linear
motion without employing any intervening rotary components. The development of one type of
LEM,

Linear synchronous motor (LSM), is illustrated in graphic form in Figure IV-1. A conventional

![Linear Synchronous Motor Diagram](image)

rotary synchronous motor (above), such as that powering an electric clock, is made up of two rings
of alternating north and south magnetic poles. The outer ring (the stator) is stationary, while the
inner one (the rotor) is free to rotate about a shaft. The polarity of the magnets on one (either) of
these rings is fixed; this element is known as the field. The magnets of the other ring, the armature,
change their polarity in response to an applied alternating current. Attractive forces between unlike
magnetic poles pull each element of the rotor toward the corresponding element of the stator. Just
as the two poles are coming into alignment, the polarity of the armature magnets is reversed,
resulting in a repulsive force that keeps the motor turning in the same direction. The armature poles
are then reversed again, and the motor turns at a constant speed in synchronism with the alternating
current which causes the change in polarity.

Linear Induction Motor (LIM) is basically a rotating squirrel cage induction motor opened out flat.
Instead of producing rotary torque from a cylindrical machine it produces linear force from a flat
one. It is not a new technology but merely design in a different form. Only the shape and the way it
produces motion is changed. But there are advantages: no moving parts, silent operation, reduced
maintenance, compact size, ease of control and installation. LIM thrusts vary from just a few to
thousands of Newtons, depending mainly on the size and rating. Speeds vary from zero to many meters per second and are determined by design and supply frequency. Speed can be controlled by either simple or complex systems. Stopping, starting, reversing, are all easy.

LEM's have long been regarded as the most promising means of propulsion for future high-speed ground transportation systems. The proposed system, while not strictly qualifying as high-speed, still derives so many advantages from the utilization of an LEM that no other propulsion means is being considered at this stage.

Within the broad range of possible LEM designs, many alternatives are available. The selection of the preferred configuration can perhaps best be understood through a discussion of the choices considered and the reasons for the rejection of the others.

1. Synchronous vs. induction motors. Far more effort has been put into research and development of linear induction motors (LIM's) than LSM's. LIM's do indeed have two distinct advantages. First of all, they are simpler and less costly to construct. The stationary element of the motor consists of nothing more than a rail or plate of a conducting material, such as aluminum. Alternating current applied to the coils of the moving electromagnets induces a fluctuating magnetic field around this conductor which provides the propulsive force. By contrast, LSM's require the installation of alternating north and south magnetic poles on both moving and stationary elements. Secondly, LIM's are self-starting, with the speed of motion being infinitely variable from zero up to the design maximum. LSM's, on the other hand, exhibit no starting torque; rotary motors of this type are generally equipped with auxiliary squirrel-cage windings so that they can act as induction motors until they reach operating speed.

LSM's possess other advantages, however, which are more than sufficient to outweigh these faults. They are far more efficient; models have been built with efficiencies of 97% or more, whereas the highest value yet attained for an LIM scarcely exceeds 70%. This is true despite the fact that rotary synchronous motors enjoy only a slight efficiency advantage over rotary induction motors; apparently the conversion to a linear geometry has a far greater effect on induction motor performance than on that of synchronous motors. Moreover, the efficiency of an LSM is relatively unaffected by the speed of travel; LIM's, on the other hand, do not reach peak efficiencies until they attain velocities which are well beyond those being considered here.

An LSM also operates at a constant speed, which depends solely on the frequency of the alternating current applied to its armature. This feature offers opportunities for absolute speed control; under normal operation, there is no way for any moving conveyance to alter its prescribed position relative to that of any other vehicle on the track. This fact imparts to any ground transportation system employing LSM's an enormously high traffic capacity, many times greater than the
maximum attainable using LIM's. The proposed system demands such a capacity if it is to fulfill its goal of providing the opportunity for individual travel from any point on the system to any other, and at any time, day or night. Reciprocally, it is this potential for carrying huge volumes of traffic, made up of both public and private vehicles and of both passengers and cargo, that can justify the extra expenditure needed for the construction of an LSM-powered system.

