THYSSENKRUPP TRANSRAPID AUSTRALIA

ThyssenKrupp

Our reference:082147 10 July, 2008

East-West Transport Options Review
Department of Infrastructure
GPO Box 2797
Melbourne VIC 3000

Dear Sirs,

SUBMISSION IN RESPONSE TO THE EAST WEST LINK NEEDS ASSESSMENT REPORT

Please find attached the submission of ThyssenKrupp Transrapid Australia in response to Sir Ron Eddington's report, *Investing in Transport*, on the East West Link Needs Assessment.

We submit that an above ground high capacity, high speed public transport system using magnetic levitation (Maglev) technology should be considered as an alternative to the proposed 17km rail tunnel proposed in the report. While an extremely expensive tunnel would be required to protect the Melbourne environment from the dirt, noise and vibration of a wheel on track train system, a quiet, fast and clean above ground Maglev system would actually enhance the city's image.

For the estimated cost of the proposed rail tunnel, a high speed Maglev express network can be provided linking Frankston, Cranbourne, Dandenong, Caulfield, CBD, Footscray and Sunshine to Tullamarine Airport and further linking Geelong, Avalon Airport and Werribee. This network should be considered as an alternative to the proposed 17km Melbourne Metro rail tunnel as the solution to provide a seamless SE-NW public fast transport corridor.

In meeting its transport challenge in the 21st century, we believe that the Government should be looking towards the transport technologies of the future, rather than the underground rail concepts of the 19th century.

ThyssenKrupp Transrapid Australia would be pleased to provide documentation to support its submission and hopes to have the opportunity to discuss these matters with you.

Yours sincerely,

Peter Hatcher
General Manager

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THYSSENKRUPP TRANSRAPID AUSTRALIA SUBMISSION
IN RESPOSE TO EAST WEST LINK NEEDS ASSESSMENT REPORT
INVESTING IN TRANSPORT

1. GENERAL INTRODUCTION

This submission is made by ThyssenKrupp Transrapid Australia (TKTA), which represents ThyssenKrupp Transrapid in Australia. Transrapid is a highly advanced high speed public transport system developed, owned and guaranteed by Siemens and ThyssenKrupp of Germany.

The need identified in Recommendation 1 of the *Investing In Transport* report for a modern public transport link between Melbourne's booming western and south-eastern suburbs is irrefutable, but TKTA submits that the report is too narrowly focussed on conventional rail technology – the technology of the 19th and 20th centuries. Maglev, the public transport technology for the 21st century, offers considerable benefits over Metro-style rail in almost every aspect, including particularly:

- Capital cost
- Operating cost
- Customer appeal
- Safety
- Speed
- Environmental impact

The *Investing In Transport* report estimates a total project cost of $7.5 billion to $8.5 billion for a 17 km rail tunnel. Using above ground Maglev technology, it would be possible to implement a complete high speed system from Geelong and Tullamarine Airport to Frankston via the CBD for less risk and cost.

Not only would such a system be aesthetically pleasing, low noise, fast and clean, but it would draw international attention to Melbourne as a city prepared to invest in proven cutting edge public transport technology.

Transrapid's Maglev System is unrivalled when it comes to noise emission, energy consumption, and land use. This innovative non-contact transportation system provides mobility with minimal environmental impact. Maglev is usually regarded as a solution tailored to longer journeys where its high speed and acceleration can significantly reduce trip times. However, it is also the best solution for lower speed (but still considerably higher than traditional rail) operation within built up areas such as the Melbourne CBD and its suburbs. The system has no moving parts, eliminating the noise and vibrations produced by wheel on track trains. The guideway takes up little space and can be elevated on pylons with a small footprint. All guideway maintenance can be performed from the guideway itself – access from the ground is not required. The system is energy efficient and all electric.

A description of Transrapid's Operating System is provided at Annex A. Further details are available at the ThyssenKrupp Transrapid website (http://www.thyssenkrupp-transrapid.de) and the Transrapid International website (http://www.transrapid.de). Two brochures on the system are also attached as pdf files:

- Transrapid Capability
- High-Tech for "*Flying on the Ground*"

2. TRANSRAPID MAGLEV IS PROVEN TECHNOLOGY

A Chinese/German built Transrapid system has been in full commercial operation in Shanghai since January 2004. The Shanghai Transrapid is the world's first commercial high-speed Maglev system. It carries over 4 million passengers a year, has travelled millions of kilometres and has operated flawlessly.

With an operating speed of 430 km/h, it travels on a 30-kilometer-long double-track guideway, connecting Long Yang Road Station in Shanghai to Pudong International Airport. The journey time is just under eight minutes. Three Transrapid vehicles, each with five sections, make up the Maglev fleet.

The customer for the project was the Shanghai Maglev Transportation Development Co. Ltd. (SMTDC), which was also responsible for building the guideway and the stations. The German industrial consortium consisting of Siemens, ThyssenKrupp and Transrapid International supplied the operating systems, which included, among other things, the vehicles, the propulsion system, the power supply and the operations control and technical systems. The contract for the Shanghai project was signed in January 2001. The maiden trip took place on December 31, 2002.

3. PREVIOUS VICTORIAN MAGLEV SUBMISSIONS

In January 2000, ThyssenKrupp Transrapid (then known as Thyssen Transrapid) submitted a detailed study to the Victorian Transport Minister for a Transrapid project to service western Melbourne. Within that study was a proposal to provide a Melbourne to Tullamarine service with an 8 minute trip time. The then Treasurer of Victoria and now Premier, Mr Brumby, has ridden Transrapid in Germany and was most impressed.

Previously, in 1992, ThyssenKrupp Transrapid submitted a proposal in the Victorian Government's tender process for a Rapid Transit Link, Melbourne CBD – Tullamarine Airport.

Transrapid's proposal was one of four short listed and the only rail solution. Following a change of government the project was cancelled.

Given these previous submissions, TKTA is concerned that the *Investing in Transport* Report has given no consideration to the use of Maglev technology to realise an East West public transport link in lieu of the proposed Metro rail tunnel.

4. CONSTRUCTION REQUIREMENTS AND COST ESTIMATES

The construction impacts arising from Transrapid's proposals would be less onerous than those arising from the conventional rail solution proposed in the report. The levels of noise, dust and vibration resulting from development of the Transrapid proposal would be less than for conventional rail, the duration of construction would be shorter, and the risk would be far less than tunnelling.

Conventional grade separation works would not be required for the Transrapid solution as the ability to elevate Transrapid track can avoid level crossings and conventional grade separation.

No significant disruption to existing rail services during the construction works would arise with the Transrapid solution.

The order of magnitude costs for a Transrapid Maglev system are:

Double guideway / km	\$ 34 million
Single guideway / km	\$24 million
Train section	\$16.5-20 million depending on configuration and furnishing

A train may consist of up to 10 sections: two end sections and up to 8 middle sections. The number of seats and standing room is determined by the kind of the Maglev vehicle and customer preference. In Shanghai 3 trains are operated with 5 sections each. The latest variant of vehicle, TR 09, has 58 seats and standing room for 61 in each middle section and 49 seats and standing room for 52 in the end sections. The vehicles can be adapted to public transport use with higher passenger capacities.

Thus, the rough estimate order of cost for a Maglev system comprising 100km of double guideway, operating 10 three-section trains (320 passengers / train) would be \$4 billion. This is considerably less than the estimate in the *Investing in Transport* report of \$7.5 billion to \$8.5 billion for 17km of conventional rail tunnel. These savings could be allocated to extending the Transrapid system to other Victorian regional centres.

5. MAINTENANCE AND OPERATING COSTS

Maintenance and operating costs for the Maglev system are very low compared with conventional trains. Because the vehicles do not come into contact with the guideway and have no wheels or mechanical brakes, maintenance costs due to mechanical wear are minimal. The system is fully computer controlled and does not require a vehicle driver.

6. CUSTOMER APPEAL

Transrapid is a clean, comfortable, quiet and fast form of public transport. A journey from the CBD to Tullamarine would take in the order of 8 minutes. The time from Frankston to the CBD would take in the order of 12 minutes and to the airport 20 minutes, including stops en route. The system's high acceleration rates allow significant reductions in travel time over even short distances; and relatively high operating speeds in the order of 250km/hr can be achieved in heavily built up areas with virtually no noise emission, since the only source of noise is wind turbulence.

Passengers on Transrapid experience negligible vibration or noise; certainly far less than in any other form of public transport.

TKTA envisages a Melbourne metropolitan Transrapid system operating entirely above ground. Travellers will not experience the discomfort of underground stations and extended periods in noisy underground tunnels. The visual impact on the Melbourne cityscape will be minimal, since the system operates on streamlined, clean, elevated guideways. Indeed, the image of streamlined, fast Transrapid Maglev vehicles gliding silently through the city will create a positive image of progress and reinforce the Government's commitment to clean green infrastructure projects.

7. NOISE AND VIBRATION IMPACT

Transrapid is virtually silent at speeds up to 200 km/h and produces virtually no vibration due to its non contact operation. At speeds above 200 km/h Transrapid produces half the noise of conventional trains at equivalent speeds. Also, because Transrapid operates on a dedicated track without any form of interaction with road vehicles or conventional trains, the system produces none of the noise of conventional trains at level crossings etc.

8. SAFETY

Safety is a principal feature of Transrapid design. Safety starts with the basic wrap–around–the–guideway design of the vehicle and extends through to the fully automatic Operation Control System. During all periods of its development, Transrapid has been subjected to detailed and comprehensive safety analyses and evaluation. As a new transportation system, Transrapid has benefited from experience with existing systems, by avoiding from the outset known accident risks and functional failures.

The safety concept of Transrapid includes:

- automatic train control and system protection with no operator responsibility for safety critical functions
- protection of passengers during ingress and egress of trains in stations by a platform gate system
- passive protective measures (barriers etc.) against the intrusion of obstacles into the vehicle's path
- fire protection measures and rescue strategy
- minimisation of hazards associated with collision with unexpected obstacles, and
- an automatic guideway inspection system.

According to independent safety analyses, Transrapid is the safest mass transportation system in the world.

Many of the collision and derailing risks that apply to a conventional train solution would not apply to the Transrapid solution due to its dedicated track, fully automated operation and control system, and its system configuration, which makes it virtually impossible to derail the vehicles.

Most importantly the health and safety risks associated with conventional train operations in long tunnels deep underground would be entirely avoided. Fire, terrorist attack and poor air quality are major issues for operating trains in tunnels. Large scale disasters and OH&S litigation are risks that would be avoided through use of an above ground Maglev system.

9. CONCLUSION

TKTA recommends that the Victorian Government fund a study to confirm the viability and cost of a Transrapid Maglev solution to Melbourne's east west public transport link needs, before accepting the recommendation of the *Investing in Transport* report's recommendation for an expensive and outdated wheel on track railway tunnel.

ANNEX A

A1. TRANSRAPID OPERATING SYSTEM

A1.1. INTRODUCTION

A1.1.1. OVERVIEW

This Annex describes the operating system of Transrapid which includes the vehicles with their levitation and guidance systems, and the propulsion, energy supply and operation control systems.

Transrapid is one of the most important technology innovations of the century. It is the first train system that operates completely non–contact and without wheels. It thereby surpasses the technical limits of wheel and rail which have constrained conventional railroads since their inception. It promises to revolutionise track–bound travel because Transrapid combines the often conflicting characteristics of speed, economics, comfort and safety into one attractive, mass transportation system.

A1.1.2. CERTIFICATION

The Transrapid system received its certification of technical readiness for application in Germany in late 1991. The extensive investigation preceding the certification covered all aspects of Transrapid technology and design with special attention being given to safety and system reliability. In preparation for the German Transrapid Berlin–Hamburg Project additional regulations have been introduced, covering Transrapid construction and operation to further ensure that Transrapid meets or exceeds all necessary transportation standards for safe, reliable, comfortable and attractive operation.

In the meantime development of the Transrapid system took another big step. Its flexible design makes the Transrapid ideal not only for long-distance applications but also for a fast airport shuttle. A new vehicle generation TR09 has been built for these applications. The new trains are characterized by larger doors and a very high standard of safety. The TR09 is, for example, the first train that is able to fight a fire actively by using an automatic sprinkler system within the vehicles. In 2006 the German approval authority, EBA (Eisenbahn Bundesamt) passed the “rules of technique” to build Transrapid lines to the very high German standards.

A1.2. TRANSRAPID SYSTEM OVERVIEW

A1.2.1. SYSTEM OVERVIEW AND CHARACTERISTICS

Transrapid is the first high speed transportation system based upon magnetic levitation technology approved for public use. With cruising speeds in the range of 300–500 km/h, energy consumption and noise emissions are significantly lower than high speed “wheel on rail” systems when compared at equal speeds. Also higher levels of safety and passenger comfort are achieved, offering tremendous advantages over traditional train systems. During Transrapid’s design, careful attention was given to safety, operational reliability, and minimisation of environmental impacts. Mature component technologies have been used extensively, thereby minimising complexity, maintenance and operational risk. In addition, high levels of redundancy in all essential systems are incorporated to ensure safe, reliable Transrapid operation. This total system approach has created a fast, safe and extremely reliable surface transportation system.

The primary characteristics / advantages of Transrapid’s Maglev system are:

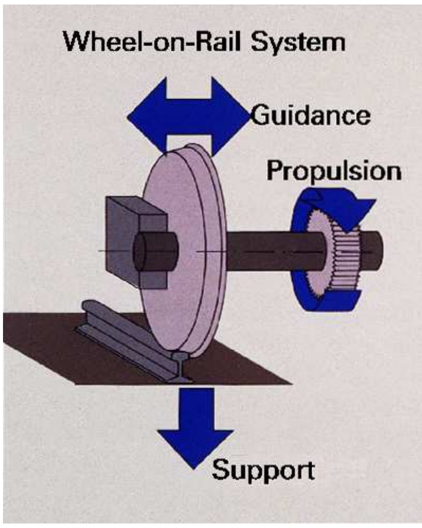
- electromagnetic levitation, guidance and propulsion systems without contact and friction
- very high cruising speeds of 300–500 km/h in rural areas
- cruising speeds of up to 250 km/h in congested urban areas
- unbeatable overall trip times for distances of up to 1,000 kilometres
- unbeatable overall trip times for short distance shuttle operation between outlying airports and city centres
- environmental friendliness:
  - low noise emission
  - low energy consumption
  - minimal land consumption
- flexible guideway parameters allowing minimal disturbance to existing landscape, fewer civil structures (bridges, tunnels) and no division of the countryside
- standard guideway configurations for at–grade and elevated construction without bridge–style structures
- ability to travel small radius curves with 12° (up to 16° in extreme cases) of cant (superelevation)
- ability to climb steep grades (up to 10%)
- virtually impossible to derail–safest of all modern transportation systems
- fully automatic operation under all weather conditions and all seasons utilising the most modern computer–based operation control system (communication, command and control)
- high acceleration of 1 m/s^2, even at speeds above 300 km/h without the need for seat belts
- high passenger comfort at all speeds
- high system availability through sophisticated system design in terms of failure tolerance, functional reliability and insensitivity towards environmental influences
- low maintenance requirements due to maintenance free design and few mechanical and moving parts (noise producing, wear and tear)
- no unsightly, maintenance intensive pantographs or electric rails (noise producing, wear and tear)

A1.2.2. LEVITATION AND GUIDANCE SYSTEMS

Transrapid's levitation and guidance systems function according to the principles of electromagnetic levitation. Instead of the mechanical solutions used for over 150 years by traditional "wheel on rail" systems, Transrapid utilises innovative non–contact, electromechanical solutions to achieve the same functions (Figure A.1).

Figure A.1:

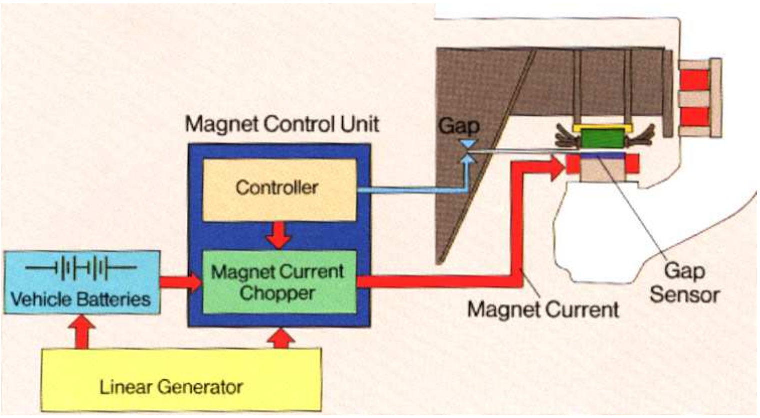
Wheel on rail and Maglev system functions



Individually controlled, non–contact, conventional technology electromagnets located in the vehicle undercarriage attract themselves up to ferromagnetic reaction rails (stator packs) attached to the underside of the guideway. Individually controlled, non–contact, conventional technology electromagnets work together with the guidance rails to hold Transrapid laterally on course. The individual levitation and guidance magnets are grouped together and mounted continuously with two degrees of freedom, on both sides along the entire length of the vehicle. A highly reliable, redundantly laid out, electronic control system ensures that the vehicle levitates at a constant gap of approximately 12 mm from the guideway (exact distance varies with vehicle speed) (Figure A.2). Each and every train section is equipped with 15 independent levitation and 13 independent guidance magnet groups.

Figure A.2

Electromagnet control



A distance of approximately 150 mm between the guideway deck plate and the underside of the levitating vehicle allows the vehicle to pass over small obstacles on the guideway without incident.

Linear generators integrated into the levitation magnets supply energy, without physical contact, to the levitation and guidance magnets as well as for on–board power. In this way, overhead wires are not required for the Transrapid system. On–board aircraft–style batteries, also charged via the linear generators, provide backup power for vehicle levitation, guidance and passenger comfort functions (lighting, ventilation) and allow the vehicle to always brake to a safe, controlled stop in the event of a propulsion system or power failure. At speeds below 80 km/h, vehicle power is supplied by the on–board batteries, while at higher speeds enough power is generated by the linear generators to cover both vehicle requirements and battery charging. When Transrapid is waiting at a station, a contactless inductive power supply system recharges the vehicle batteries.

As with all operation–critical Transrapid systems, sufficient redundancy is built into the levitation and guidance systems, on–board power supply, battery and linear generator systems to ensure proper operation under all conceivable conditions.

A1.2.3. GUIDEWAY AND OPERATING PARAMETERS

Guideway Parameters

Transrapid's flexible, high performance alignment parameters with small curve radii, superb gradient climbing ability and at–grade and elevated guideway designs, allowing guideway heights of up to 20 m without bridge structures, give it the ability to pass through urban and rural landscapes with minimal disturbance to the existing scenery, flora and fauna.

The prefabricated guideway beams can be expediently erected onto concrete substructures, thereby minimising overall construction time and disturbance to the local economies along the route. These flexible parameters mean less earthworks, fewer civil structures, as well as allowing the Transrapid alignment to travel around existing impediments instead of through them.

