

Use of Maglev as Sustainable Development

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ABSTRACT- Maglev is a completely new mode of transport that will join the ship, the wheel, and the airplane as a mainstay in moving people and goods throughout the world. Maglev has unique advantages over these earlier modes of transport and will radically transform society and the world economy in the 21st Century. Compared to ships and wheeled vehicles—autos, trucks, and trains—it moves passengers and freight at much higher speed and lower cost, using less energy. Compared to airplanes, which travel at similar speeds, Maglev moves passengers and freight at much lower cost, and in much greater volume. In Maglev—which is short for MAGnetic LEVitation—high speed vehicles are lifted by magnetic repulsion, and propelled along an elevated guide way by powerful magnets attached to the vehicle. The vehicles do not physically contact the guide way, do not need engines, and do not burn fuel. Instead, they are magnetically propelled by electric power fed to coils located on the guide way. Our topic covers the detailed knowledge of its construction. Working principle, its significances in today's world sustainable development

I. INTRODUCTION

Magnetic levitation is the latest in transportation technology and has been the interest of many countries around the world. The idea has been around since 1904 when Robert Goddard, an American Rocket scientist, created a theory that trains could be lifted off the tracks by the use of electromagnetic rails. Many assumptions and ideas were brought about throughout the following years, but it was not until the 1970's that Japan and Germany showed interest in it and began researching and designing.

The motion of the Maglev train is based purely on magnetism and magnetic fields. This magnetic field is produced by using high-powered electromagnets. By using magnetic fields, the Maglev train can be levitated above its track, or guideway, and propelled forward. Wheels, contact with the track, and moving parts are eliminated on the Maglev train, allowing the Maglev train to essentially move on air without friction.

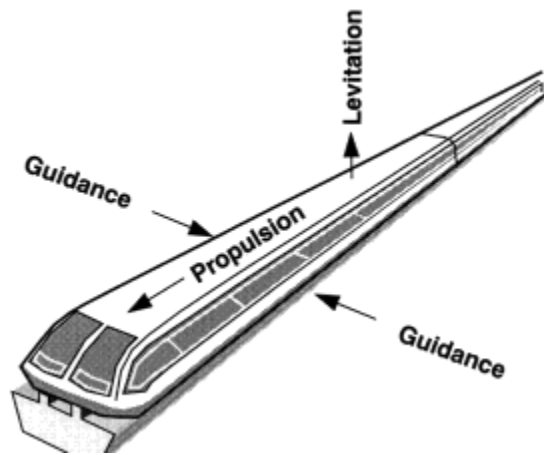


FIGURE [1]

I. BASIC PRINCIPLE OF MAGLEV TRAIN

Maglev can be used for both low and high speed transportation. The low speed Maglev is used for short distance travel. Birmingham, England used this low speed transportation between the years of 1984 and 1995. However, engineers are more interested in creating the high-speed Maglev vehicles. The higher speed vehicle can travel at speeds of nearly 343mph or 552 km/h. Magnetic Levitation mainly uses two different types of suspension, which are Electromagnetic Suspension and Electrodynamic Suspension. However, a third suspension system (Intuctrack) has recently been developed and is in the research and design phase. These suspension systems are what keep the train levitated off the track.

II. PROPULSION SYSTEM

Electrodynamic Propulsion is the basis of the movement in a Maglev system. The basic principle that electromagnetic propulsion follows is that “opposite poles attract each other and like poles repel each other”. This meaning

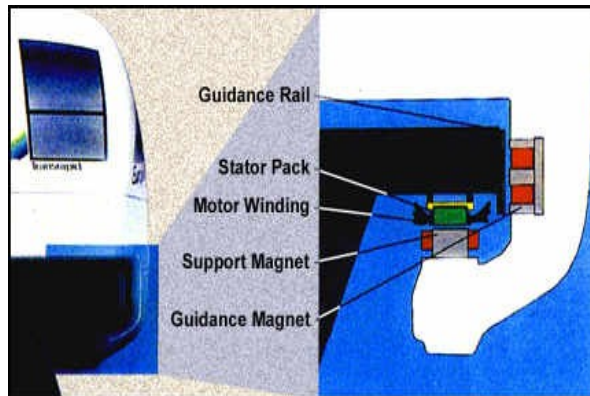
that the north pole of a magnet will repel the north pole of a magnet while it attracts the south pole of a magnet. Likewise, the south pole of a magnet will attract the north pole and repel the south pole of a magnet. It is important to realize these three major components of this propulsion system. They are:

- A large electrical power source
- Metal coils that line the entire guideway
- Guidance magnets used for alignment

The Maglev system does not run by using a conventional engine or fossil fuels. The interaction between the electromagnets and guideway is the actual motor of the Maglev system. To understand how Maglev works without a motor, we will first introduce the basics of a traditional motor. A motor normally has two main parts, a stator and a rotor. The outer part of the motor is stationary and is called the stator. The stator contains the primary windings of the motor. The polarity in the stator is able to rapidly change from north and south. The inner part of the motor is known as the rotor, which rotates because of the outer stator. The secondary windings are located within the rotor. A current is applied to the secondary windings of the rotor from a voltage in the stator that is caused by a magnetic force in the primary windings. As a result, the rotor is able to rotate.

Now that we have an understanding of how motors work, we can describe how Maglev uses a variation on the basic ideas of a motor. Although not an actual motor, the Maglev’s propulsion system uses an electric synchronous motor or a linear synchronous motor. The Maglev system works in the same general way the compact motor does, except it is linear, “meaning it is stretched as far as the track goes”. The stators of the Maglev system are usually in the guiderails, whereas the rotors are located within the electromagnetic system on the train. The sections of track that contain the stators are known as stator packs. This linear motor is essential to any Maglev

system. The picture below gives an idea of where the stator pack and motor windings are located.



FIGURE[2]

- PARTS OF THE ELECTROMAGNETIC SYSTEM

- The guideway for Maglev systems is made up of magnetized coils, for both levitation and propulsion, and the stator packs. “An alternating current is then produced, from the large power source, and passes through the guideway, creating an electromagnetic field which travels down the rails”. As defined by the Encarta Online dictionary, an alternating current is “a current that reverses direction.” The strength of this current can be made much greater than the normal strength of a magnet by increasing the number of winds in the coils. The current in the guideway must be alternating so the polarity in the magnetized coils can change. The alternating current allows a pull from the magnetic field in front of the train, and a push from the magnetic field behind the train. This push and pull motion work together allowing the train to reach maximum velocities well over 300 miles per hour.



FIGURE[3]

PROPULSION SYSTEM IN EDS

This propulsion is unique in that the current is able to be turned on and off quickly.

Therefore, at one instance there can be a positive charge running through a section of the track, and within a second it could have a neutral charge. This is the basic principle behind slowing the vehicle down and breaking it. The current through the guiderails is reversed causing the train to slow, and eventually to completely stop. Additionally, by reversing the current, the train would go in the reverse direction. This propulsion system gives the train enough power to accelerate and decelerate fairly quickly, allowing the train to easily climb steep hills.

The levitation, guidance, and propulsion of the electromagnetic suspension system must work together in order for the Maglev train to move. All of the magnetic forces are computer controlled to provide a safe and hazard free ride. The propulsion system works hand in hand with the suspension system on the Maglev system.

III. MAGNETIC LEVITATION SYSTEM

Magnetic levitation means “to rise and float in air”. The Maglev system is made possible by the use of electromagnets and magnetic fields. The basic principle behind Maglev is that if you put two magnets together in a certain way there will be a strong magnetic attraction and the two magnets will clamp together. This is called "attraction". If one of those magnets is flipped over then there will be a strong magnetic repulsion and the magnets will push each other apart. This is called "repulsion". Now imagine a long line of magnets alternatively placed along a track. And a line of alternatively placed magnets on the bottom of the train. If these magnets are properly controlled the trains will lift off the ground by the magnetic repulsion or magnetic attraction. On the basis of this principle, Magnetic