**Linear induction motor (LIM) in magnetic levitation**

The High Speed Surface Transport (HSST) system is propelled by linear induction motor. The HSST primary coils are attached to the carriage body and the track configuration is simple, using the steel rails and aluminum reaction plates. The HSST levitation system uses ordinary electromagnets that exerts an attractive force and levitate the vehicle. The electro-magnets are attached to the car, but are positioned facing the under side of the guide way's steel rails. They provide an attractive force from below, levitating the car.

This attractive force is controlled by a gap sensor that measures the distance between the rails and electromagnets. A control circuit continually regulates the current to the electro-magnet, ensuring that the gap remains at a fixed distance of about 8 mm, the current is decreased. This action is computer controlled at 4000 times per second to ensure the levitation.

As shown in figure, the levitation magnets and rail are both U shaped (with rail being an inverted U). The mouths of U face one another. This configuration ensures that when ever a levitational force is exerted, a lateral guidance force occurs as well. If the electromagnet starts to shift laterally from the center of the rail, the lateral guidance force is exerted in proportion to the extent of the shift, bringing the electromagnet back into alignment. The use of an electro-magnetic attractive force to both levitate and guide the car is a significant feature of HSST the system.

We can visualize an HSST linear motor as an ordinary electric induction motor that has been split open and flattened. This of linear motor has recently been used in various fields the fig illustrates in the HSST, the primary side coils of motor are attached to the car body in the secondary side reaction plates are installed along the guide way. this component acts as induction motor and ensures both propulsion and breaking force without any contact between car and guide way. This system a car mounted primary linear induction system. The ground side requires only a steel plate backed by an aluminum or copper plate, meaning that the rail source is simple.

One of the HSST's unique technical features is modules that correspond to the bogies on connectional rolling stock. Figure shows each consist primarily of a member of electromagnets for levitation guidance, a linear motor for propulsion and braking, and a hydraulic break system. The two modules on the left and right sides of the car connected beams and this unit is called levitation bogie because the levitation bogies run the entire length of the car, the load car and load on guide way are spread out and the advantages of magnetic levitation can be fully exploited.
Characteristics of LIM

In most vehicular propulsion systems, provision must be made for increasing the power when the demand increases due to acceleration, a heavier load, increased drag, headwinds, or climbing a hill. In the case of an automobile, this is done through manipulation of both the accelerator and the transmission. But all of this is accomplished automatically when an LIM is used. Whenever more power is needed, the moving magnet begins to lag further behind the stationary one; this results in an immediate increase in thrust. No separate control is needed.

Moreover, when an LIM-powered vehicle descends a steep hill or decelerates into a station, the moving motor advances to a position where it leads the stationary one. Under these conditions, the motor performance is shown in the left half of Figure. This automatically results in the production of electrical energy which is fed back into the system with a frequency and phase coherent with the line voltage. In other words, LIM's are automatically regenerative.

REQUIREMENTS OF AN URBAN MAGLEV

A thorough requirements document should be prepared during the initial stage of the program. This document creates a common set of guidelines, which is intended to keep the design team focused during the design/development process. Included are requirements for the system and major subsystems to assure the performance, ride comfort and safety of the passengers.
cost of propulsion coils could be prohibitive, a propeller or jet engine could be used.

**Stability**

Earnshaw's theorem shows that any combination of static magnets cannot be in a stable equilibrium.[29] However, the various levitation systems achieve stable levitation by violating the assumptions of Earnshaw's theorem. Earnshaw's theorem assumes that the magnets are static and unchanging in field strength and that the relative permeability is constant and greater than 1 everywhere. EMS systems rely on active electronic stabilization. Such systems constantly measure the bearing distance and adjust the electromagnet current accordingly. All EDS systems are moving systems (no EDS system can levitate the train unless it is in motion).