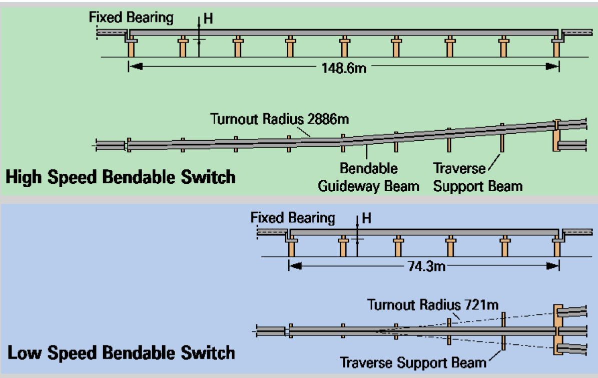
An at–grade guideway is typically used for rural route segments where topography is relatively flat. An elevated guideway is typically used in hilly terrain, congested urban areas with numerous grade separations, as well as areas which are environmentally sensitive or used for agriculture, to minimise disruption to the existing conditions. Where desired, this allows unrestricted animal migration, does not impede natural water flows and existing roads and paths can be maintained, so that farming and existing thoroughfares are not restricted. Its elevated guideway allows Transrapid to conform to difficult terrain unlike conventional "wheel on rail" technology where the topography has to conform to the rail alignment.

Transrapid guideway switch

Guideway switches that physically transfer vehicles from one guideway to another using a flexible guideway beam are also unique to the Transrapid system. Guideway switches are available in two–way or three–way versions for low and high speed turnouts. Low speed switches are approximately 75 m long with a maximum turnout speed of 100 km/h and high speed switches are approximately 150 m with a maximum turnout speed of 200 km/h. These are depicted in Figure A.3.

Figure A.3

Transrapid Guideway Switch



Operating Parameters

The Transrapid system is technologically capable of higher performance than is normally allowed for passenger comfort reasons. The Transrapid system is designed as a ground transportation system with passenger ride comfort as its primary goal. To allow all passengers, including children and senior citizens, the freedom to walk around during the trip, Transrapid's high technical abilities are limited to ensure passengers receive the best possible ride comfort as well as the shortest possible trip times.

These comfort criteria also dictate Transrapid's alignment. Designed to fit into existing public corridors (road, rail, power line) wherever possible, these parameters govern how closely this can be achieved at a local level.

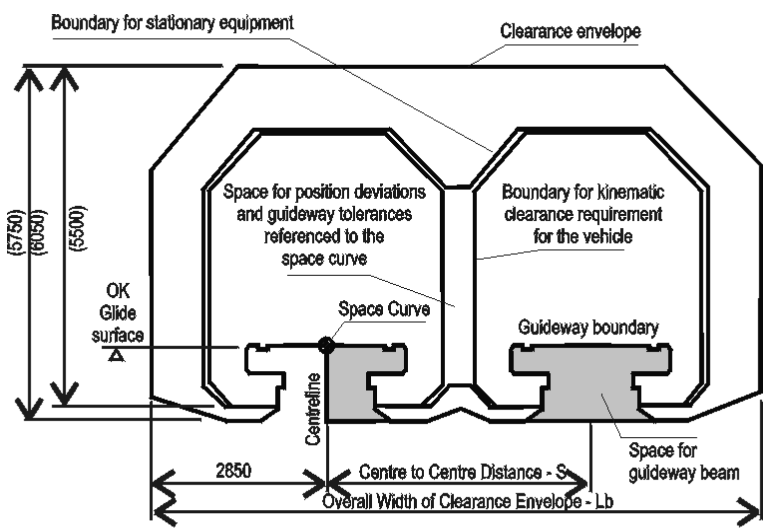
A1.2.4. TRANSRAPID CLEARANCE ENVELOPES

Transrapid has smaller static and dynamic clearance envelopes than high speed trains for two reasons:

- Transrapid's active vehicle levitation/guidance system does not allow it to "sway" as much on its track, and
- Transrapid has a smooth, clean exterior which does not produce much turbulence, thereby allowing it to pass closer to other Transrapid trains and external structures.

Figure A.4

Transrapid Clearance Envelope



This results in a smaller centre to centre distance between tracks than high speed rail lines and a smaller overall clearance envelope. Transrapid's clearance envelope for double track guideway is shown in Figure A.4. The envelope for single track guideway would be half of that for double track. Double track guideway separation requirements are shown in Table A.1.

The Transrapid tunnel cross–sectional areas are also smaller than those for high speed trains and vary according to the operating speed and length of the given tunnel. Indicative values for tunnel cross–sections at 400 km/h for double and single track guideway are 180 m^2 and 90 m^2 respectively for tunnels of 150m and longer. For tunnels less than 25m in length, the standard clearance envelope is used. The dimension of the tunnel cross-section may vary slightly depending on the profile and shape of the version of train used.

A1.3. PROPULSION AND ENERGY SUPPLY SYSTEMS

A1.3.1. OVERVIEW

In conventional transportation systems, the propulsion unit, namely the motor, is located in the vehicle. With Transrapid, the motor, consisting of ferromagnetic stator packs and three–phase cable winding, is mounted on both sides along the underside of the guideway (Figure A.5). Transrapid is both propelled and braked using a synchronous longstator linear motor. The operation of this equally non–contact, propulsion and brake system is analogous to a rotating electric motor whose stator is cut open and stretched along the underside of the guideway and whose rotor (excitation) function is assumed by the levitation magnets in the vehicle. In contrast to the rotating field in a conventional motor, the longstator linear motor produces an electromagnetic travelling wave which, through interaction with the vehicle's levitation magnets, propels the vehicle along the guideway (Figure A.6).

Figure A.5

Longstator Linear Motor

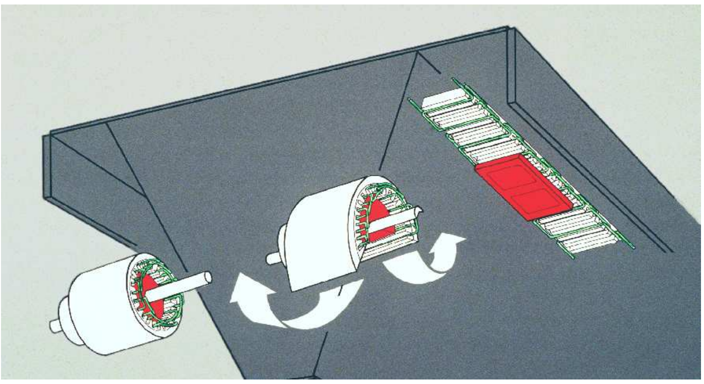
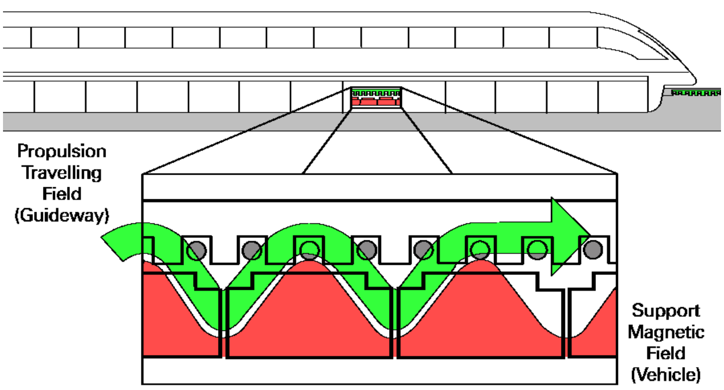


Figure A.6

Longstator Travelling Wave



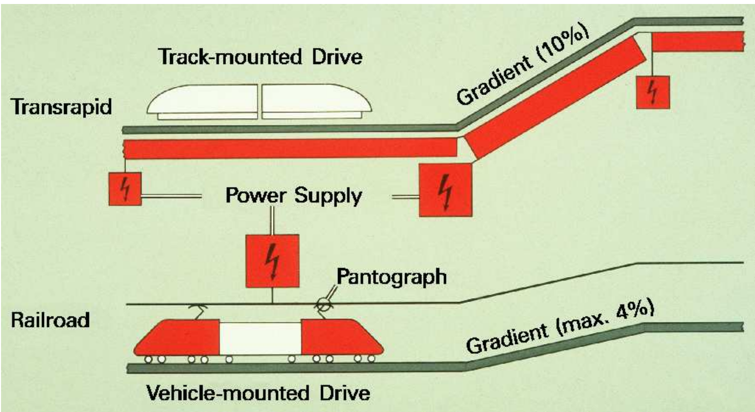
With the help of converters, the propulsion system thrust can be regulated by changing the strength and frequency of the alternating current to allow the vehicle to accelerate smoothly from standstill to full speed. By slowing down and/or reversing the direction of the travelling wave, the motor becomes a generator and the vehicle decelerates, without contact, to a smooth, controlled and safe stop (regenerative braking). In some instances, this braking energy can even be fed back into the public power grid, thereby improving even more the Transrapid's low energy consumption. In the event of public power or propulsion system failure, independent backup brake systems in each vehicle section provide safe and accurate braking to the next available stopping area.

The levitation, guidance and propulsion systems of Transrapid are designed with high functional redundancy, failure–tolerant architecture and automatic diagnostics. In this way, individual problems do not lead to shut–downs of operation. In worst case situations, operational performance may be limited but the safe and timely completion of the trip is always assured.

The longstator motor in the guideway is divided into segments which are supplied with power and switched on and off only as the vehicle passes by. In this way, energy losses are minimised. The energy from the public power grid is fed to the motor segment containing the vehicle via two functionally independent substations, which are connected respectively to the right and left side of the guideway motor. The distance between substations and their installed power is commensurate with the required vehicle performance for the motor segment. Thus for motor segments where the vehicle is accelerating or climbing steep grades, more power is provided than is required for constant speed or level guideway segments (Figure A.7). In contrast to conventional transportation systems where the vehicle's motor is sized for the maximum performance requirement (but seldom needed) and is therefore predominately an uneconomical load, Transrapid's motor is tailored locally to the landscape and operational requirements along the entire route.

Figure A.7

Propulsion performance tailored to route requirements



Since Transrapid's propulsion system is located in the guideway, the vehicle is passive and can be built lighter. Wheels, brakes, axles, transmissions, pantograph and motor are no longer needed. Instead of wear and tear prone, maintenance intensive mechanical components, Transrapid uses predominately wear–free, low maintenance electronics. All train sections also have identical levitation, guidance and power supply components thereby simplifying maintenance and spare parts.

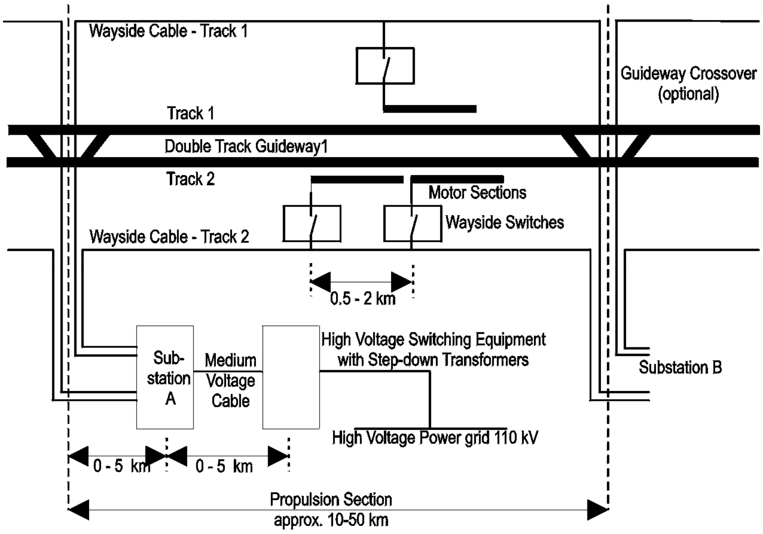
Propulsion System Structure

The propulsion system of Transrapid is installed along the route within the guideway. This allows the different propulsion components to be sized to fit the local topography and performance requirements. Each guideway segment's propulsion system is individually sized and configured to the requirements of the route and the operations concept. The propulsion system layout, especially the location of the substations, must be addressed early in the planning process. Within the bounds of the system parameters, there are usually numerous possible variations, each of which can differ significantly in terms of the resulting availability, comfort and expandability.

Transrapid's propulsion system is functionally divided into three groups of components: energy supply, substation and wayside components. Figure A.8 shows a general overview.

Figure A.8

Transrapid propulsion system overview



A1.3.2. ENERGY SUPPLY

The energy supply portion of the propulsion system receives the energy from the public grid and steps it down to the levels required by the Transrapid system and distributes this energy to all route and system components requiring electrical power. The incoming power from the grid is generally about 110 kV 50 Hz, and the propulsion system utilises approximately 20 kV for its internal needs. Within the energy supply system components are also provided for power factor correction functions, to ensure Transrapid meets grid connection loading requirements. The supply equipment may be co–located with its associated substation or sited up to 5 km away. The energy supply components generally require approximately 1500 m^2 of open area.

The energy supply systems provide power for the route in general, all wayside equipment (motor section switches, transformers, etc.), guideway power rails, guideway switches, OCS antennas, etc. The medium and low voltage power is transmitted via the wayside cabling, either in trenches along the guideway, or in cable trays attached to the guideway.

A1.4. VEHICLES

A1.4.1. OVERVIEW

Transrapid trains are modern, attractive, spacious, vehicles that adhere to the latest aircraft, railroad and public transportation standards. Flexible, modular design allows for customer–driven versions, such as suburban, intercity, and cargo/freight trains which all share the same basic components and attributes.

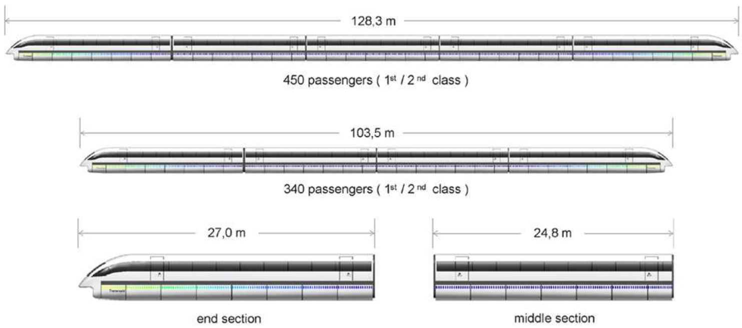
Lightweight vehicle end and middle sections, constructed of profiled, composite sandwich panels, are configured into trains of two to ten sections to handle the expected ridership volume on the given route (Figure A.9). The seating capacity of individual sections ranges can vary from approximately 60 for spacious First Class seating to nearly 120 for high density seating for short distance, commuter applications. Since the Transrapid's motor is in the guideway, the train's performance is influenced neither by its length nor by its payload.

Two Transrapid vehicle styles – end or middle sections are available to configure trainsets, irrespective of transport function. Although the body design varies according to the end use (passenger, cargo, freight), the undercarriage and all remaining components are identical.

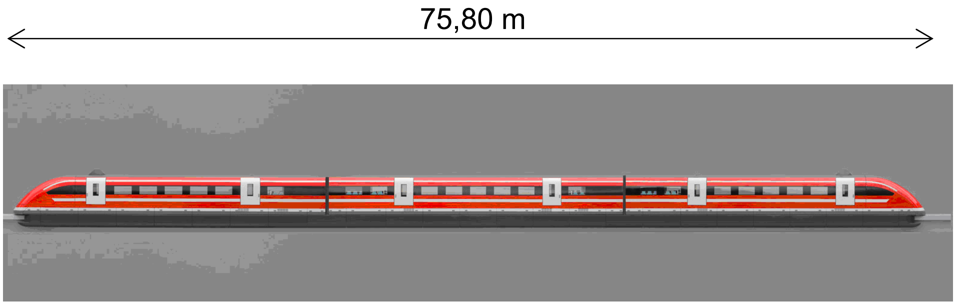
Transrapid trains are made up of two end sections and up to eight middle sections. Each end section is fitted with a driver's compartment, vehicle on–board operation control system (OCS), and the payload area for passengers, cargo, or freight. Although a Transrapid driver is not required, the trend is to have one to meet passenger expectations. The driver's passive role is monitors all vehicle functions via the operator console and to be available for assistance during unscheduled situations. Middle sections are similar in overall composition to end sections but do not have the driver's compartment or OCS equipment.

Figure A.9

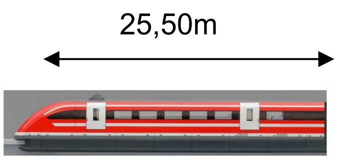
Transrapid 08 vehicle - Typical long-distance application



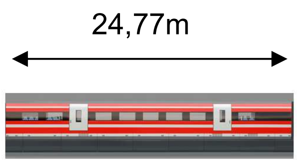
Transrapid 09 vehicle - Typical airport shuttle application



321 – 449 passengers (only 2nd class)



End section

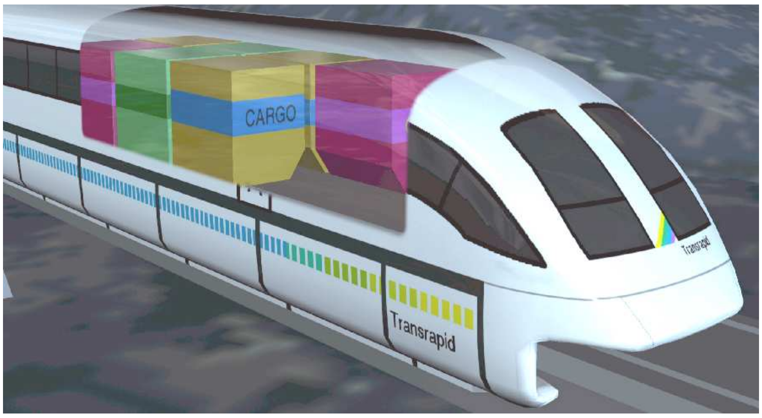


middle section

This is also true of cargo/freight trains (Figure A.10). Designed to handle standard shipping containers, individual cargo sections are capable of transporting up to 18.3 tonnes of high priority or express goods at the same phenomenal speeds as passenger vehicles. Cargo sections may be assembled to form dedicated superspeed cargo trains or added to passenger vehicles to carry baggage or additional goods according to the operator's requirements. Heavy duty freight trains are also available which can carry up to 30 tonnes per section at speeds up to 200 km/h.

Figure A.10

Transrapid cargo vehicle



A1.4.2. VEHICLE STRUCTURE

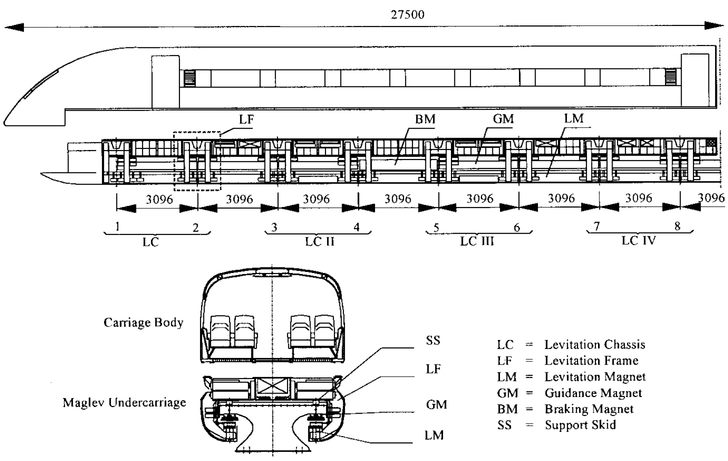
Transrapid Undercarriage

Each vehicle section consists of two main elements, a Maglev undercarriage and a carriage body (Figure A.11). The main elements are independently assembled and equipped and then integrated to form a complete vehicle section.

Contained in the vehicle undercarriage are all of the Maglev components, levitation and guidance magnet modules, primary and secondary suspension systems, on–board battery systems, on–board power supplies, vehicle electronics and heating / ventilation / airconditioning systems.