Levitation is broken into two main types of suspension or levitation,

1. Electromagnetic Suspension.

2. Electrodynamic Suspension.

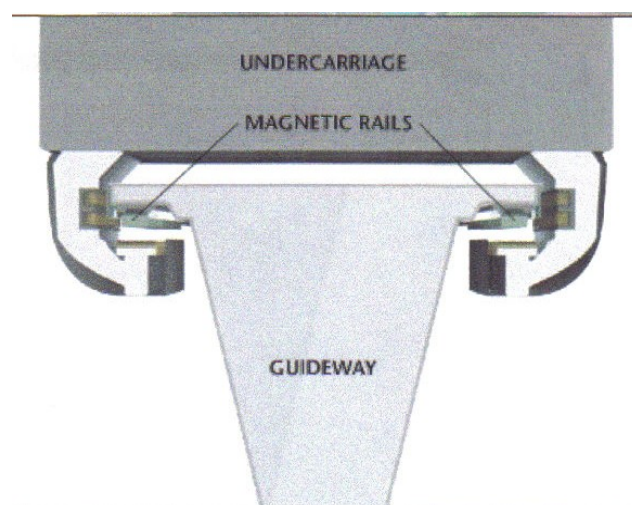
A third type of levitation, known as Inductrack, is also being developed in the United States.

IV. ELECTROMAGNETIC SUSPENSION SYSTEM(EMS)

Electromagnetic Suspension or EMS is the first of the two main types of suspension used with Maglev. This suspension uses conventional electromagnets located on structures attached to the underside of the train; these structures then wrap around a T-shaped guiderail. This guiderail is ferromagnetic, meaning it is made up of such metals as iron, nickel, and cobalt, and has very high magnetic permeability. The magnets on the train are then attracted towards this ferromagnetic guiderail when a “current runs through the guiderail and the electromagnets of the train are turned on”. This attraction lifts the car allowing it to levitate and move with a frictionless ride. “Vehicle levitation is analyzed via on board computer control units that sample and adjust the magnetic force of a series of onboard electromagnets as they are attracted to the guideway”.

The small distance of about 10mm needs to be constantly monitored in order to avoid contact between the train’s rails and the guiderail. This distance is also monitored by computers, which will automatically adjust the strength of the magnetic force to bring this distance back to around 10mm, if needed. This small elevation distance and the constant need

for monitoring the Electromagnetic Suspension System is one of its major downfalls.



• FIGURE[4]

CROSS SECTION OF ELECTROMAGNETIC SUSPENSION SYSTEM

The train also needs a way to stay centered above the guideway. To do this, guidance coils and sensors are placed on each side of the train’s structures to keep it centered at all points during its ride, including turns. Again, the gap should be around 10mm, so computers are used to control the current running through the guidance magnets and keep the gap steady. In addition to guidance, these magnets also allow the train to tilt, pitch, and roll during turns. To keep all distances regulated during the ride, the magnets work together with sensors to keep the train centered. However, the guidance magnets and levitation magnets work independently.

There are several advantages to this system. First, the train interlocks with the guiderail making it impossible to derail. Noise is extremely limited with this system because there is no contact between the train and its track. In

addition, there aren't many moving parts, which reduces the noise and maintenance of the system. With fewer parts, there is less wear and tear on the system. The Maglev train is also able to travel on "steep gradients and tight curves". Figure [4] shows the metal beams which attach to the underside of the train. An example of Electromagnetic Suspension is shown in Figure [5] below. Before a Maglev system can be made, a choice must be made between using this type of suspension or Electrodynamic Suspension.



- FIGURE [5]

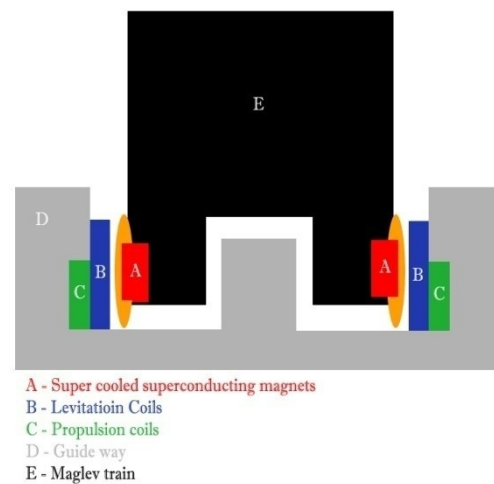
PHOTOGRAPH OF MALEV TRAIN(EMS)

V. ELECTRODYNAMIC SUSPENSION SYSTEM

The second of the two main types of suspension systems in use is the Electrodynamic Suspension (EDS). EDS uses superconducting magnets (SCM) located on the bottom of the train to levitate it off of the track. By using super cooled superconducting magnets, the electrical resistance in superconductors allows current to flow better and creates a greater magnetic field. The downside to using an EDS system is that it requires the SCMs

to be at very cold temperatures, usually around 5 K (-268°C) to get the best results and the least resistance in the coils. The Japanese Maglev, which is based on an EDS system, uses a cooling system of liquid nitrogen and helium.