Because Maglev vehicles essentially fly, stabilisation of pitch, roll and yaw is required by magnetic technology. In addition translations, surge (forward and backward motions), sway (sideways motion) or heave (up and down motions) can be problematic with some technologies.

**POWER AND ENERGY USAGE**

Power for maglev trains is used to accelerate the train, and may be produced when the train slowed ("regenerative braking"), it is also usually used to make the train fly, and to stabilise the flight of the train, for air conditioning, heating, lighting and other miscellaneous systems. Power is also needed to force the train through the air ("air drag").

At low speeds the levitation power can be significant, but at high speeds, the total time spent levitating to travel each mile is greatly reduced, giving reduced energy use per mile, but the air drag energy increases with the speed-squared, and hence at high speed dominates.

**Benefits of Magnetic Levitated Transportation system:**

* Unlike conventional transportation systems in which a vehicle has to carry the total power needed for the most demanding sections, the power of the maglev motor is dependent on the local conditions such as flat or uphill grades.

* Maglev uses 30% less energy than a high-speed train traveling at the same speed (1/3 more power for the same amount of energy).

* The operating costs of a maglev system are approximately half that of conventional long-distance railroads.

* Research has shown that the maglev is about 20 times safer than airplanes, 250 times safer than conventional railroads, and 700 times safer than automobile travel.
* Despite the speeds up to 500 km/hour, passengers can move about freely in the vehicles at all times.

* Maglev vehicle carries no fuel to increase fire hazard

* The materials used to construct maglev vehicles are non-combustible, poor transmitters of heat, and able to withstand fire penetration.

* In the unlikely event that a fire and power loss occurred simultaneously, the vehicle is automatically slowed down so that it stops at a predefined emergency power station.

* A collision between two maglev trains is nearly impossible because the linear induction motors prevent trains running in opposite directions or different speeds within the same power section.

**Current Projects:**

Germany and Japan have been the pioneering countries in MagLev research. Currently operational systems include Transrapid (Germany) and High Speed Surface Transport (Japan). There are several other projects under scrutiny such as the SwissMetro, Seraphim and Inductrack. All have to do with personal rapid transit.

**Other Applications:**

NASA plans to use magnetic levitation for launching of space vehicles into low earth orbit. Boeing is pursuing research in MagLev to provide a Hypersonic Ground Test Facility for the Air Force. The mining industry will also benefit from MagLev. There are probably many more undiscovered applications

**Boones and Banes:**

**BOONS:**

Maintenance: Because the train floats along there is no contact with the ground and therefore no need for any moving parts. As a result there are no components that would wear out. This means in theory trains and track would need no maintenance at all.

Friction: Because maglev trains float, there is no friction. Note that there will still be air resistance

Less noise: because there are no wheels running along there is no wheel noise. However noise due to air disturbance still occurs.

Speed: As a result of the three previous listed it is more viable for maglev trains to travel extremely fast, i.e. 500km/h or 300mph
BANES:

1. Maglev guide paths are bound to be more costly than conventional steel railways.

2. The other main disadvantage is lack with existing infrastructure. For example if a high speed line between two cities it built, then high speed trains can serve both cities but more importantly they can serve other nearby cities by running on normal railways that branch off the high speed line. The high speed trains could go for a fast run on the high speed line, and then come off it for the rest of the journey. Maglev trains wouldn't be able to do that; they would be limited to where maglev lines run. This would mean it would be very difficult to make construction of maglev lines commercially viable unless there were two very large destinations being connected. The fact that a maglev train will not be able to continue beyond its track may seriously hinder its usefulness.

COMPARISION:

Compared to conventional trains

Major comparative differences between the two technologies lie in backward-compatibility, rolling resistance, weight, noise, design constraints, and control systems.