Figure A.11

Vehicle structure



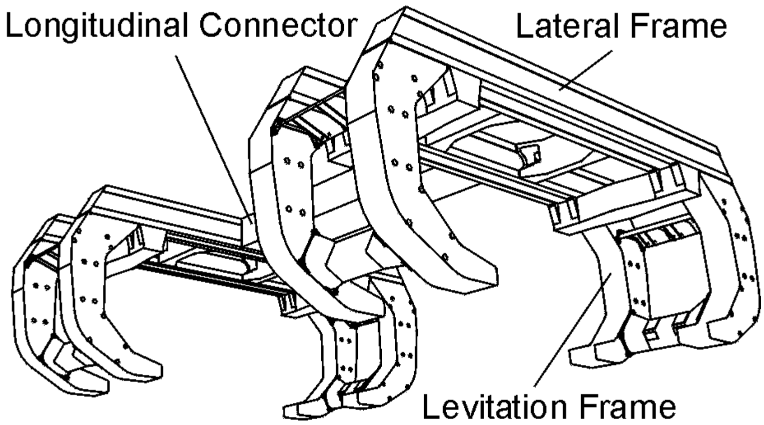
Two separate suspension systems are included in Transrapid vehicles: a primary suspension between the levitation and guidance magnets and their mounts and a secondary between the levitation chassis and the vehicle body with passenger compartment. The levitation and guidance magnets are mounted via the primary suspension to independent levitation chassis units in each vehicle section. The levitation chassis units are then connected to the vehicle body via the secondary suspension. Suspension movement is required to allow the magnets to adjust to minor differences in the guideway and to smooth out the ride for passengers thereby minimising the tolerance requirements on the guideway to an acceptable level.

The basic element of the vehicle suspension system is the levitation chassis unit. Four levitation chassis units (Figure A.12) are installed in each vehicle section and these channel the forces from the levitation, guidance, propulsion and braking modules into the vehicle as a whole.

The levitation chassis units are fastened to the carriage body by means of differential linkages, an air suspension system, and mechanical roll stabilisers with all movable parts of magnet mountings and the chassis to carriage body fixed in position with stiff, maintenance free, metal rubber bearings.

Figure A.12

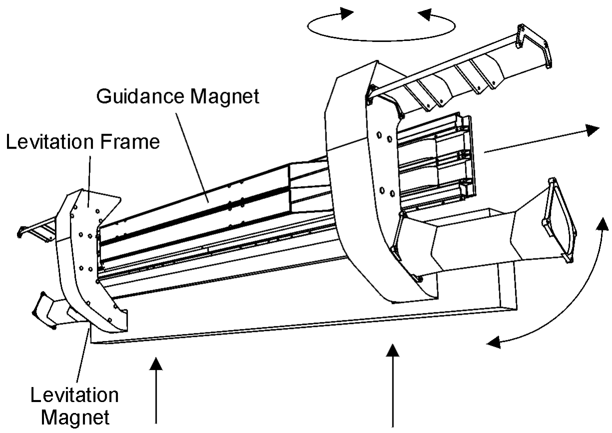
Levitation chassis unit



Each levitation chassis has four levitation frames which are mounted in pairs on either side of the vehicle and linked by a transverse beam to form a structure which straddles and wraps around the guideway. The levitation frames to which the magnets are fixed at each of their lower ends make up the smallest complete independently functioning unit of the propulsion, braking and guidance system. The levitation and guidance magnets are mounted with two degrees of freedom to the levitation frames to allow small variances between magnet and guideway to be compensated for. Additional braking magnets are provided in the centre of each vehicle section in place of guidance magnets on both sides of the vehicle. Also attached to the levitation chassis units are the mechanical skids which support the vehicle when stationary.

Figure A.13

Magnet module



The pre–assembled and exchangeable component groups mounted on identical levitation chassis units give the vehicle's Maglev undercarriage a high degree of modularity. To facilitate installation and maintenance of the levitation, guidance and braking magnets, they are pre–assembled to a pair of levitation frames to provide an exchangeable magnet module (Figure A.13).

The high degree of modularity facilitates the manufacture of relatively large numbers of similar components which can be made more efficiently, and allows a relatively small number of basic elements to be held in stock as replacement parts.

The aluminium sub–floor structure of the vehicle houses all of the subassembly groups of the Maglev undercarriage. It has a smooth lower surface made from longitudinally welded extrusions which run the full length of the vehicle. Above this base platform, longitudinal and transverse partitions are mounted to form a series of partially enclosed spaces into which the vehicle's electrical, electronic and pneumatic systems are installed using slide–in units. The halogen free, power and control cabling systems are installed separately in EMF shielded cable channels. The functional links between the power and control cabling are also physically separated and EMF shielded, and are located inside closed connection boxes located between the transverse beams of the levitation chassis units.

To prevent dirt and snow from entering the Maglev undercarriage, robust cladding protection elements are provided, both internally and externally. The cladding system is optimised aerodynamically and provides simple access for maintenance purposes.

Vehicle Body

To provide a light, stiff structure for the vehicle body, a hybrid design using aluminium hollow profiles and aluminium clad foam sandwich panels is used. This type of hybrid profile/sandwich structure has low weight combined with high isotropic stiffness. The aluminium clad sandwich panels have polyetherimide foam as core material which meet the highest rail requirements for polymeric materials in terms of fire, smoke and toxicity. The panels also exhibit excellent damage tolerance.

The sandwich panels are mounted between longitudinal profiles which run the full length of the vehicle. The profiles have not only been designed to provide the necessary strength, but also to be multi–functional. They provide the fixation of the sandwich panels which form the vehicle skin as well as being equipped with attachment channels to install various components and systems such as airconditioning, lighting and the vehicle's interior cladding.

The various structural components are joined using mechanical fixing systems, welding and adhesive bonding, as required by the design. A combination of joining methods employing both laser welding and riveting is used to join the sandwich panels to the extruded profile framework.

The nose elements are self–supporting sandwich structures made from Glass Fibre Reinforced/Polyester (GRP) resin clad layers with a foam core. The sandwich structure of the nose and its two front windows are capable of withstanding, without penetration, the impact of a 1 kg standard projectile with an impact speed of 600 km/h.

The side wall–floor elements as well as the roof are attached using rivets to the vehicle's aluminium profile skeleton to form an over 24 metre long tubular structure. The two end walls for a middle section or an end wall and a nose for an end section are riveted and adhesively bonded respectively in place to complete the vehicle body. The complete structure is designed to withstand static pressures of +/–6000 Pa (to accommodate tunnel entry) and dynamic pressure variations of +/–2500 Pa (to accommodate passing trains).

An end section body shell, with nose and nose substructure but without doors, windows or interior, weighs under 6.2 tonnes. An equivalent middle section weighs under 5.16 tonnes.

Vehicle Interior

The Transrapid interior design concept (Figure A.14) addresses a number of objectives:

- modular construction
- flexibility to meet the customer's special requirements
- many identical components for all interior variants
- flexible seating arrangements
- flexible lighting
- flexible passenger information and entertainment systems
- a design which accommodates additional functional units without major modifications to the structure (units such as toilets, telephones, on–board catering)
- stress–free joints for fixing the main interior panels into the structure
- fastening of the interior panels with elastic elements to reduce transmission of noise from the exterior shell.

Figure A.14

Vehicle interior

The side walls and columns between windows are covered by single insulated sandwich panels with integrated roller blinds. The partitioning between the passenger compartment and entrance area is partially removable to provide access for maintenance purposes to the passenger compartment door assembly and to the airconditioning units. The entire floor is covered with sound damping tiles fitted below a carpet covering.

Each vehicle section has two independent airconditioning plants. Air distribution is one–third to the above window side ducting and two–thirds to the roof ducting. The exhaust ducting is situated below the windows, behind the side wall cladding. Two smoke detector units are also installed per section. Built–in evacuation tube units are located by each of the vehicle's outside doors. First aid equipment and fire extinguishers are also built into the wall panels at the end of each vehicle section.

Flexible seating arrangements are available to allow first, business, and economy class seating as desired by the customer. Luggage racks in 2.5 and 2.2 metre modular lengths are provided as well as baggage/coat areas. The luggage rack design uses longitudinal aluminium profiles, glass, and perforated steel sheeting. The design meets the required standards as well as providing additional sound damping.

All passenger vehicles including their on–board toilet facilities are designed for access by passengers with limited mobility. The toilet facilities are the most modern available with closed–circuit fresh and waste water systems, minimum water use flush systems, and they are easy to clean and maintain.

Indirect lighting integrated into the ceiling is used to illuminate the passenger compartment. In addition each seat is equipped with a reading light. Four round roof lights and two floor lights are installed to illuminate the entrance area. Loud speakers and two graphic display units per passenger compartment are built into the walls separating the compartments.

A1.4.3. TRAIN CONFIGURATION

The principal dimensions and principal parameters of Transrapid's end and middle vehicle sections are shown in Figure A.15.

Intercity Trains

Transrapid intercity trains will be fitted with the appropriate level of passenger comfort including First and Business Class seating, in–seat entertainment, catering services, toilet facilities, baggage/coat areas, etc. Access doors on both sides of the train will be provided at each end of each section.

Composed of two First Class and four Business Class sections, they will be able to comfortably carry approximately 504 seated passengers per trip. In First Class, seating arrangements of 2+2 seats and in Business Class, 2+3 seats are available.

Suburban Trains

Transrapid suburban trains will be outfitted commensurate with the short trip times and the commuting nature of the patronage. In addition to the standard doors on both sides of each section end, an additional pair with be located in mid–section to facilitate entering/exiting.

Maintenance Vehicles

Included in the system are a variety of Maglev and conventional maintenance vehicles to provide expedient scheduled and unscheduled maintenance along the route.

A three section Maglev vehicle of similar design to the passenger trains will carry out daily non–contact, guideway dimensional inspections, periodic non–contact, guideway visual inspections, and allow fast access to all areas along the route. It will carry a complement of test, inspection and maintenance equipment and be controlled and monitored by the Operation Control System in the same fashion as the passenger trains.

Diesel powered, rubber tyred vehicles will also be available for guideway maintenance and inspection work with extendable arms and work platforms for work on the sides and undersides of the guideway. Since all guideway maintenance work is designed to be accomplished from the guideway, special guideway maintenance vehicles have been developed and are foreseen to handle the necessary long–term maintenance tasks. In addition to these guideway specific vehicles, conventional road vehicles are also provided for all inspection and maintenance duties in the substations, and at the wayside components installed along the route (wayside switches, guideway switches, etc.).

Figure A.15

Principal Transrapid trainset dimensions

		TR08	TR09
Length	End section	26.99 m	25.5 m
	Middle section	24.77 m	24.77
Width		3.70 m	3.7 m
Height above track without antenna		3.2 m	3.35 m
Operating speed		Up to 500 km/h	Up to 500 km/h

		TR08	TR09
Empty weight, passenger vehicle	End section	50.0 t	56.8 t
	Middle section	49.1 t	56.0 t
Payload capacity, passenger vehicle	End section	12.0 t	12.7 t
	Middle section	15.4 t	15.0 t
Empty weight, cargo vehicle	End section	47.3 t	
	Middle section	46.2 t	
Payload capacity, cargo vehicle	End section	14.7 t	
	Middle section	18.3 t	

	2 Sections	6 Sections	10 Sections
Length	51.0 m	153.06 m	252.14m
Empty weight	113.6 t	296.4 t	492.8 t
Payload capacity	24 t	85.6 t	147.2 t
Total weight	124 t	382 t	640 t
Seats*	98+104 standing	472 – 696	808 – 1184
Application type	TR 09 Airport connector	TR08 City pair connector	TR08 Long distance/ network

** Can be varied to meet customer requirements for seat density. Figures shown include toilet and baggage racks*

A1.5. SYSTEM CONTROL AND COMMUNICATIONS

A1.5.1. OVERVIEW

All aspects of Transrapid's operation are controlled and monitored by the Operation Control System (OCS). The OCS is a radio–based, decentralised command and control system which is designed to be technically safe at all times and in all situations. It monitors and safely controls all aspects of the Transrapid system without relying on human operators for safety supervision. The communication and operation control system is fully automated and maintains the train's speed within the operating specifications (safe speed enforcement) and provides a safe and unobstructed travel path (route integrity).

Communication between the vehicles and the control centre is handled by redundant radio–based, data transmission systems. Unlike other ground–based transportation systems which have physical contact between the vehicle and the track during operation, the non–contact operation of the Transrapid dictates that all communication occurs via radio. Two independent, on–board, vehicle control systems are connected to separate antennas on each end of the vehicle. These vehicle antennas are in constant line–of–sight contact with two different radio transmission masts, set at multi–kilometre intervals along the guideway. In this way, communication between the vehicles and the central control system is always ensured.

In addition to the control and supervision of the route based on the pre–programmed schedules and the commands of the central operators, the OCS also collects maintenance and failure information and directs it back to the maintenance archive and scheduling system at the Central Maintenance Facility.

As with all Transrapid systems, the OCS uses modular, failure tolerant design with a high level of redundancy to ensure the absolute safety and comfort of the passengers and personnel. The strategy employed in the command and control of the Transrapid system is based on the segregation of the safety relevant and non safety relevant functions into two sections, both in functional as well as physical terms.

The safety relevant command and control functions as well as the transmission of the associated operational signals are realised by the central control system. The safety requirements to which this is subject correspond to those of the highest safety integrity level. All operational communications have redundant paths and components to ensure system safety and reliability.

For the non safety relevant functions, on–line diagnostic systems are applied to automatically detect defective components and subassemblies in the various route and vehicle subsystems and send diagnostic reports to the maintenance centre.

The advantages of this strict segregation are:

- optimisation of the safety relevant functions with hardware subassemblies developed for the specific requirements of the Transrapid system
- minimisation of the safety related assessment procedure, and
- simplified realisation utilising software solutions with industry standard functional components.

Since Transrapid is a closed circuit system operating on dedicated guideways without direct interaction with other transport modes, only non–safety related information would be exchanged with other transportation systems. Therefore direct link–ups with other transportation systems are not required which further simplifies scheduling and operational issues. Interaction between existing systems and Transrapid will be limited to exchanging coordination information to ensure maximum convenience for passengers.

All aspects of operational control were subject to intense scrutiny during certification processes to validate their suitability for mission critical application.

A1.6. ENVIRONMENTAL CHARACTERISTICS

Transrapid is the most environmentally friendly mass transportation system available. With lower energy consumption and noise emissions than high speed trains at comparable speeds, lower land consumption, more flexible route alignment parameters, low stray magnetic field strengths and shorter trip times due to its higher average speeds and faster acceleration, Transrapid is truly an innovation in transportation technology. This Section will highlight the primary environmental advantages of Transrapid despite its high speeds.

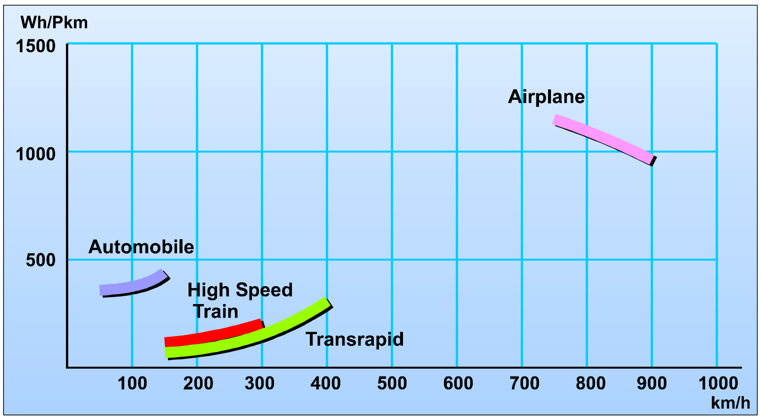
A1.6.1. ENERGY CONSUMPTION

The low energy consumption of the Transrapid system results from its lack of friction (non–contact technology), the high efficiency of its synchronous longstator motor, and the economical vehicle data such as low weight and low aerodynamic resistance (no pantograph, smooth exterior and underbody). For these reasons, when travelling at the same speed, the Transrapid consumes approximately 30% less energy than the German high speed rail system ICE. Or formulated another way, for the same energy input, the Transrapid produces approximately one–third more output/performance. The primary energy consumption for common modes of travel is shown in Figure A.16.

When compared with road and air travel, Transrapid is even more energy efficient. For equal distances, the specific energy consumption of automobile travel is three times higher and for air travel, five times higher than the Transrapid system.

Figure A.16

Primary energy consumption

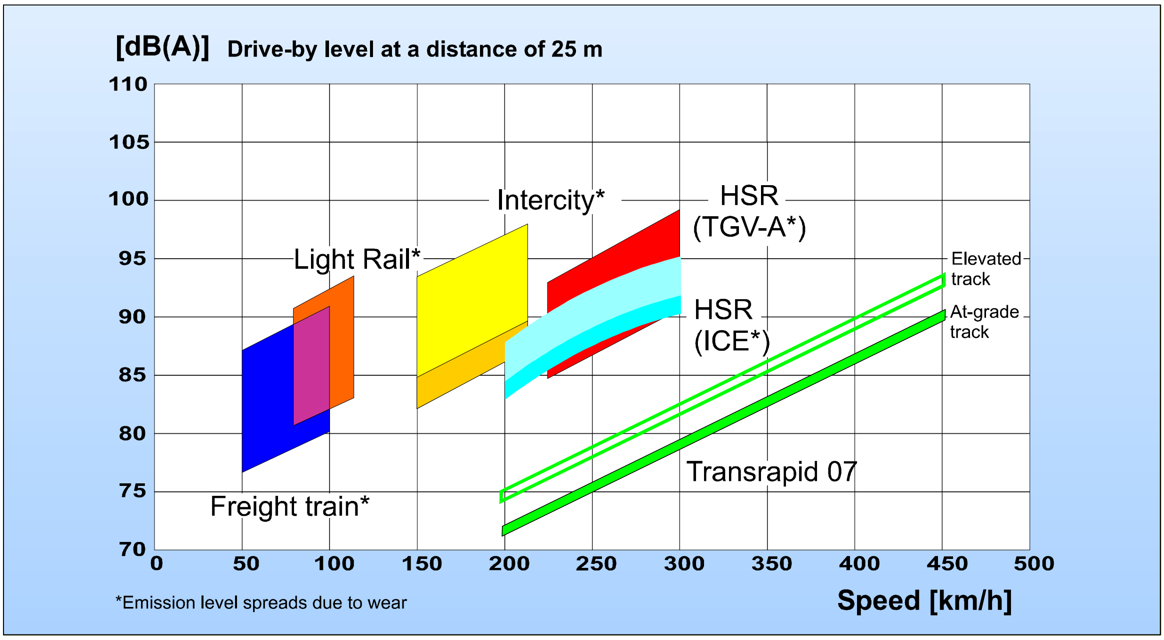


A1.6.2. NOISE

All traditional mass transportation systems emit primarily three types of noise– motor, rolling, and aerodynamic (wind). With the Transrapid, its motor is electric and can not be heard. Since there are no wheels, there can be no rolling noise. The Transrapid's aerodynamic noise is only apparent above 200 km/h, the speed at which it travels through urban areas. Comparison measurements by the safety/testing institute, TÜV Rheinland in Germany have shown that the Transrapid at 300 km/h is approximately half as loud as an Intercity train at 160 km/h and even quieter than a light rail train at 100 km/h. Even in open areas travelling at speeds of 400 km/h, the Transrapid is quieter than a modern high speed train at 250 km/h. A comparison of transportation system noise levels is shown in Figure A.17.

Figure A.17

Noise Emission



A1.6.3. LAND CONSUMPTION

Regardless of whether the guideway is at–grade or elevated, the Transrapid system requires less land for its route. With its active levitation and guidance systems and smooth aerodynamic shape (low turbulence), Transrapid trains can pass closer to each other, thereby allowing a shorter track–to–track distance than conventional railroads.