To understand what's really going on here, let's start from the inside out. The first major difference between EDS and EMS is the type of track. Whereas with EMS the bottom of the train hooks around the edges of the track, an EDS train literally floats on air, as shown in the figure [6].



- FIGURE [6]

THE ELECTRODYNAMIC SUSPENSION SYSTEM

The outside guides act like the cushions used to prevent gutter balls in bowling only an EDS train has a magnetic safety net to keep the train centered, unlike your traditional bowling ally. If the train is knocked in the horizontal direction, the field on the side it shifts to becomes greater and the field on the opposite side weakens due to this increase in distance. Therefore, in order to restore equal magnetic forces from each side, the train is pushed back into the center of the guideway and the strength of the magnetic fields reduces to their normal strength. This is one reason why EDS is a much more stable suspension system. A second reason why the Electrodynamic Suspension system

is more stable is that it is able to carry a much heavier weight load without having its levitation greatly affected. As the gap between the train and vehicle decreases, forces between the SCMs located on the train and the magnets on the track repel each other and increase as the train gets heavier. For example, if weight is added to the train, it is going to want to get closer to the track; however it cannot do so because repulsion forces grow stronger as the poles on the train sink closer to the similar poles on the guideway. The repulsive forces between the magnets and coils lift the train, on average, about 4 to 6 inches above the track, which virtually eliminates any safety issues regarding the train losing levitation and hitting its guideway. This brings us to the next thing we encounter as we move out from the center of the guideway. Levitation coils repel the SCMs underneath the train, providing the restoring forces to keep the train aligned.

Propulsion coils are located next. The propulsion system of the Electrodynamic Suspension system is quite similar to Electromagnetic propulsion, but does vary slightly. To propel the train, the guideway has coils running along the top and bottom of the SCMs. Induced current within these coils creates alternating magnetic fields that attract or repel the SCMs, sending the train in the forward or reverse direction. Because the trains are moving by magnetic waves that push and pull it forward, it's virtually impossible for trains to collide since they are in essence "riding the same magnetic waves".

No engine or other power source is required to keep the train moving except the initial speed that is required to begin levitation. Therefore wheels are required to keep the train moving until about 100 km/hr (65 mph) where it can then begin to levitate.

Finally, the guideway has rails that encompass the outside of the train. Within these rails are the propulsion coils and levitation coils needed to keep the train moving and levitating above the bottom of the track. Because the train has

its own safety net of magnetic force to keep it centered, the rails simply provide a place for other coils to be located and used. This railway provides no other means of support for the train since the bulk of the train is floating above the entire track.



FIGURE[7]
NEW LEADING JAPANESE EDS CAR,
MLX01-901

EDS suspension has several positive and negative aspects to it. To begin, initial costs are high and most countries do not have the money or feel the need to spend it on this kind of transportation. Once up and running however, an EDS Maglev runs only on electricity so there is no need for other fuels. This reduction in fuel will prove to be very important to the sustainability of Maglev. One huge disadvantage of the EDS system is the great cost and inconvenience of having to keep the super cooled superconductive magnets at 5K. Another drawback is that in the event of a power failure, a Maglev train using EDS would slam onto the track at great speeds. This is a second reason for the wheels that are primarily used to get the train moving quickly enough for levitation. The wheels would need to have a shock system designed to compensate for the weight of the car and its passengers as the train falls to the track. In Japan, where EDS Maglev is in its testing stage, trains average about 300 km/hr and have been clocked at 552 km/hr, which is a world record for rail speed. Compared to Amtrak trains in the United States, which travel at an average of 130 km/hr, Maglev can get people where they need in

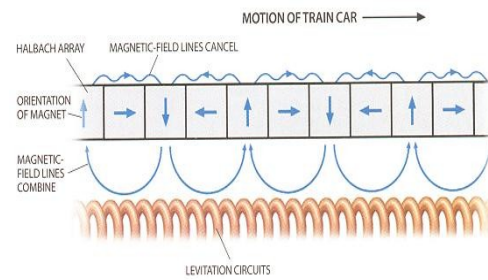
about half of the time. The EMS and EDS suspension systems are the two main systems in use, but there is a possibility for a third to soon join the pack.