Backwards Compatibility Maglev trains currently in operation are not compatible with conventional track, and therefore require all new infrastructure for their entire route. By contrast conventional high speed trains such as the TGV are able to run at reduced speeds on existing rail infrastructure, thus reducing expenditure where new infrastructure would be particularly expensive (such as the final approaches to city terminals), or on extensions where traffic does not justify new infrastructure.

Efficiency Due to the lack of physical contact between the track and the vehicle, maglev trains experience no rolling resistance, leaving only air resistance and electromagnetic drag, potentially improving power efficiency.[32]

Weight The weight of the large electromagnets in many EMS and EDS designs is a major design
issue. A very strong magnetic field is required to levitate a massive train. For this reason one research path is using superconductors to improve the efficiency of the electromagnets, and the energy cost of maintaining the field.

**Noise.** Because the major source of noise of a maglev train comes from displaced air, maglev trains produce less noise than a conventional train at equivalent speeds. However, the psychoacoustic profile of the maglev may reduce this benefit: A study concluded that maglev noise should be rated like road traffic while conventional trains have a 5-10 dB "bonus" as they are found less annoying at the same loudness level.[33][34]

**Design** Comparisons Braking and overhead wire wear have caused problems for the Fastech 360 railed Shinkansen. Maglev would eliminate these issues. Magnet reliability at higher temperatures is a countervailing comparative disadvantage (see suspension types), but new alloys and manufacturing techniques have resulted in magnets that maintain their levitational force at higher temperatures.

As with many technologies, advances in linear motor design have addressed the limitations noted in early maglev systems. As linear motors must fit within or straddle their track over the full length of the train, track design for some EDS and EMS maglev systems is challenging for anything other than point-to-point services. Curves must be gentle, while switches are very long and need care to avoid breaks in current. An SPM maglev system, in which the vehicle permanently levitated over the tracks, can instantaneously switch tracks using electronic controls, with no moving parts in the track. A prototype SPM maglev train has also navigated curves with radius equal to the length of the train itself, which indicates that a full-scale train should be able to navigate curves with the same or narrower radius as a conventional train.

Control Systems EMS Maglev needs very fast-responding control systems to maintain a stable height above the track; this needs careful design in the event of a failure in order to avoid crashing into the track during a power fluctuation. Other maglev systems do not necessarily have this problem. For example, SPM maglev systems have a stable levitation gap of several centimeters.

**Compared to aircraft**

For many systems, it is possible to define a lift-to-drag ratio. For maglev systems these ratios can exceed that of aircraft (for example Inductrack can approach 200:1 at high speed, far higher than any aircraft). This can make maglev more efficient per kilometre. However, at high cruising speeds, aerodynamic drag is much larger than lift-induced drag. Jet transport aircraft take advantage of low air density at high altitudes to significantly reduce drag during cruise, hence despite their lift-to-drag ratio disadvantage, they can travel more efficiently at high speeds than maglev trains that
operate at sea level (this has been proposed to be fixed by the vactrain concept). Aircraft are also more flexible and can service more destinations with provision of suitable airport facilities.

Unlike airplanes, maglev trains are powered by electricity and thus need not carry fuel. Aircraft fuel is a significant danger during takeoff and landing accidents. Also, electric trains emit little carbon dioxide emissions, especially when powered by nuclear or renewable sources.

Conclusion

The MagLev Train: Research on this ‘dream train’ has been going on for the last 30 odd years in various parts of the world. The chief advantages of this type of train are: 1. Non-contact and non-wearing propulsion, independent of friction, no mechanical components like wheel, axle. Maintenance costs decrease. Low noise emission and vibrations at all speeds (again due to non-contact nature). Low specific energy consumption. Faster turnaround times, which means fewer vehicles. All in all, low operating costs. Speeds of up to 500kmph. Low pollutant emissions. Hence environmentally friendly.

The MagLev offers a cheap, efficient alternative to the current rail system. A country like India could benefit very much if this were implemented here. Further possible applications need to be explored.