The smaller footprint of both at–grade and elevated guideway reduces the overall amount of land required and with its ability to flexibly co–locate with existing transportation or power line corridors, less new land needs to be purchased for the route.

Transrapid guideway foundations are located below the ground surface which avoids the dividing of landscapes and allows small animals and water to flow under the guideway without hinderance. In areas where the route utilises elevated guideway, the original land use can be retained with little or no interference. Environmentally sensitive areas can also be traversed using elevated guideway with minimal effect on the existing habitats.

A1.6.4. MAGNETIC FIELDS

The intensity of the Transrapid's stray magnetic fields is extremely low. It is comparable with the residual strength of the earth's magnetic field and therefore much lower than that of many household appliances. A hair dryer or colour TV is surrounded by much higher strength stray magnetic fields than those found in the passenger compartment of the Transrapid.

Table A.3

Magnetic Field Strengths

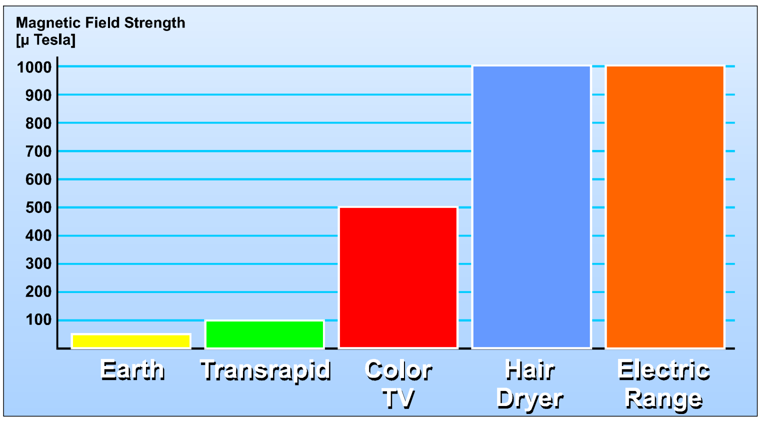
Location and Frequency	Field Strength (see note)
Extreme Low Frequency Fields (3Hz to 3kHz)	–
Passenger Compartment	10 µT
Near Guideway	6.5 – 9.5 µT
Passenger Station	2 µT
Static Field (<3Hz)	0 – 33.5 µT

Note: These values were measured independently by Electric Research and Management Inc.

Transrapid has through careful design reduced the levels of residual external electromagnetic fields to very low levels. Reductions are usually at least a factor of 10 below current German and European Standards.

Figure A.18

Magnetic Field Strengths



Magnetic component of electromagnetic field in close proximity to passengers compares well to the earth's magnetic field of 50 µT. Measured values at locations in the passenger compartment are given in Table A.3. Figure A.18 compares stray magnetic field strengths associated with typical appliances and Transrapid.

Externally, cables carrying high voltage supplies are fully insulated and either buried in the ground or only switched on for brief periods (longstator cable windings as the train passes by). Hence they do not generate fields over large areas such as do conventional trains using rails and catenary cables where 25 kV will be applied. Unlike conventional rail, using pantographs to collect traction power that often generate sparks and wide band electromagnetic interference, Transrapid has no moving electrical contact to generate wide band electromagnetic interference from sparks. All Transrapid electrical switching takes place in controlled environments.

A1.7. SAFETY

A1.7.1. OVERVIEW

Safety is a principal feature of Transrapid design. Safety starts with the basic wrap–around–the–guideway design of the vehicle and extends through to the fully automatic Operation Control System. During all periods of its development, the Transrapid has been subjected to detailed and comprehensive safety analyses and evaluation. As a new transportation system, the Transrapid profits from the experiences with existing systems, by avoiding from the outset known accident risks and functional failures.

The safety concept of the Transrapid includes:

- automatic train control and system protection with no operator responsibility for safety critical functions
- protection of passengers during ingress and egress of trains in stations by a platform gate system
- passive protective measures (barriers etc.) against the intrusion of obstacles into the vehicle's path
- fire protection measures, including an active automatic sprinkler system within the vehicle, and rescue strategy
- crashworthiness to minimise hazards associated with collision with unexpected obstacles, and
- automatic guideway inspection system.

According to independent safety analyses, Transrapid is the safest mass transportation system in the world.

A1.7.2. DESIGNED-IN SAFETY FEATURES

Basic design ensures the vehicle can virtually not be derailed. At crossing points where Transrapid alignments intersect with road and rail links, Transrapid will be grade separated to ensure there is no opportunity for physical contact.

The nose area of the end section is reinforced, shaped to deflect most guideway obstructions aside, and has a crush zone to absorb larger collisions without subjecting the passengers to a dangerous situation.

Unlike conventional railways, there are no exposed high voltage components such as overhead supply cables. All electrical components are fully insulated and/or enclosed or buried to prevent unauthorised contact. System safety is also enhanced since only relatively short sections of the guideway (motor sections) are powered at any one time (as the train physically passes). Other sections are inherently safe with no power applied.

The design of the longstator propulsion system and the operation control system technically prevents two trains from being in the same motor section at the same time. And even if this did theoretically occur, the fact that the motor is in the guideway would force both trains to travel at the same speed in the same direction, thereby again preventing a collision.

Neither train “drivers” nor operation centre personnel are allowed safety responsibility for any aspect of the system. This prevents human error from causing an event which could lead to a safety relevant situation. The operation control system which does have this responsibility is designed and built with full technical and operational redundancy (hot backup with 2 out of 3 systems always operating and checking each other) with automatic shut–down routines to prevent any situation escalating to a level where human safety could be involved.

All OCS functions are exhaustively tested to ensure safe operating conditions prevail under all conditions. At the operating speeds envisaged, human reaction time would invariably be inadequate. The OCS is therefore designed to initiate, control and safely monitor all system functions. Basic system safety is incorporated into the OCS procedures. All hardware and software components and functions are assembled of modular units, each individually and independently tested, approved and documented under all conceivable operating conditions prior to inclusion into the overall system.

All aspects of the operational control system are subjected to intense scrutiny during the design, commissioning and certification/approval phases of the Project to ensure their suitability for mission critical command and control.

A1.7.3. OPERATIONAL BACK–UP FEATURES

As part of the overall Transrapid safety concept, detailed concepts and procedures have been developed to handle either automatically or manually all foreseeable operational situations. As part of this process all situations are classified as safety or not safety relevant. Safety relevant situations are handled without operator safety responsibility and not safety relevant situations are dealt with as needed to best suit the Transrapid technology and the nature of Transrapid operation. All concepts, procedures and regulations are given the highest levels of scrutiny by independent experts during the development, design, build and commissioning processes to ensure that they truly accomplish the intended result and meet all pertinent safety and operational regulations.

An example of this rigorous safety evaluation is the Transrapid concept of safe hovering. This states that Transrapid will always have the capability to complete its mission in a safe, timely manner. The primary goal is always to complete the trip to the next available station. In most daily situations, sufficient redundancy is available in the system effected to allow operation to continue without notice to the passenger and correction/repair to occur outside of the normal operations period.

Should the propulsion system lose external power for example (from the public grid), on–board vehicle batteries will maintain levitation and all on–board functions to allow the train to automatically brake in a controlled and safe fashion to the next predetermined stopping area. Here the train will wait until the situation causing the power loss is corrected. In the stopping area, the contactless inductive power supply system IPS will recharge the batteries and access for evacuation vehicles will be provided, should the delay be greater than deemed appropriate for the passengers on board. After correction of the situation, the train will automatically resume its trip.

A1.8. MAINTENANCE

A1.8.1. OVERVIEW

As required in the German Maglev Construction and Operations Ordinance, maintenance measures have to be defined in maintenance programs. The principles and techniques upon which the maintenance programs are based are subject to approval by the regulating authorities. For the Transrapid system, the principles and techniques have been determined for both the maintenance measures and expense, using a methodology of maintenance analysis similar to that of civil aviation and adopted on the basis of experience and test results at the Emsland Test Facility. Maintenance activities are mainly determined by inspection of mechanical structure in vehicles and guideway and by exchange of defective electronic components.

The primary objectives to developing the maintenance philosophy for Transrapid were:

- maximise system availability
- maintain system operation after individual failure through component redundancy
- minimise operation and maintenance costs through modular design utilising standard components where available.

The Transrapid design ensures there is no moving contact, during normal operation, between vehicles and guideway. This lack of contact minimises maintenance activities and ensures a long service life.

The Transrapid decentralised maintenance philosophy and the maintenance facilities are equipped to handle the daily, periodic, unscheduled and long–term overhaul type maintenance for the Transrapid vehicles and all equipment and components involved in the system.

Where possible, Transrapid functional (electronic and mechanical) systems are designed and built into modular easily replaceable units. These modules are typically only removed and replaced with fully functional units. In this way, rapid turnaround of the vehicles and/or return to service for components is assured, thereby ensuring industry standard levels of availability and reliability at minimum maintenance cost. The units removed from service are then tested and repaired off–line, either on–site in the maintenance facility or at a subcontractor or unit supplier. Whenever possible these testing and quality assurance functions are handled by automatic equipment and systems. Some vehicle modules for example, require over 6000 automated tests to certify them fit for service.

A1.8.2. DIAGNOSTIC MAINTENANCE SYSTEM

The Transrapid systems continuously undergo diagnostic testing with resulting data fed into the maintenance database. Data may be a failure notification or information such as system start up or OK notification. When testing detects a functional failure, a failure notification is automatically forwarded to the maintenance database. Failure notifications are stored after checking for prior reports for the same failure.

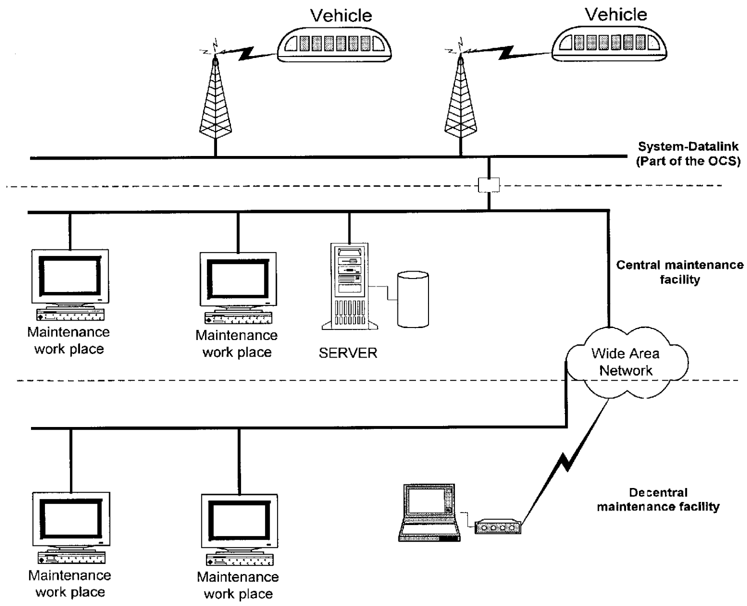
User interaction on the maintenance database is limited to:

- add unrecognised defects and obtain statistics
- maintenance staff acknowledgement of failures and initialisation of maintenance action
- maintenance staff acknowledgement of repair completion to clear fault status

To trace problems the maintenance system allows a full history to be kept on all modules.

Figure A.19

Diagnostic maintenance system overview



A1.8.3. USABLE SYSTEM LIFESPAN

The Transrapid system has been designed for long service life when proper operational and maintenance procedures are followed. Where possible, all systems are designed and built to only require periodic inspections and minimum or no daily maintenance activities.

The trains are the only major "moving part" in the system and obviously require the most maintenance. In general, major overhauls are expected every 8–10 years with interior refurbishing every 10–15 years depending on use and operator desires. Routine service visits to the central maintenance facility would be expected approximately every eight weeks. This would include the replacement of failed non–critical modules.

An overview of the usable lifespans of the major Transrapid subsystems is shown in Table A.4. These technical lifespans are expected for the subsystems when operated and maintained according to the Transrapid operation and maintenance standards and specifications.

Table A.4

Technical lifespans

Guideway	
Superstructures (guideway beams and transfer tables) including guideway equipment (mechanical components)	80 years
Substructures	80 years
Bendable switch beams depending on operating profile:	
three way switches	>25 – 80 years
two way switches	> 30 – 80 years
Operating System	
Central operating facility, substations, wayside switches	30 years
Wayside cable, energy and signal transmission systems	40 years
Trains	35 years

A1.9. COMPARISON OF COMPETING TECHNOLOGIES

Transrapid does not conform to the traditional view of rail technology. Table A.5 compares key parameters to illustrate how Transrapid is more efficient, less intrusive and more flexible than a typical high speed rail system.

Table A.5

Technology Comparison

Parameter	**Transrapid**	**Typical High Speed Rail System (see note 1)**
Maximum operating speed		
Rural	500 km/h	300 km/h
Urban	250 km/h	100 km/h
Acceleration times		
0 – 200 km/h	62 s	104 s
0 – 300 km/h	104 s	370 s
0 – 400 km/h	159 s	–
Distance for acceleration		
0 – 200 km/h	1.72 km	4.40 km
0 – 300 km/h	4.34 km	20.9 km
0 – 400 km/h	8.82 km	–
Braking distance from 300 km/h	4.34 km	4.96 km
Energy consumption (see note 2)		
200 km/h	22 Wh/Plkm	29 Wh/Plkm
300 km/h	34 Wh/Plkm	51 Wh/Plkm
Noise levels at 25m		See note 3
200 km/h	72-73 dB(A)	82-84 dB(A)
300 km/h	79-80 dB(A)	90-91 dB(A)
400 km/h	86-88 dB(A)	–
Maximum gradient capability	10%	4%
Maximum cant (superelevation) in extreme cases	12° 16°	6.9°
Minimum curve radii		
200 km/h	0.7 km	1.4 km
300 km/h	1.59 km	3.2 km
400 km/h	2.83 km	–
Minimum vertical radii at 200 km/h		
Sag	2.57 km	14 km
Crest	5.15 km	16 km

Notes: 1. These measurements are for ICE 3

2. Measured for a standard speed profile with maximum speed shown

3. This measurement is for ICE 1

Transrapid International

A joint company of
Siemens and ThyssenKrupp

High-Tech for "Flying on the Ground"

Maglev System Transrapid

Driving Without Wheels – *Flying Without Wings*

The maglev system Transrapid is a track-bound transportation system for passenger and high-value cargo traffic. It is the first fundamental innovation in railroad technology since the construction of the first railroad.

The non-contact technology of the maglev system Transrapid – electronics are used instead of mechanical components – overcomes for the first time the technical and economic limitations of wheel-on-rail technology.

In operation, the Transrapid is quieter, more cost-efficient, and consumes less energy than any other railroad system. It is virtually impossible to derail and comfortable at all speeds. The guideway of the Transrapid consumes less space and can be flexibly aligned to fit the existing landscape.

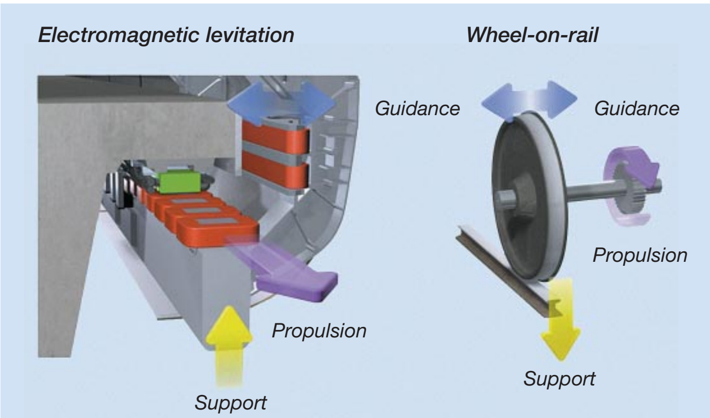
The maglev system Transrapid is the transportation technology of the future. It is ready for revenue operation and the advantageous system characteristics of this new railroad technology "Made in Germany" give it the lead throughout the world.

Essential system characteristics of the Transrapid maglev system are:

- *the non-contact and non-wearing levitation, guidance, and propulsion technology which is independent of friction*
- *the synchronous longstator linear motor integrated into the guideway*
- *the high standards of safety and comfort at all speeds*
- *the high acceleration and braking power*
- *the flexible route alignment of the guideway due to small curve radii and high grade climbing ability (10%)*
- *the low noise emission*
- *the low specific energy consumption and low operating costs*
- *the minimal land consumption of the guideway for both at-grade and elevated versions*

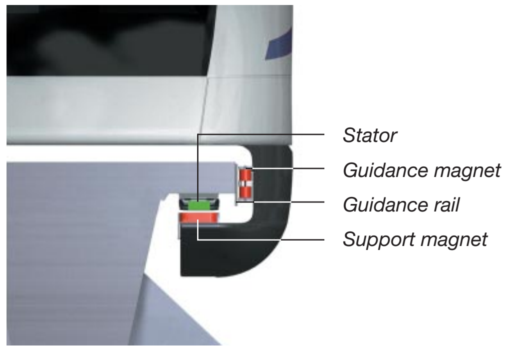
Electricity and Electronics – *Instead of Mechanics*

The Transrapid maglev system has no wheels, axles, transmissions, and overhead wires. It doesn‘t roll, it hovers. The wheels and rails of the railroad are replaced by non-contact, electromagnetic support, guidance, and propulsion systems.



Support and Guidance System

The non-contact support and guidance system of the Transrapid maglev system functions according to the principle of electromagnetic levitation. It uses the attractive forces between the individual, electronically controlled electromagnets in the vehicle and the ferromagnetic reaction rails which are installed on the underside of the guideway. The support magnets pull the vehicle up to the guideway from below, the guidance magnets keep it laterally on track.



The support and guidance magnets are arranged on both sides along the entire length of the vehicle.

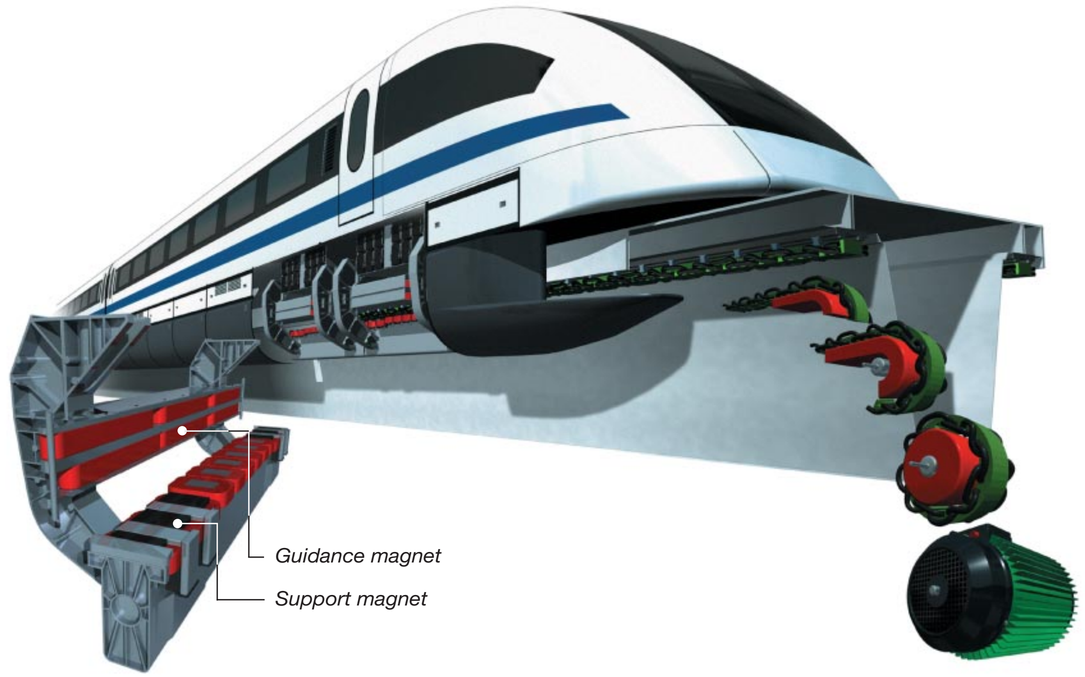
A highly reliable, fully redundant electronic control system ensures that the vehicle hovers at an average distance of about 10 mm (3/8 in) from its guideway. The distance between the top of the guideway and the underside of the vehicle during levitation is 150 mm (6 in), enabling the maglev vehicle to hover over objects or a layer of snow.