VI. NEW TRACK IN THE RUNNING

Engineers are constantly trying to improve on previous technology. Within the past few years the United States has been developing a newer style of Maglev called the Inductrack, which is similar to the EDS system. This system is being developed by *Dr. Richard Post* at the Lawrence Livermore National Laboratory. The major difference between the Inductrack and the Electrodynamic System is the use of permanent magnets rather than superconducting magnets.

This system uses an “arrangement of powerful permanent magnets, known as a Halbach array, to create the levitating force”. The Halbach array uses high field alloy magnetic bars. These bars are arranged so the magnetic fields of the bars are at 90° angles to the bars on either side, which causes a high powered magnetic field below the array.

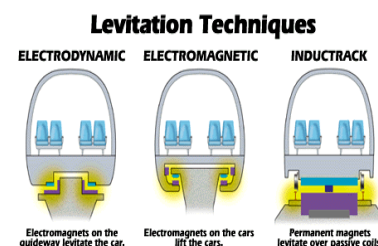
The Inductrack is similar to that of the EDS system in that it uses repulsive forces. The magnetic field of the Halbach array on the train repels the magnetic field of the moving Halbach array in the guideway. The rails in the system are slightly different. The guideway is made from “two rows of tightly packed levitation coils”. The train itself has two Halbach arrays; one above the coils for levitation and the other for guidance. As with the EMS and EDS system, the Inductrack uses a linear synchronous motor. Below is a picture of the Halbach array and a model of the Inductrack system.



• FIGURE [8]
MODEL OF THE INDUCTRACK

A major benefit of this track is that even if a power failure occurs, the train can continue to levitate because of the use of permanent magnets. As a result, the train is able to slow to a stop during instances of power failure. In addition, the train is able to levitate without any power source involved. The only power needed for this system is for the linear synchronous motor and “the only power loss that occurs in this system is from aerodynamic drag and electrical resistance in the levitation circuits”.

Although this type of track is looking to be used, it has only been tested once on a 20-meter track. NASA is working together with the Inductrack team to build a larger test model of 100 meters in length. This testing could eventually lead to a “workable Maglev system for the future”. The Inductrack system could also be used for the launching of NASA’s space shuttles. The following picture displays side by side all three types of levitation systems.

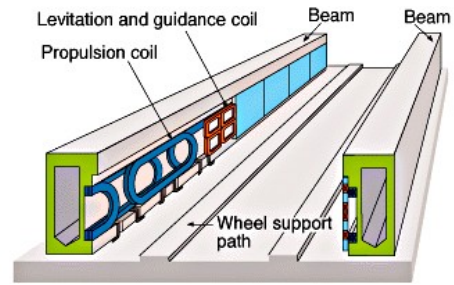


- FIGURE [9]
 - IMAGE OF THREE TYPES OF LEVITATION TECHNIQUES

VII. LATERAL GUIDANCE SYSTEMS

The Lateral guidance systems control the train's ability to actually stay on the track. It stabilized the movement of the train from moving left and right of the train track by using the system of electromagnets found in the undercarriage of the MagLev train. The placement of the electromagnets in conjunction with a computer control system ensures that the train does not deviate more than 10mm from the actual train tracks.

The lateral guidance system used in the Japanese electrodynamic suspension system is able to use one "set of four superconducting magnets" to control lateral guidance from the magnetic propulsion of the null flux coils located on the guideways of the track as shown in Fig.[10]. Coils are used frequently in the design of MagLev trains because the magnetic fields created are perpendicular to the electric current, thus making the magnetic fields stronger. The Japanese Lateral Guidance system also uses a semi-active suspension system. This system dampens the effect of the side to side vibrations of the train car and allows for more comfortable train rides. This stable lateral motion caused from the magnetic propulsion is a joint operation from the acceleration sensor, control device, to the actual air spring that dampens the lateral motion of the train car.