The design of the Transrapid support, guidance, and propulsion systems is modular, failure tolerant, and equipped with automatic diagnostic systems. This ensures that the failure of individual components does not result in a disturbance of operation.

Propulsion System

The synchronous longstator linear motor of the Transrapid maglev system is used both for propulsion and braking. The function of this non-contact propulsion and braking system can be derived from the functional principle of a rotating electric motor whose stator is cut open and stretched along both sides of the guideway. Instead of a rotary magnetic field, the motor generates an electromagnetic traveling field. The support magnets in the vehicle function as the rotor (excitation portion) of the electric motor.

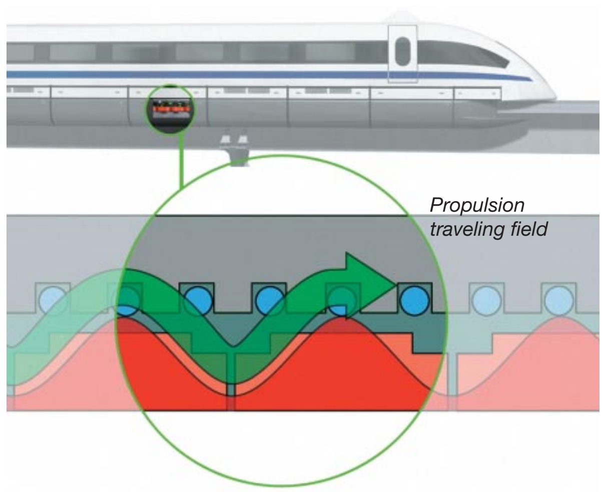
In contrast to the conventional railroad, the primary propulsion component of the Transrapid maglev system – the stator packs with three-phase motor winding – are not installed in the guideway but in the guideway.



By supplying alternating current to the three-phase motor winding, an electromagnetic traveling field is generated which moves the vehicle, pulled along by its support magnets which act as the excitation component. The speed can be continuously regulated from standstill to full operating speed by varying the frequency of the alternating current. If the force direction of the traveling field is reversed, the motor becomes a generator which brakes the vehicle without any contact. The braking energy can be fed back into the public network.

The longstator linear motor in the guideway is divided into individual motor sections which are only supplied with power as the vehicle passes.

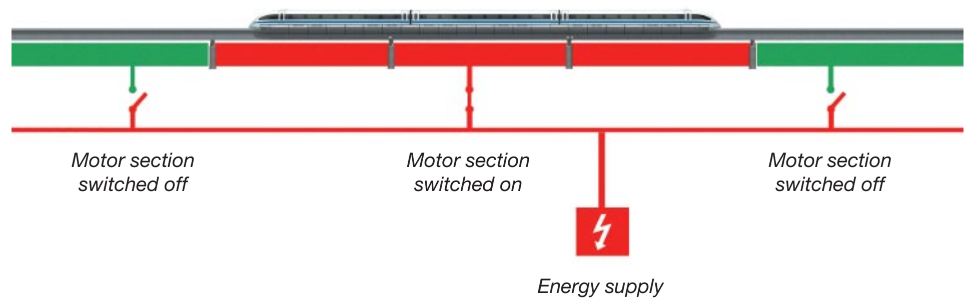
The location and the installed power of the substations depends on the requirements on the propulsion system.



In sections where high thrust is required, e.g. gradients, acceleration, and braking sections, the power of the substations is higher than on level sections which are traveled at constant speed.

And because the primary component of the propulsion system is installed in the guideway, Transrapid vehicles need not carry the entire motor power for the peak requirements, as is the case with other types of vehicles.

The support and guidance system is supplied with energy without contact via the linear generators integrated into the support magnets. No overhead wires are required for the Transrapid. In the event of a power failure, energy is supplied from on-board batteries which are charged by the linear generators during travel.



Technology Made for the Times – and Comfortable Travel

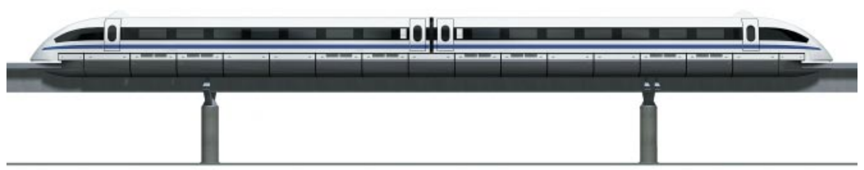
Transrapid – Vehicles for Passengers and High-Value Cargo

The Transrapid vehicles are flexibly configured to fit the requirements of the most diverse applications. The vehicle sections are built using lightweight, modular structures and can be combined into trains with two to ten sections depending on the application and traffic volume. In addition to passengers, the Transrapid can also carry high-value cargo in specially designed cargo sections. These can be used for dedicated high-speed cargo trains or added to passenger trains for mixed service.

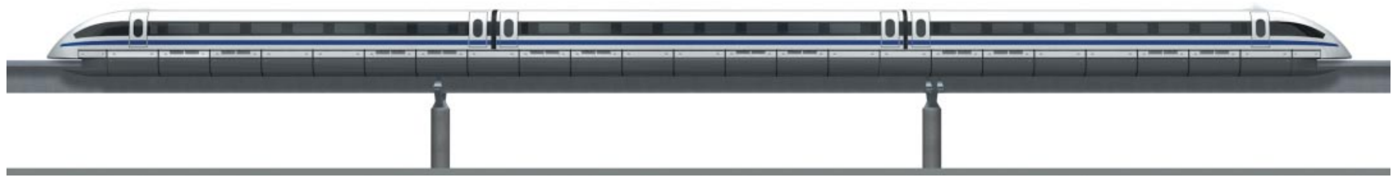
Together, the vehicle body and the maglev undercarriage form a vehicle section. Each vehicle section has four levitation chassis which serve to transmit the forces for propulsion, support, guidance, and braking. To ensure optimum traveling comfort, the levitation chassis are connected to the vehicle body via a self-leveling air spring and pendulum suspension.

All moving mechanical elements between the vehicle body and the magnets are mounted on vibration-dampening rubber/metal elements. A support and a guidance magnet or a support and a brake magnet are mounted to a pair of levitation frames to form a single magnet module.

Standardized fastening elements are used for the interior furnishings of the vehicles. These furnishings are modularly designed so the requirements of the operator can be met in an economical and flexible fashion.



Two sections



Three sections

The on-board equipment is supplied with power without contact (as are the support and guidance systems). Near stations the on-board power is supplied by power rails mounted to the guideway.

The Transrapid vehicles can be designed almost exclusively under aerodynamic aspects. Therefore, there is little air turbulence when a Transrapid vehicle passes by. The pressure distribution along the vehicle and its impact on oncoming vehicles has been calculated using methods developed in the aeronautical and aerospace industries and confirmed by measurements at the Transrapid Test Facility (TVE). Travel comfort is not affected when one vehicle passes another because the vehicle body is pressure-sealed.

Technical Data			
Length	*end section*	*25.5 m/27.0 m*	*83.7 ft/88.6 ft*
	middle section	*24.8 m*	*81.4 ft*
Width		*3.7 m*	*12.1 ft*
Height		*4.2 m*	*13.8 ft*
Maximum operational speed			*500 km/h (310 mph)*
Empty weight, passenger vehicle	*per section*		*approx. 53 t*
Empty weight, cargo vehicle	*per section*		*approx. 48 t*
Useful payload, cargo vehicle	*per section*		*approx. 15 t*
Seats, passenger vehicle	*end section*		*max. 92*
	middle section		*max. 126*

The Best “Way” –
Precision on Every Level

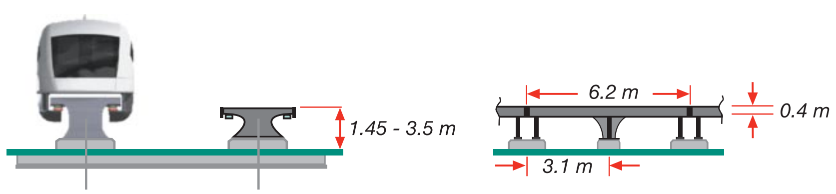
In conventional railroad systems, the function of the track is limited to supporting the loads from the vehicle and guiding it along the route. By comparison, the Transrapid‘s guideway has the propulsion system integrated into it and together with the vehicle, they form an integrated system. To achieve the best possible ride comfort, the requirements of the guideway in terms of fabrication, equipment, availability, and service life are especially high. Whether at-grade or elevated, whether concrete or steel construction, the Transrapid guideway meets all of these requirements. The precision of the functional surfaces is ensured by integrating the entire process – from initial layout of the route to manufacture of the guideway components to final installation and commissioning on site – using the most modern, computerized equipment and techniques.

Single and double track guideways (length of guideway beams from 6 m to 62 m / 20 ft - 203.4 ft) can be built in steel, concrete, and hybrid construction. The guideway can be installed at-grade or elevated depending on the local situation. The track center-to-center distance of the double track guideway is 4.4 m up to 300 km/h or 5.1 m up to 500 km/h (14.4 ft up to 185 mph or 16.7 ft up to 310 mph). The clearance envelopes are 10.1 m and 11.4 m (33.1 ft and 37.4 ft), respectively; the track gauge is 2.8 m (9.2 ft).

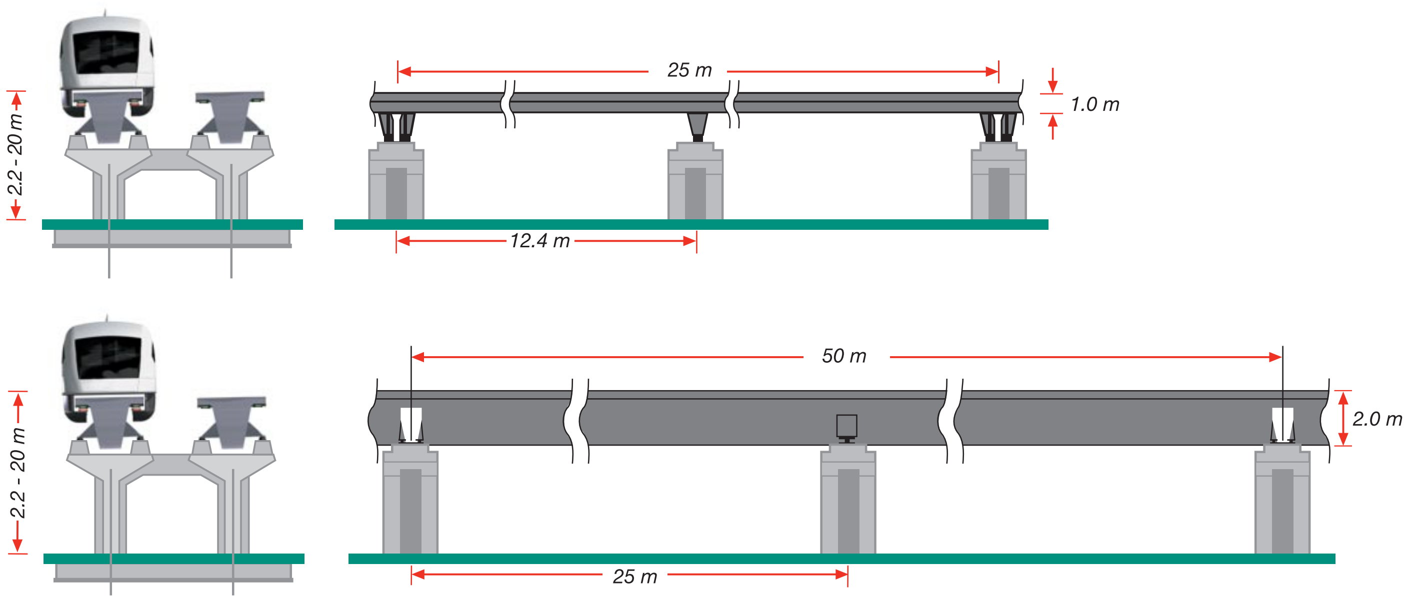
Elevated Guideway

Elevated guideway is especially appropriate in areas which should not be separated for environmental or agricultural reasons and/or where existing traffic routes should not be effected by the new line. Variable column heights of up to 20 m (65 ft) and standard beam spans of up to 31 m (102 ft) allow flexible adaptation of the guideway to the topography.

At-grade guideway



Elevated guideway



At-Grade Guideway

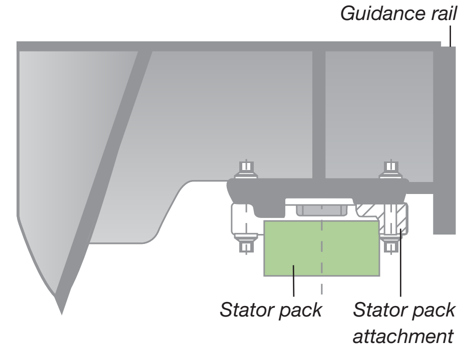
The guideway is installed at-grade mainly where it can be collocated with existing traffic routes (roads, railroads) as well as in cuttings, tunnels, and on primary civil structures such as bridges and stations. Specific features are the standard beam span of 6 m - 12 m (20 ft - 40 ft) and gradients of 1.45 m to 3.5 m (4.8 ft - 11.5 ft).

Switches

The Transrapid maglev system changes tracks using steel bendable switches. They consist of continuous steel box beams with lengths between 78 m and 148 m (256 ft - 486 ft) which are elastically bent by means of electromagnetic setting drives and securely locked in their end positions. This function is electronically controlled and safeguarded.

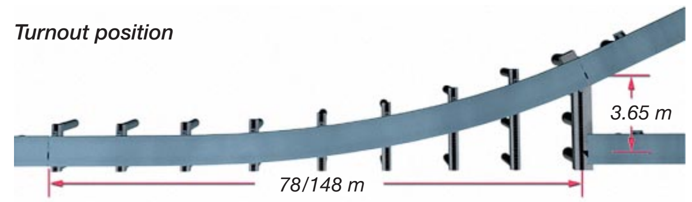
Bendable switches can be designed as two-way or three-way switches, either at-grade or elevated. In the straight position, the vehicle can cross the switch without speed restrictions, in the turnout position, the speed is limited to 200 km/h (125 mph) (high speed switch) or 100 km/h (62 mph) (low speed switch).
In parking and maintenance facilities, tracks can also be changed using a transfer table. These operate by laterally moving a straight length of guideway (with the vehicle sitting stationary on top) to access multiple tracks.

Guideway structure



Straight position

Turnout position



The Best “Way” –
Precision on Every Level

Substructures

The amount of ground work required for the guideway foundations depends on the local soil conditions. Typically, flat foundations are sufficient. Pile foundations are necessary only where local soil conditions are difficult. In all cases, the foundations lie approx. 30 cm (12 in) below the surface to minimize effects on water run-off and small animals. There are also passages for small animals below the at-grade guideway.

Tunnels

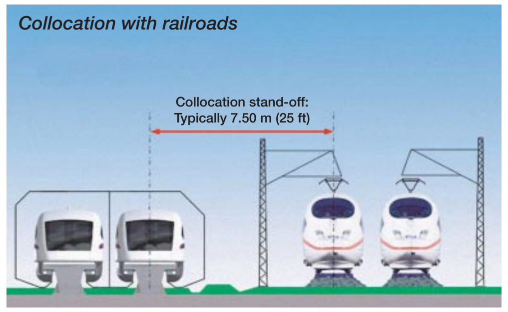
With its flexible route alignment parameters, the Transrapid guideway can be adapted to a great extent to the landscape. Therefore, tunnels are seldom necessary, even in hilly and mountainous terrain. Even when they are required, the tunnel cross-sections necessary for the Transrapid are smaller than those of railroads. This is due to the smooth, aerodynamic shape of the vehicle and small clearance envelope.

Typical tunnel cross-sections for tunnels longer than 150 m (492 ft) and vehicles with 2 to 8 sections are shown in the table:

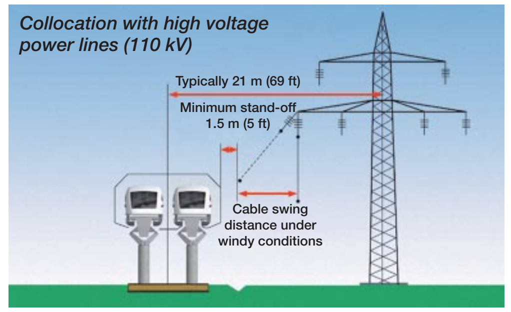
Cross-sectional area, tunnel length > 150 m (492 ft)			
for a speed of:	*250 km/h* *155 mph*	*400 km/h* *250 mph*	*450 km/h* *280 mph*
single track tunnel	*36 m^2* *388 ft^2*	*85 m^2* *915 ft^2*	*120 m^2* *1292 ft^2*
double track tunnel	*70 m^2* *753 ft^2*	*180 m^2* *1938 ft^2*	*225 m^2* *2422 ft^2*

Route Alignment Parameters

The active magnetic guidance and the flexibility in the design of the propulsion system in the guideway to meet the specific required conditions enable particularly favorable route alignment parameters for the Transrapid maglev system. These favorable parameters also allow the guideway to be flexibly adapted to the landscape as well as enabling collation with existing traffic routes.



Collocation with railroads



Collocation with high voltage power lines (110 kV)

Connection with other modes of transport and routes

Transrapid stations are all typically designed as intermodal stations with other transport systems, railways, road and air. They are planned to be easily reached and are laid out so that the traveller has a convenient connection into long-distance trains, local trains, road transport or to the airport for more distant destinations. Railways and Transrapid are especially complementary to one another, forming an attractive combination for the traveller.

The degree of acceptance and economics of the Maglev depend on accessibility of the stations. This is why great care is taken at the planning stage to ensure there is convenient connection not just with the railways, but with road systems also.

The overburdened roads can only be effectively relieved when the change to the alternative mode is as convenient as possible for the motorist. This is guaranteed by connection of the stations to the trunk road network and to park-and-ride facilities.

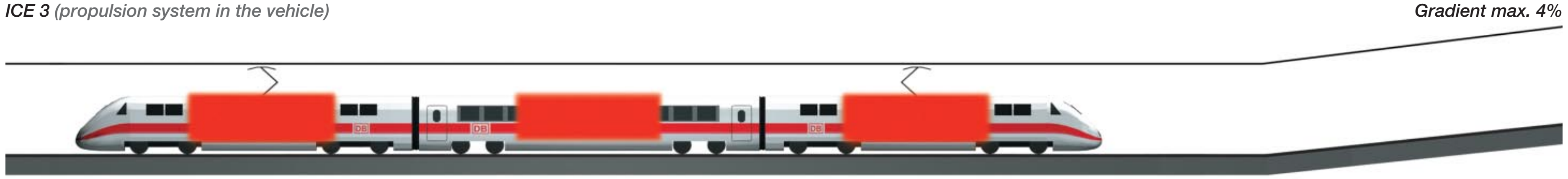
For these reasons, the planning takes into account both existing railway stations and connections into the individual transport network.

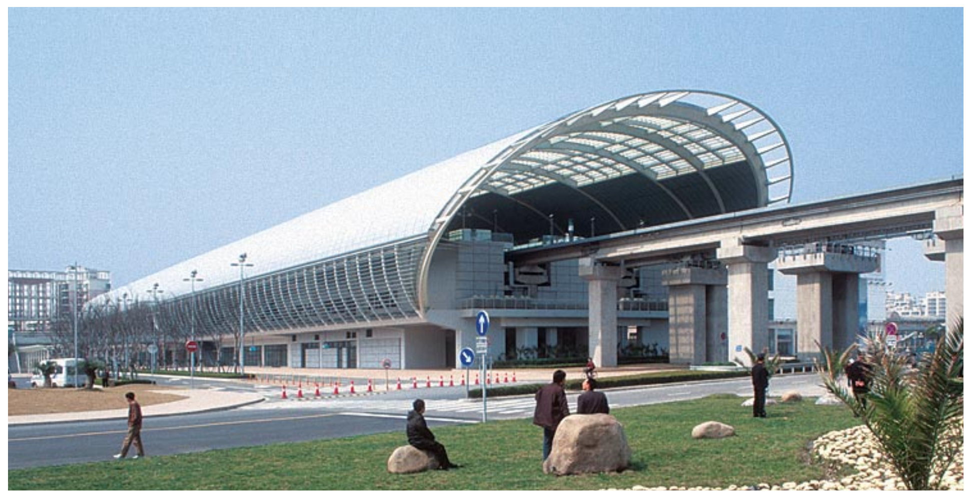
Transrapid (propulsion system in the guideway)

Gradient 10%

ICE 3 (propulsion system in the vehicle)

Gradient max. 4%





The Best System –
Innovation for More Safety

Despite the high speeds of up to 500 km/h (310 mph), you are safer on board the Transrapid than in any other means of transport. The vehicle virtually cannot derail because it wraps around its guideway. And since grade crossings are not allowed, nothing can get in its way.

Collisions between Transrapid vehicles are also ruled out due to the technical layout of the system and the section-wise switching of the "guideway motor". The vehicle and the travelling field of the guideway motor move synchronously, i.e. with the same speed and in the same direction. Additionally, the section of the longstator linear motor in which the vehicle is moving is only switched on as the vehicle passes.

With regard to fire protection, the Transrapid meets the highest requirements of the relevant standards. There are no fuels or combustible materials on board. Only materials that are highly fire resistant, poor conductors of heat, burn-through-proof, and heat-proof are used in the vehicles. As an additional safety precaution, the vehicle sections can be separated by fireproof doors.

Other important elements of the safety concept are:

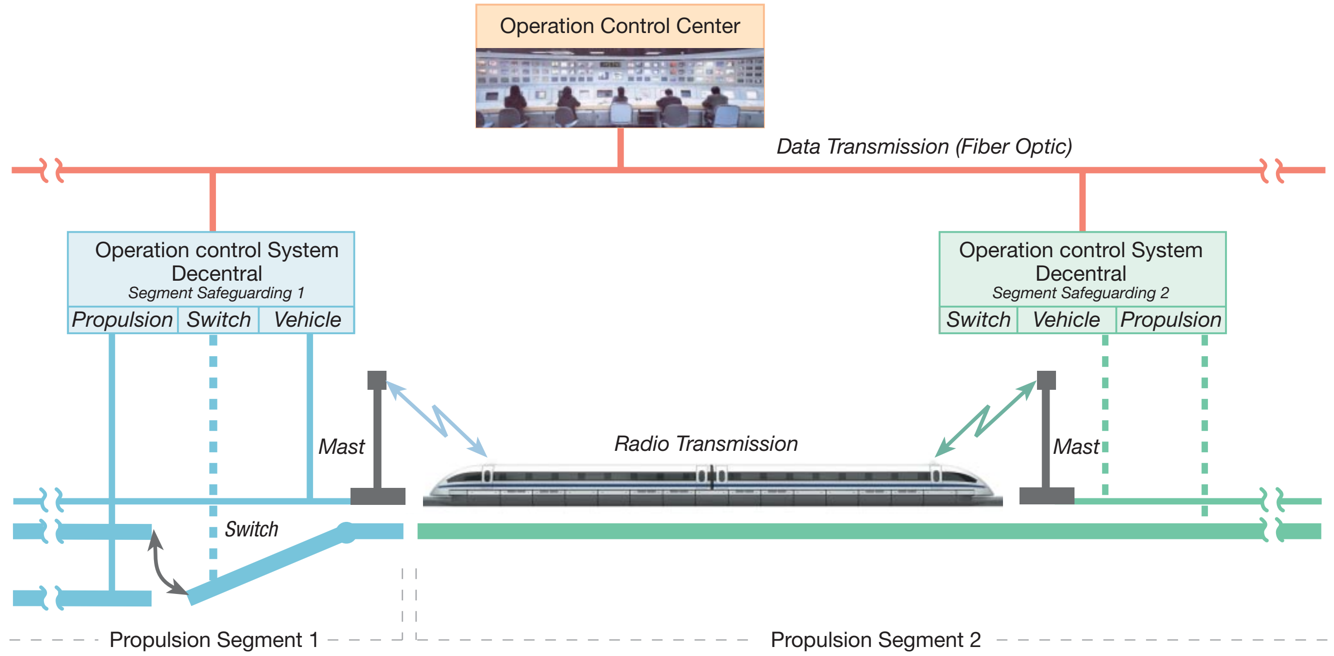
- automatic train protection
- passive protection equipment to prevent damage to the guideway structure and violation of the vehicle's clearance envelope
- automatic inspection of the guideway
- protection of the passengers during boarding and exit in the stations by means of platform doors and gap bridges

Even if the power from the public grid fails while the vehicle is running, only the propulsion system (motor) is lost. The vehicle levitation system and all on-board equipment are supplied from on-board batteries, so the vehicle continues to levitate and move forward with its existing "momentum".

If the next station is too far away, the vehicle will be automatically braked to a stop at the next available auxiliary stopping area. These areas are set up for this purpose along the route and convenient access is provided for support services, should they be required.

Under these circumstances, the vehicle is braked using eddy current brakes located in each section, also supplied from the on-board batteries. The eddy-current brakes slow the vehicle down to 10 km/h (6 mph), upon which the vehicle then sets down on its skids and stops.

Even in the rare case of a significant technical failure in the Transrapid system, the vehicle will always be brought to a stop automatically at an auxiliary stopping area.



Operation Control System

The operation control system of the Transrapid maglev system is characterized by central automatic control of the operation according to programmed trip schedules in conjunction with decentral monitoring and safeguarding of all routes and vehicle movements. The conventional tasks of the train driver, i.e. the proper control of driving and braking operations according to the train's location, are completely replaced by the Transrapid operation control system.

The equipment for safeguarding operation are located in the vehicle and in stationary facilities. A highly reliable, line-of-sight radio transmission system is used to exchange data between the two. The specific arrangement of the radio masts along the route ensures that the two redundant antennas on the vehicle can always receive signals from two separate radio masts at all times.

The vehicles are securely located using digitally encoded flags mounted on the guideway and the vehicle's speed limit is constantly supervised. The automatic shut down of the propulsion power and the activation of the vehicle's eddy-current brakes are primary safety functions of the operation control system when a speed limit has been exceeded. Additionally, the distance between adjacent vehicles along the route, operation of the guideway switches, the passenger protection equipment in the stations, as well as many other functions and processes are controlled and safeguarded by the operation control system.

The elimination of safety responsibility by the operating personnel during revenue operation and the certified, high safety standard for signal technology in the Transrapid equipment guarantee a high level of safety in the entire system.

Additional tasks of the operation control system include documentation of the vehicle operation and providing up-to-date information for both the operating personnel and passengers.

A Comparison of Economic Efficiency – Good Reasons for New Ways

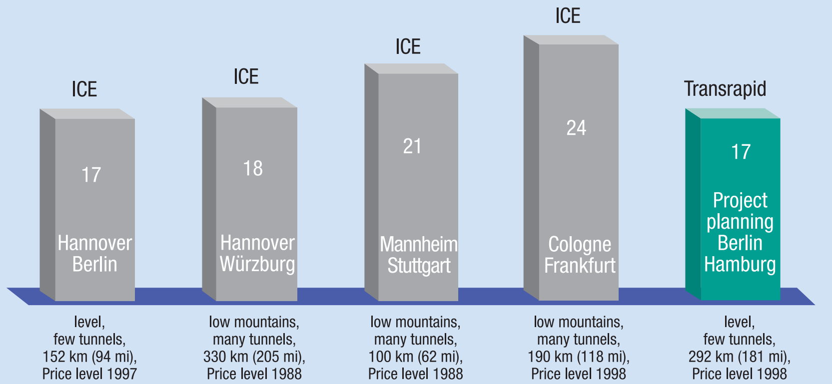
Investment Costs

The manufacture and construction of the guideway infrastructure are a significant portion of the overall Transrapid maglev system investment costs. Despite the higher performance of these routes though, the investment costs for Transrapid maglev routes are comparable to those for high-speed rail.

A comparison of the infrastructure investment costs favors the Transrapid maglev system even more when the route passes through difficult terrain. Here the flexible route alignment parameters of the Transrapid (small curve radii, high grade climbing ability, standard elevated guideway, etc.) can be used to adapt the guideway to the surroundings instead of the other way around. The need for expensive civil structures such as bridges and tunnels can therefore be reduced significantly.

The high average speeds of the Transrapid translate into short trip times. They also result in smaller vehicle fleet sizes than comparable high speed rail systems because fewer vehicles are required to handle the same volume of traffic. Fewer vehicles mean lower investment costs, both for the vehicles themselves and for the maintenance and parking facilities required for the route – they may also be smaller.

Guideway Infrastructure Investment Costs for German ICE and Transrapid Routes
cost in million € / double track km



New route including track infrastructure, operation/maintenance facilities without trains and stations

New route including guideway infrastructure, operation/maintenance facilities without vehicles and stations

Operation and Maintenance Costs

The operation and maintenance costs of the Transrapid maglev system are lower than those of comparable transportation systems. In general, the operation and maintenance costs fall into three categories – personnel, maintenance, and energy consumption. The following applies to the Transrapid:

- The smaller vehicle fleet requires fewer operating and maintenance personnel as well as fewer spare parts and materials.
- With its fully automatic operation, the personnel requirements are lower in general compared with other transportation systems.
- The specific energy consumption (per seat) is lower than comparable transportation systems at equivalent speeds.
- The vehicle loads on the guideway are distributed (no point loading) which result in lower static and dynamic loads over the entire speed range and consequently, less stress on the guideway.
- The non-contact technology reduces mechanical wear and tear (vehicle operation causes neither misalignment nor wear of the guideway structure, equipment, and surfaces).
- Most mechanical components which may wear have been replaced by non-wearing electronic and electromagnetic components.

Maintenance

Central and decentral maintenance facilities for the vehicles are located along the route, depending on the operational requirements. They are laid out and equipped to allow quick replacement of faulty components and modules which can later be repaired on- or off-site.

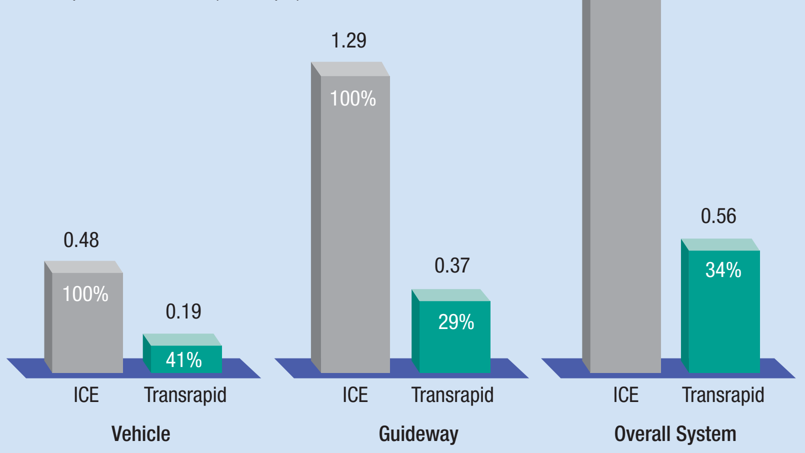
Due to the non-contact and non-wearing technology, maintenance of the guideway and the guideway equipment is primarily restricted to the conventional civil structures, unless damage occurs through external influences which cannot be foreseen.

The guideway is inspected and monitored from the guideway itself by means of a special maintenance vehicle which is equipped with modules for various activities, such as:

- dimensional measurement systems for detection of changes to the guideway, in particular to the stator packs, guidance rails, and beam bearings
- an optical inspection system with digital image processing to check and monitor the condition of the guideway components and surfaces

An access road along the guideway is not required for maintenance purposes.

Overall System Maintenance Costs
Cent per seat-km at Operating Speed:
ICE = 250 km/h (155 mph)
Transrapid = 450 km/h (280 mph)



Where the Air is Clean –
An Environmentally Friendly System

Environmental Compatibility

The development and introduction of a new transportation system like the Transrapid maglev system makes the most sense when it is also has ecological advantages and can contribute to a reduction in pollution caused by traffic.

Positive environmental characteristics of the Transrapid:

- *No rolling or propulsion noise due to the non-contact technology.*
- *Independent of the type of primary energy.*
- *No emission of combustion gases or other pollutants along the route.*
- *Low land consumption of the elevated and at-grade guideway. Continued use of the space under the elevated guideway, e.g. for agriculture.*
- *No division of the landscape, developed structures, or biological habitats through use of the elevated guideway.*
- *No impairment of game movements with the elevated guideway and uninhibited passage for amphibians and small animals under the at-grade guideway.*
- *Few embankments and cuttings and thus minimal disruption of the landscape.*
- *Ability to adapt to the topographic conditions with the various guideway types and flexible route alignment parameters.*

Noise Emission

Sound can be unpleasant or even painful but also as something so beautiful that we expose ourselves to it voluntarily. Whether or not a sound is pleasant or deemed as noise depends on the personal assessment of each individual. Such a subjective sensation cannot be measured objectively.

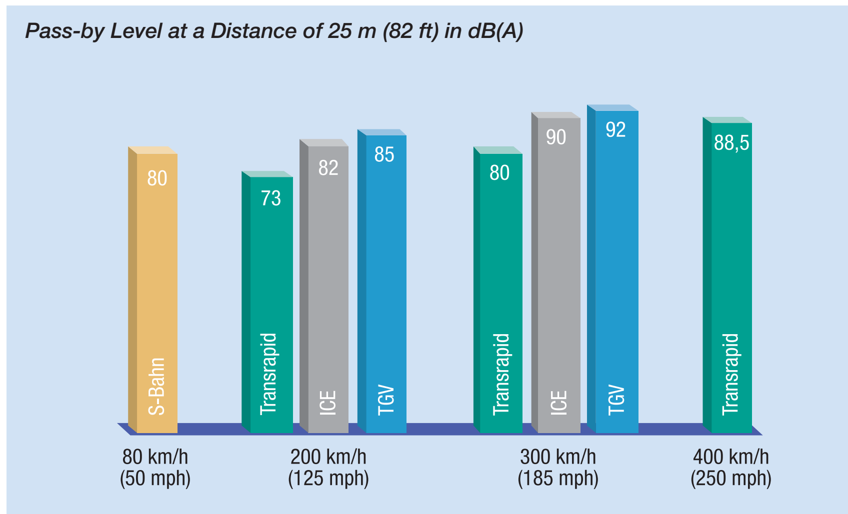
However, sound levels can be measured, i.e. the pressure variations generated by a source of sound in the air. Sound pressure levels are measured in dB (A). This international measuring unit imitates the sensitivity of the human ear. The scale ranges from 0 dB (A) (audible threshold) to 130 dB (A) (pain threshold).

Between the thresholds of audibility and pain, the human ear‘s range of sensitivity to acoustic pressure is wide. To be able to capture this range between the values 0 to 130 dB (A), the decibel scale is logarithmic. An increase of 10 dB (A) is perceived as a doubling of the loudness of the noise.

Compared with other transport systems, the Transrapid is extremely quiet. There is no rolling or propulsion noise. At speeds up to 250 km/h (155 mph), the Transrapid hovers almost without noise through cities and metropolitan areas.

Due to the non-contact levitation and propulsion technology, the noise emission of the superspeed maglev system at speeds above 250 km/h (155 mph) is mainly determined by aerodynamic noise.

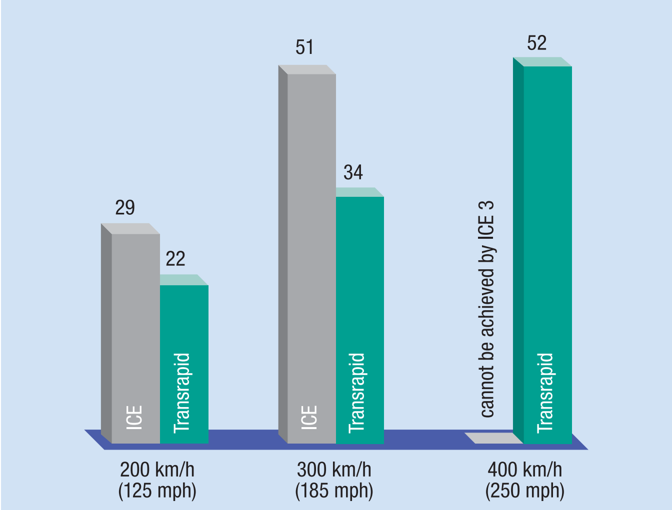
The pass-by noise levels of the Transrapid have been extensively measured at the Transrapid Test Facility (TVE).



Where the Air is Clean –
An Environmentally Friendly System

Energy Consumption

The favorable energy consumption figures of the Transrapid system are a result of the use of modern power electronics, the lack of electro-mechanical energy conversion using friction-based elements for propulsion and on-board power supply, the high efficiency of the synchronous longstator motor with excitation by the vehicle's support magnets, and the favorable vehicle data, e.g. the low mass of approx. 0.5 t per seat and the low running resistance of approx. 0.2 kN per seat at 400 km/h (250 mph).



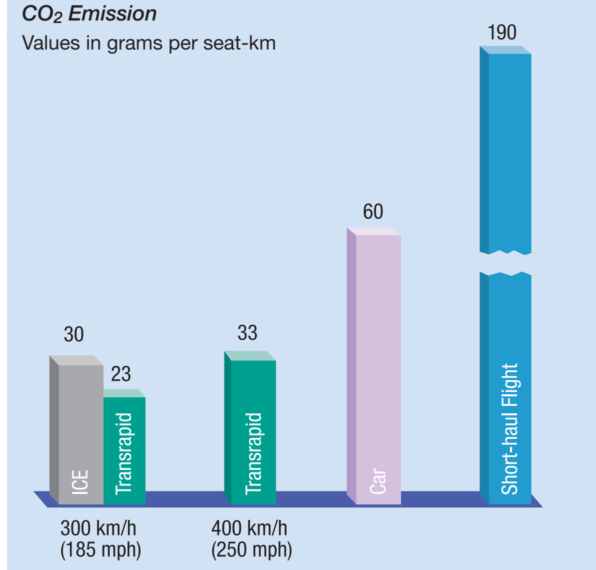
Specific Energy Consumption
Values in watt-hours (Wh) per seat-km

The secondary energy demand encompasses traction power including electricity for on-board consumption.