- FIGURE [10]

A SKETCH OF THE COMBINED LEVITATION, PROPULSION AND GUIDANCE SYSTEM

The lateral guidance system found in the German transrapid system(EMS) is similar to the Japanese model. In a combination of attraction and repulsion, the MagLev train is able to remain centered on the railway. Once again levitation coils are used to control lateral movement in the German MagLev suspension system. The levitation coils are connected on both sides of the guideway and have opposite poles. The opposites poles of the guideway cause a repulsive force on one side of the train while creating an attractive force on the other side of the train. The location of the electromagnets on the Transrapid system is located in a different side of the guideways. To obtain electro magnetic suspension, the Transrapid system uses "the attractive forces between iron-core electromagnets and ferromagnetic rails." In addition to guidance, these magnets also allow the train to tilt, pitch, and roll during turns. To keep all distances regulated during the ride, the magnets work together with sensors to keep the train centered.

VIII. ADVANTAGES OF MAGLEV

A. Magnetic Fields

- Intensity of magnetic field effects of Maglev is extremely low (below everyday household devices)

- Hair dryer, toaster, or sewing machine produce stronger magnetic fields

B. Energy Consumption

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

Speed	ICE Train	Maglev Train
200 km/hr	32 Wh/km	32 Wh/km
250 km/hr	44 Wh/km	37 Wh/km
300 km/hr	71 Wh/km	47 Wh/km
400 km/hr	-	71 Wh/km

C. Noise Levels

- No noise caused by wheel rolling or engine
- Maglev noise is lost among general ambient noise
- At 100m - Maglev produces noise at 69 dB
- At 100m - Typical city center road traffic is 80 dB

D. Vibrations

- Just below human threshold of perception

E. Power Supply

- 110kV lines fed separately via two substations

F. Power Failure

- Batteries on board automatically are activated to bring car to next station
- Batteries charged continuously

G. Fire Resistance of vehicles

- Latest non-PVC material used that is non-combustible and poor transmitter of heat
- Maglev vehicle carries no fuel to increase fire hazard

H. Safety

- 20 times safer than an airplane
- 250 times safer than other conventional railways
- 700 times safer than travel by road
- Collision is impossible because only sections of the track are activated as needed. The vehicles always travel in synchronization and at the same speed, further reducing the chances of a crash.

I. Operation Costs

- Virtually no wear. Main cause of mechanical wear is friction. Magnetic Levitation requires no contact, and hence no friction.
- Components normally subjected to mechanical wear are on the whole replaced by electronic components which do not suffer any wear
- Specific energy consumption is less than all other comparable means of transportation.
- Faster train turnaround time means fewer vehicles

IX. LIMITATIONS OF MAGLEV

There are several disadvantages with maglev trains. Maglev guide paths are bound to be more costly than conventional steel railways. 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, 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. Of the 5000km that TGV trains serve in France, only about 1200km is high speed line, meaning 75% of TGV services run on existing track. The fact that a maglev train will not be able to continue beyond its track may seriously hinder its usefulness.

A possible solution

Although it is not seen anywhere a solution could be to put normal steel wheels onto the bottom of a maglev train, which would allow it to run on normal railway once it was off the floating guideway.

X. CONCLUSION

Railways using MagLev technology are on the horizon. They have proven to be faster than traditional railway systems that use metal wheels and rails and are slowed by friction. The low maintenance of the MagLev is an advantage that should not be taken lightly. When you don't have to deal with the wear and tear of contact friction you gain greater longevity of the vehicle. Energy saved by not using motors running on fossil fuels allow more energy efficiency and environmental friendliness.

Maglev will have a positive impact on sustainability. Using superconducting magnets instead of fossil fuels, it will not emit greenhouse gases into the atmosphere. Energy created by magnetic fields can be easily replenished. The track of a Maglev train is small compared to those of a conventional train and are elevated above the ground so the track itself will not have a large effect on the topography of a region. Since a Maglev train levitates above the track, it will experience no mechanical wear and thus will require very little maintenance.

Overall, the sustainability of Maglev is very positive. Although the relative costs of constructing Maglev trains are still expensive, there are many other positive factors that overshadow this. Maglev will contribute more to our society and our planet than it takes away. Considering everything Maglev has to offer, the transportation of our future and our children's future is on very capable tracks.

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