When compared at equivalent distances, the specific primary energy consumption of automobile traffic is three times higher and air traffic five times higher than the Transrapid.

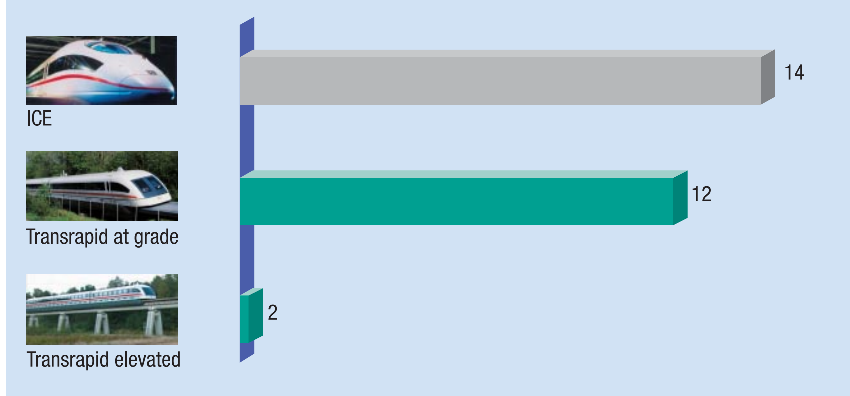
CO_2 Emission

Lower energy consumption also means lower CO_2 emission. The CO_2 emission depends on the primary energy consumption, the method and raw materials used to generate the energy, and how it is distributed.



CO_2 Emission
Values in grams per seat-km

The Transrapid maglev system is supplied from the public electricity network.
The German ICE is supplied from Deutsche Bahn's electricity network which has lower CO_2 emissions per watt-hour (Wh) than the public network.



Land Consumption in Comparison (m^2/m)

Land Consumption

The Transrapid maglev system requires the lowest amount of space and land for the guideway infrastructure and related facilities in comparison with other transportation systems.

The space required for standard, elevated, double track guideway for the Transrapid including substations and wayside equipment is approx. 2.1 m^2/m (6.89 ft^2/ft).

The space required for standard, at-grade, double track guideway including substations and wayside equipment is approx. 12 m^2/m (39.37 ft^2/ft).

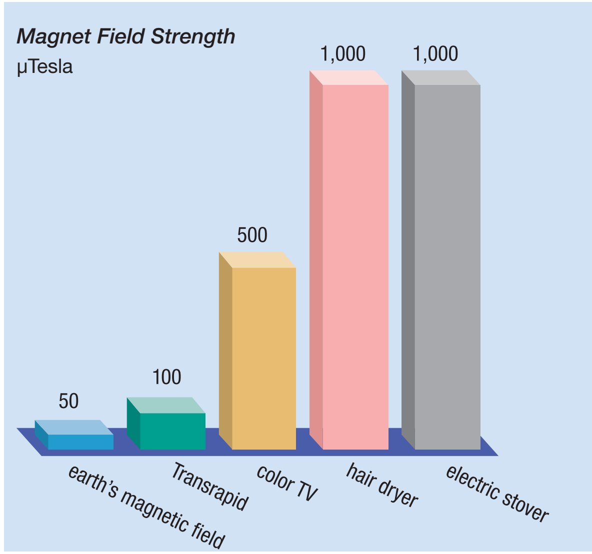
An access road along the guideway is not required after construction has been completed – neither for safety reasons nor for maintenance of the guideway and wayside equipment.

Where the Air is Clean –
An Environmentally Friendly System

Magnetic Fields

The impact of magnetic fields produced by the Transrapid maglev system on passengers and the environment is extremely small. It is in fact, comparable to the earth's residual magnetic field and thus far below the field intensity produced by many common household appliances. A hair dryer, a toaster, or an electric sewing machine are surrounded by far stronger magnetic fields than those occurring in the passenger compartment of the Transrapid vehicle. The magnetic fields along the guideway are even weaker.

The electromagnetic fields generated in the longstator motor, the support and guidance system, and the radio transmission system have been measured by various experts including the *Forschungsgesellschaft für Energie und Umwelttechnologie* (Research Association for Energy and Environmental Technology) on behalf of the *Bundesanstalt für Arbeitsmedizin* (German Federal Office for Occupational Medicine). Over the entire frequency range, the electromagnetic field intensities are 20 to 1,000 times lower than the admissible limits in the Bundesimmissionsschutz-Verordnung (German Federal Immission Control Act). Thus adverse effects on pace-makers or magnetic cards (e.g. credit cards) are ruled out.



Aerodynamic Effects

The air flow surrounding the Transrapid has been extensively studied at the Transrapid Test Facility (TVE) with the following results:

- There are no perceivable aerodynamic effects under the elevated guideway over the entire speed range.
- Aerodynamic effects comparable to gentle wind can be detected when the Transrapid vehicle passes over the at-grade guideway. Small pebbles on the ground directly under the vehicle and guideway are not disturbed.
- The air flow velocity along the vehicle at a distanceof 1 m (3.3 ft) and a speed of 350 km/h (220 mph) is less than 10 km/h (6 mph).

Vibration

When the Transrapid passes by, vibrations are passed from the guideway into the ground via the foundations. These vibrations are subject in Germany to the Federal Immisson Control Act. In accordance with DIN 4150, vibration severity is measured in KB and takes account of the duration and intensity of the influence (similar to the assessment level for sound immission).

Measurements at the Transrapid Test Facility (TVE) have shown that the vibrations at a distance of 25 m (82 ft) and a speed of 250 km/h (155 mph) (a typical speed in urban areas) are below the "threshold of feeling" for human beings. At a distance of 50 m (164 ft), no vibration is perceivable at any speed.

Weather Influences

A tremendous advantage of track-bound transportation systems is that they are relatively unaffected by the weather. This also true for the Transrapid maglev system. Its non-contact technology functions even under extreme weather conditions.

- The propulsion components of the Transrapid maglev system are protected underneath the guideway from snow and ice.
- If more snow or ice collects on the guideway than the specifications allow, a special vehicle will clear the guideway. Clearing is made easier by the smooth upper surface of the guideway.
- Cross winds and gusts have little effect on theTransrapid because of its active control and guidance system. Wind velocities of up to 30 m/s (67 mph) have no effect on operation at all. At theTransrapid Test Facility (TVE), it has been proved that the vehicle can be operated without difficulty at speeds up to 350 km/h (220 mph) with wind gusts up to 150 km/h (94 mph).

Attractive Trip Times – On All Connections

The Transrapid is versatile and suited for many applications. As a fast link between a city center and its outer-lying airport, as a cost-effective and fast connection between city pairs or as long distance transportation system. As part of a sophisticated and powerful intermodal network in which all transportation systems are connected in a sensible way. And not only for high-speed passenger service but also for high-value goods that require urgent delivery.

Modern airports are often located far outside of cities. Frequently, the journey to or from the airport takes as long as the flight itself. A Transrapid city-to-airport link can shorten overall travel time significantly. Available capacities can be better utilized with the traffic volume being handled in an optimal fashion. For such a link, the Transrapid can cover a distance of about 30 km (19 miles) in less than 10 minutes.

Travel Speed

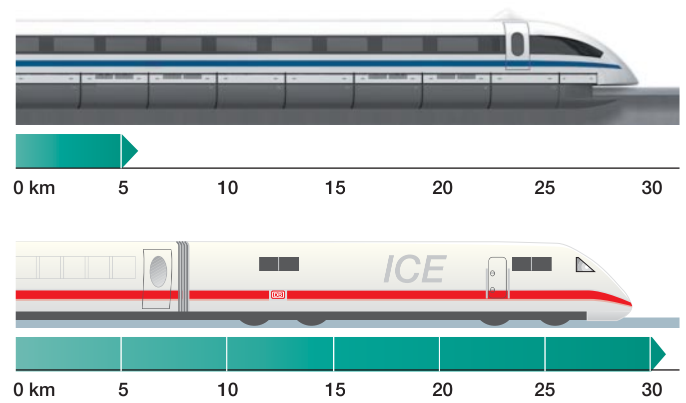
The Transrapid is not only fast, but it can also accelerate quickly to high speeds. 300 km/h (185 mph) can be reached after a distance of only 5 km (3 miles). Modern high-speed trains require more than 28 km (18 miles) and at least four times as long to reach the same speed. The Transrapid maglev system can therefore be used to advantage not only for long distances but also for short and medium distances in metropolitan areas with short intervals between stops.

Modern high-speed railroads generally run at speeds of up to 300 km/h (185 mph) on specially designed and built routes.

The non-contact levitation and propulsion technology of the Transrapid maglev system allows cost-effective operation at considerably higher speeds (500 km/h / 310 mph).

Its extraordinary dynamic performance, high average speed, and a propulsion system which can be tailored to the landscape and conditions, allow Transrapid trip times comparable to those of airplanes for medium and long distances. Even intermediate stops increase the trip time by just a few minutes.

Acceleration to 300 km/h (185 mph)



Transrapid – a Joint Project of Siemens, ThyssenKrupp and Transrapid International.

SIEMENS

With the Transportation Systems (TS) division, Siemens is one of the leading partners to the international railway industry. As single source supplier and system integrator, TS combines comprehensive know-how in its fields of competence Automation & Power, Rolling Stock, Turnkey Systems and Integrated Services – from operation control systems to traction power supplies to rolling stock for mass transit, regional and mainline services. Forward-looking service concepts and extensive experience in project management complement the portfolio. Components supplied for the Transrapid: propulsion system, power supply, operation control system, communication systems and conductor rails.

ThyssenKrupp

ThyssenKrupp has decades of experience with locomotive and wagon building and played a significant role in the successful development of the ICE. Based on the know-how acquired, ThyssenKrupp realized the necessity to overcome the technical and commercial limitations of the wheel-on-rail technology. With the proof of function of the long-stator magnetic levitation technology and the leadership in the development of the system, ThyssenKrupp laid the foundation for the Transrapid system which is now being implemented. Components supplied for the Transrapid: vehicles, propulsion components and guideway equipment.

Transrapid International

To complete the partnership for the Transrapid system, Siemens and ThyssenKrupp have established Transrapid International as a joint company for systems engineering, system integration, marketing, and maintenance support.

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Transrapid Capability

A company
of ThyssenKrupp
Technologies

ThyssenKrupp Transrapid

ThyssenKrupp

Transrapid – a joint project undertaken by ThyssenKrupp, Siemens, and Transrapid International

ThyssenKrupp

Several decades ago, the technology group ThyssenKrupp recognised the necessity of overcoming the technical and commercial limitations of wheel-on-rail technology. As a consequence, ThyssenKrupp began to concentrate on track guided transportation, developing a fundamental innovation in railway engineering: the Transrapid. The magnetic levitation train doesn't have any wheels, axels, gears or overhead contact line. It doesn't roll, it hovers. In place of the wheel and rail of the railway, the Transrapid employs a zero contact electromagnetic support, guidance and drive system – wear-free electronics instead of mechanical components.
With its proof of the functioning of the longstator magnetic levitation technology and its leading role in system development, ThyssenKrupp laid the foundations for the Transrapid system. ThyssenKrupp supplies vehicles, propulsion components and guideway equipment for the Transrapid system.

SIEMENS

Siemens Transportation Systems is one of the largest technology companies for railway systems internationally and one of the leading solution partners for innovative and sustainable mobility systems for rail based urban, regional and intercity transportation: from railroad automation and power supply, rolling stock and complete turnkey systems, to forward-looking service concepts. In addition to technically innovative systems, Siemens guarantees rail operators worldwide safer, more efficient and customer friendly transport solutions via its comprehensive know-how in project management, engineering, system integration and project management.
Siemens Transportation Systems supplies the propulsion system, power supply, operation control and communication equipment for the Transrapid system.

Transrapid International

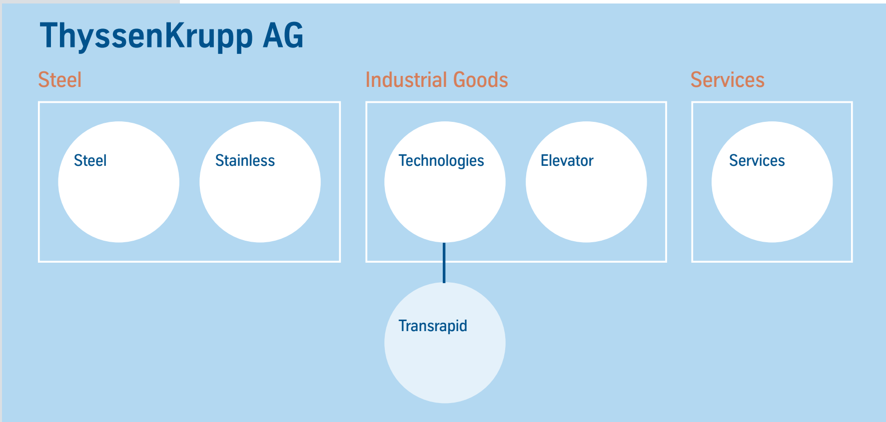
To complete the partnership for the Transrapid system, Siemens and ThyssenKrupp have established Transrapid International as a joint company for systems engineering, system integration, marketing, and maintenance support.

Contents.

Transrapid – made by ThyssenKrupp.
From drawing board to application.

From the drawing board in the test laboratory to day-to-day use in transportation: ThyssenKrupp has propelled the development of magnetic levitation technology right from the start. Now, this innovative railroad system can contribute to maintaining mobility anywhere in the world.

2003 will see the start-up of the first Transrapid test service. And increasingly more countries are turning to 21st century rail technology for resolving their transportation problems. Wherever you find the Transrapid you will find ThyssenKrupp.




TR 07 1989


TR 08 1999

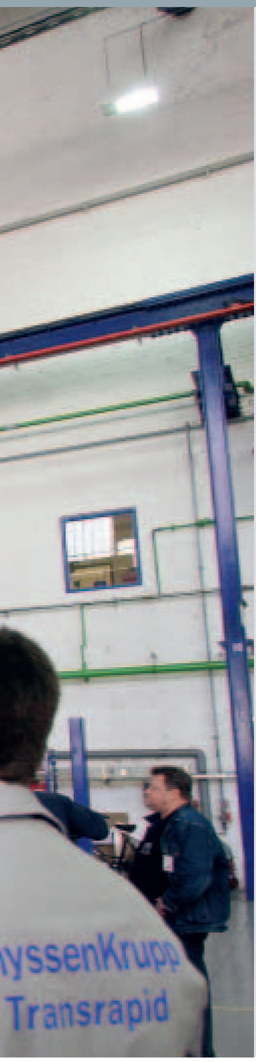

TR 09 2007

ThyssenKrupp.
Center of expertise for the Transrapid.

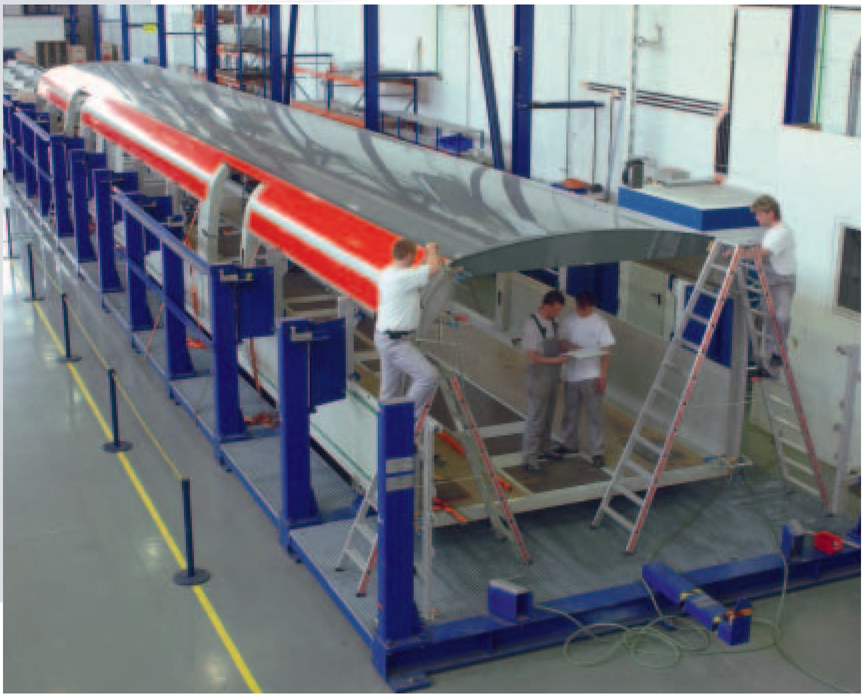
Undercarriage structure

Wiring the undercarriage structure

Assembl



ThyssenKrupp in Kassel and in Munich: two centers of expertise for magnetic levitation technology. This is where Transrapid know-how is at home. Here Thyssen-Krupp engineers developed and optimized the innovative railroad technology – the long-stator linear motor and the electromagnetic levitation system. ThyssenKrupp itself manufactures such high-tech components as the magnetic-current actuators, clearance sensors and electronic levitation controllers. Other key guideway subsystems and components, like the bendable guideway switches and the stator packs, are also "made by ThyssenKrupp."



Assembling the body of the coach

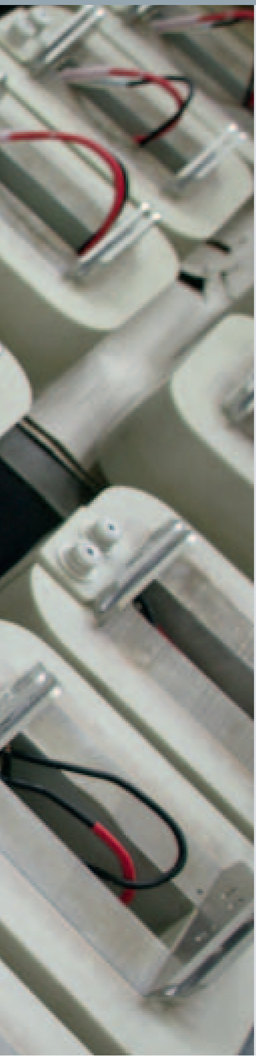
ing the body of the coach

Transrapid component production.
Stator packs, magnet modules, sensors and other devices.

Sensor production

Equipment production

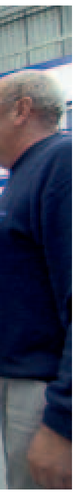
Component inspection

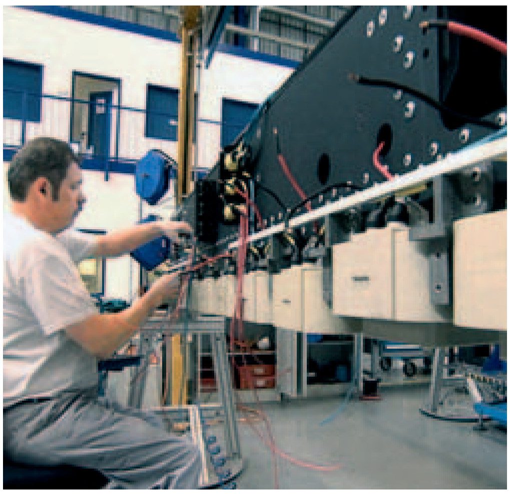


ThyssenKrupp has developed and optimized a special technology for the series production of the stator packs used in the "guideway motor." A ThyssenKrupp group company supplies the electric sheet that goes into the stator packs.

The components required for supporting, guiding and braking the Transrapid, such as magnets and sensors, are manufactured at the production site in Kassel and pre-assembled into modules for later integration into the complete system.

Stator pack production





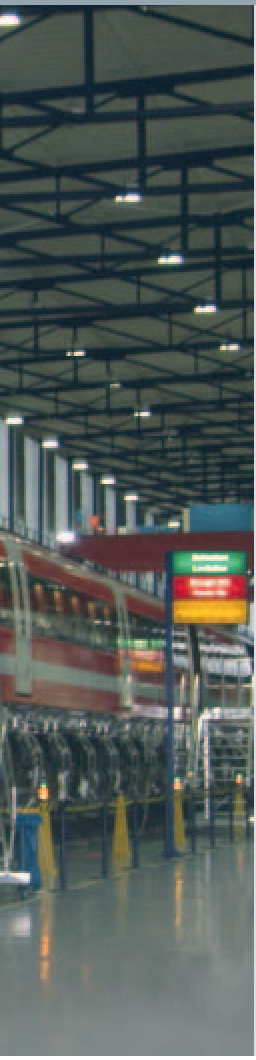
Magnet module assembly

Pressure gelation

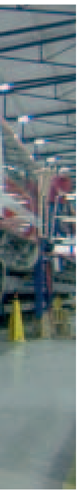
Transrapid production.
Integration, final assembly.

Assembly of the levitation/guidance system

Levitation/guidance system



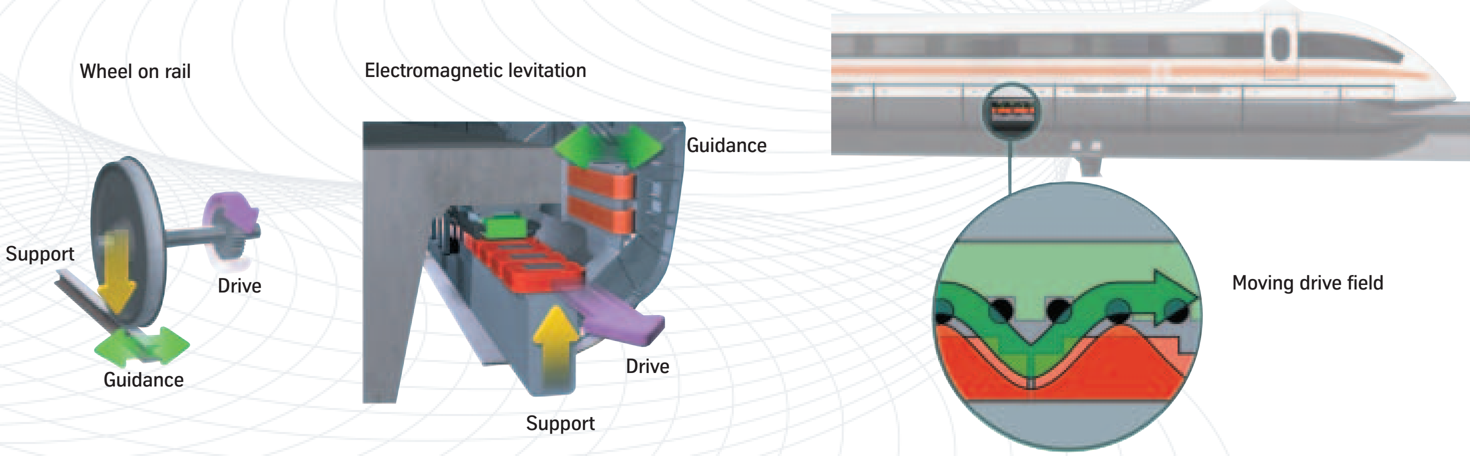
Generations of test vehicles and prototypes for the Transrapid system have been built by ThyssenKrupp. This is also the case with the levitation vehicles for the successful Shanghai project. The vehicle fleet for the Transrapid project in Munich will also be built by ThyssenKrupp.



Fitting the doors

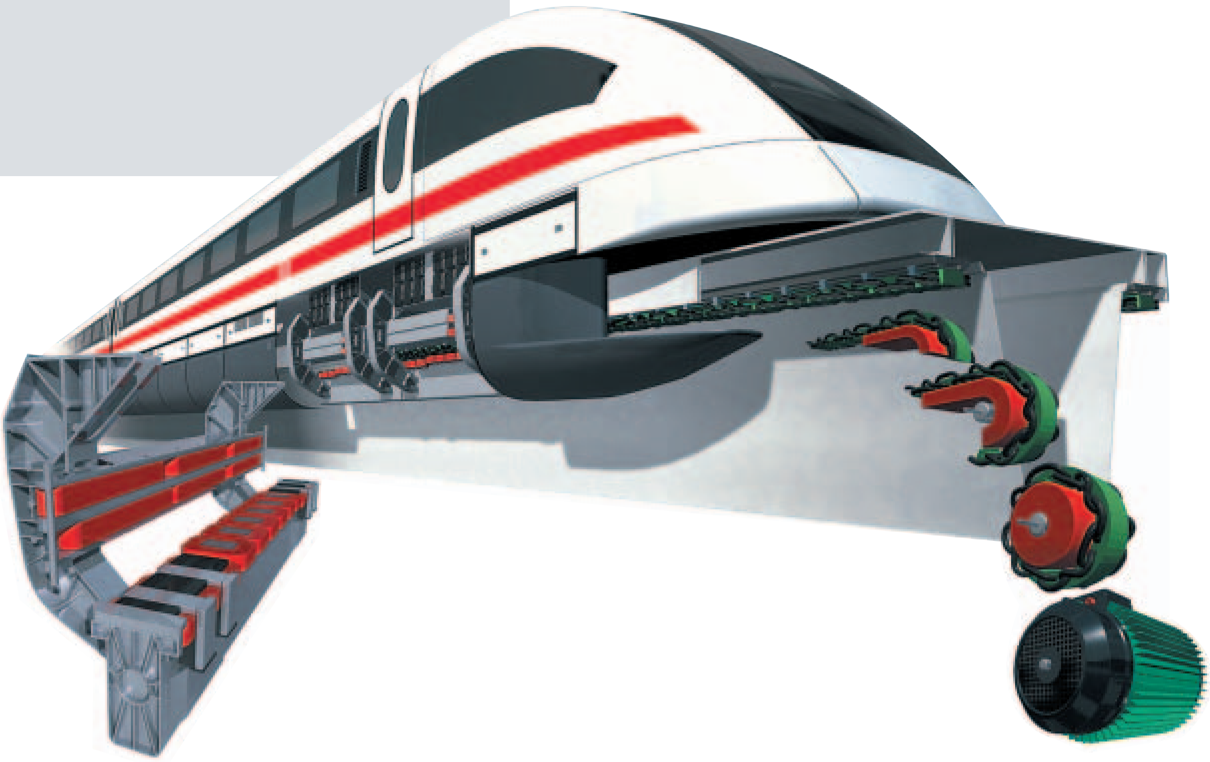
Fitting the side windows

The Transrapid.
Electronics instead of mechanical components.



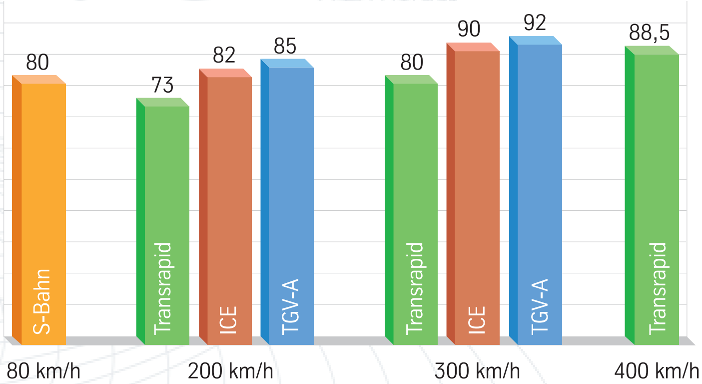
The Transrapid is the most fundamental innovation in railroad engineering since construction of the first railroads. It hovers instead of rolling – without any contact with the guideway. Electronics instead of mechanical components: the electromagnetic levitation and drive system takes over the wheel-on-track function. Supporting magnets pull the vehicle from below toward the guideway, while guidance magnets keep it sideways on track. An electronic control system ensures that the clearance between the vehicle and the guideway always remains constant. With zero contact, the vehicle is accelerated and decelerated by its long-stator linear motor nested in the guideway.

Unlike all other conventional transport systems, the long-stator linear drive is installed within the guideway itself – not within the vehicle. It operates like a rotating electric motor with "cut-open" and "stretched" stator: the current generates a moving electromagnetic field, which pulls the vehicle without any contact by virtue of its supporting magnets acting as an exciter. The vehicle is decelerated by reversing the direction of force of the moving field.



The Transrapid.
With equal emphasis on economy and ecology.

Passing-noise level in dB(A) at a distance of 25 m

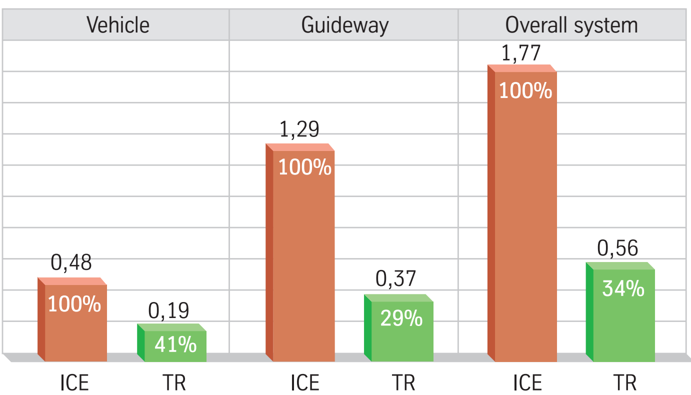


Contactless and low-wear magnetic levitation technology combines new levels of efficiency and environmental compatibility. Depending on application, the Transrapid reaches a speed of up to 550 km/h within no time at all. There is no motor or rolling noise.

"Flying" into cities and densely populated areas at a speed of 200 km/h, the Transrapid is barely perceptible. Its energy expenditure at all speeds is well below that of modern trains. The guideway itself takes up less ground space than other transport systems. Routing parameter flexibility allows it to blend with the local landscape and urban environments or run parallel with existing traffic or utility lines.

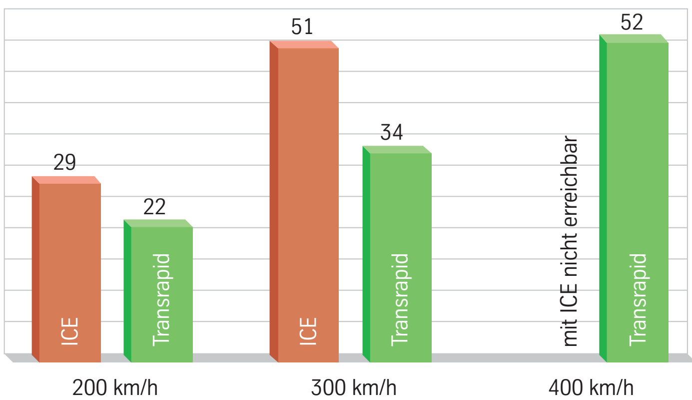
Whether as an airport feeder line, a fast regional system or high-speed link over medium and large distances – magnetic levitation meets all the requirements placed on a modern transportation system of today and tomorrow. It is faster than conventional trains. Yet particularly efficient and environment-friendly, even at lower operating speeds, since after all, it is not always the speed that counts.

Maintenance costs per seat/kilometer
Eurocent/seat-km



Operating speed: ICE (high-speed train) = 250 km/h,
TR (Transrapid) = 450 km/h

Specific energy consumption
Wh/seat-km



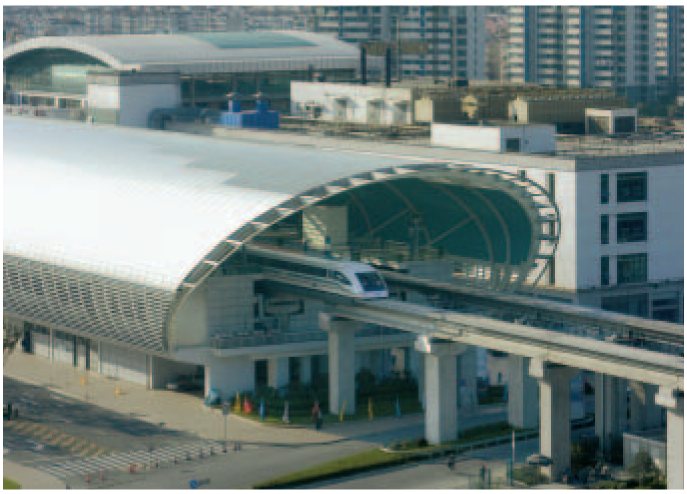
The Transrapid.

The most attractive connection worldwide.

The Transrapid is versatile and suitable for a variety of applications: as a swift link between a city and its main airport, a fast regional system in densely populated areas, a rapid and economical connection between one metropolis and another and as a constituent of a highly developed and efficient transportation network within which a variety of systems are intelligently interconnected. It is not only suitable for fast passenger traffic, but also as a transportation system for urgently needed premium quality goods.

Today's major airports are mostly far away from downtown. Frequently, a trip from or to the airport including check-in/out takes as long as the entire flight. A city-to-airport connection with the Transrapid cuts the overall travel time. Capacities are better utilized, the overall volume of traffic is contained. The Transrapid takes less than 10 minutes for a distance of around 30 km.

But the Transrapid is not only fast, it also accelerates in no time at all. Within a distance of five kilometers it reaches a speed of 300 km/h. Modern high-speed trains need more than 30 km and four times longer for the same speed. So the maglev system is not only ideally suited for long distances, but especially for short or medium runs or densely populated regions with shorter stop-to-stop distances. Its extraordinary drive dynamics, its super travel speed and its discrete-design drive configuration, allowing for topographical parameters, permit travel times comparable to medium and long distances. Even a number of interim stops will only extend the overall transit time by mere minutes.



Transrapid Shanghai route.
The start of a new rail system.

Shanghai is seeing the dawn of a new era in rail transportation. The construction of the world's first Transrapid route started in Shanghai in March 2001. At the beginning of 2004, the system will commence commercial operation. At a speed of 430 km/h, the Transrapid links the 14-million metropolis with Pudong International Airport, which is to be expanded into Asia's largest air traffic gateway. It will take around 8 minutes to travel the 30 km. It is now planned to extend the urban line to Hongqiao Airport and continue it to Hangzhou.

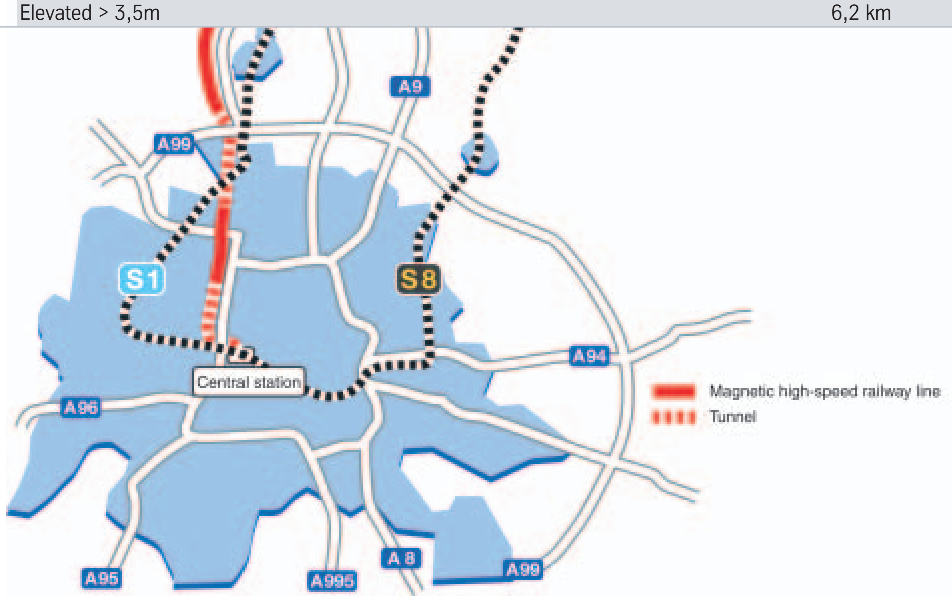
Vehicle data Shanghai			
Number of sections			5
Length			128,8 m
Width			3,7 m
Height			4,2 m
Maximum design speed		505 km/h	
Number of seats, passenger vehicle	End section (ES)	1st class	56
	Middel section (MS)	2nd class	110
	End section (ES)	2nd class	78

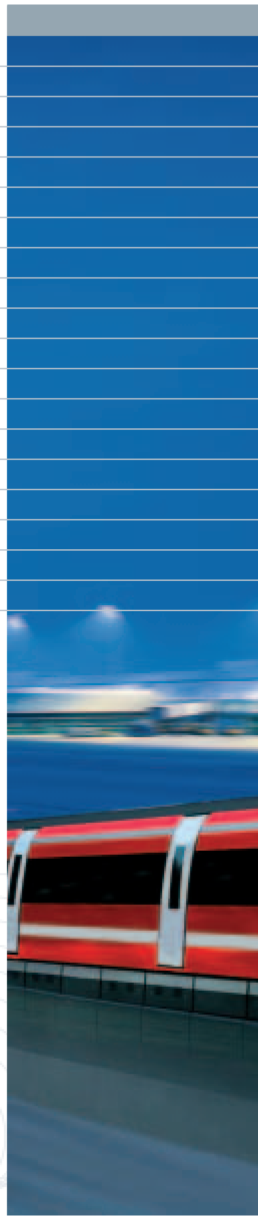
Project data Shanghai		
Route length		30 km double track
Connection to the maintenance center		3 km singel track
Stations		2
Number of vehicles		3 vehicles with 5 sections each
Traffic volume	in 2005	10 million passengers
	in 2010	20 million passengers
	in 2020	33 million passengers
Operating speed (max.)		430 km/h
Travel time		8 minutes
Frequency of service		10 minutes
Hours of daily operation		18 hours

Transrapid route Munich.
The Transrapid between airport and main station. The best connection!

Munich's central station and the Franz Josef Strauß Airport are two large transportation hubs in southern Germany – almost 40 kilometres apart. To date there is no quick and efficient connection between the two. Only the Transrapid can fill this gap: conveying passengers at ten minute intervals in a ten minute journey from the airport to the central station. Environmentally friendly, safe and quick!

Vehicle data Munich (Transrapid 09)		
Number of sections		3
Length		75,80 m
Width		3,70 m
Height		4,25 m
Maximum design speed / planned operational speed		505 km/h / 350 km/h
Transport capacity	**without luggage compartment**	**with luggage compartment**
Seats	156	148
Standing room (base area > standing room)	82,1 m^2	74,1 m^2
Total no. of passengers, when all seats are occupied, 1 person per m^2 standing room (normal capacity)	239 passengers	222 passengers
Total no. of passengers, when all seats are occupied, 2 person per m^2 standing room (full capacity)	321 passengers	296 passengers
Total no. of passengers, when all seats are occupied, 4 person per m^2 standing room (maximum capacity)	449 passengers	412 passengers
Unladen weight		170t
Project data Munich		
Total route length	37,4 km	
Bundling with motorway	18,7 km	(50%)
Bundling with road/railway	2,9 km	(8%)
Tunnel	8,7 km	(23,3%)
Ground level	22,5 km	(60,1%)
Elevated > 3,5m	6,2 km	(16,6%)





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