

Feasibility, Financial, and Environmental Analysis of an Advanced Maglev-Based Intermodal System

Andreas Steingröver, Rasmus Krevet, and Robert L. Bertini

The magnetically levitated (maglev) intermodal system named Auto-shuttle is a new transportation concept that can be built along existing major transportation arteries such as freeways. The technical feasibility, financial aspects of a sample application, and key environmental features of this system are examined. Compared to automated vehicles driving autonomously, Autosshuttle demonstrates substantially higher degrees of safety, environmental friendliness, and economy.

The magnetically levitated (maglev) intermodal system named Autosshuttle is a new transportation concept that can be built along existing major transportation arteries such as freeways. At an Autosshuttle entrance, station cars, trucks, and buses each enter single, transparent cabins. Soon after, each cabin enters the system and travels at a constant speed of 180 km/h (112 mph) to the individually desired freeway exit. The desired destination may be changed during the journey using a voice recognition module. With a "Take Next Exit" request, the cabin stops at that exit after approximately 3 min. The transported vehicle leaves the cabin through the opened front door. The fare is paid with a credit card en route. The fare is less than the operating costs of driving on the parallel freeway (i.e., less expensive than fuel and vehicle wear and tear). Departures are quasi-continuous. During the journey, convoys with very little air resistance are formed to consume very low energy. Entrances and exits are as frequent as on an ordinary freeway. Exits for which the user does not request an exit are passed without loss of time. At the desired exit, the cabin switches out of the convoy and brakes automatically. The door-to-door average speed is very high, even for short trips. A 12,000-kg (3-ton) maglev prototype vehicle especially suited for Autosshuttle has been built at the Technical University of Braunschweig, Germany. Transportation of an average car by Autosshuttle corresponds with an equivalent diesel consumption of 43 km/L (102 mi/gal). For a 40,000-kg (40-ton) truck the equivalent figure would be 7.6 km/L (18 mi/gal). Emissions during operation and raw material consumption for construction are very low. The space consumption is up to 3.6 times lower than that of a freeway. The capacity of a single Autosshuttle line corresponds to that of a 15-lane freeway. An economic study for a 56-km (35-mi) long line along an existing freeway in Germany shows exceptionally good economic viability. Assuming a 28 percent mode shift from the freeway to Autosshuttle, an unsubsidized company building and operating this line would realize high profits. A preliminary acceptance

study has yielded a much higher expected value for the mode shift percentage. Profitable operation is possible on short lines already. Compared with individually operated vehicles on a freeway, this intermodal system demonstrates substantially higher degrees of safety, environmental friendliness, and economy.

CURRENT SITUATION

One of the most serious transportation problems worldwide is the abundant traffic congestion in urban areas and in ecologically critical corridors. All recent traffic predictions show that motor vehicles will dominate future travel volumes. Developing countries will experience tremendously increasing traffic volumes, and forecasts for industrialized countries also predict increasing road traffic. The reasons for this increased traffic relate to the flexibility, comfort, independence, and generally acceptable cost of road transportation. With an increase in traffic, the road user is affected mainly in the form of traffic jams and increased accident risks. Roadside residents and the environment suffer from the physical space requirements (property required to construct or expand a highway), neighborhood division, noise, energy consumption, emissions, and accident risks.

New technologies such as alternative propulsion concepts for highway vehicles and telematics are very useful, but major attenuation of traffic problems cannot be expected as long as individually operated highway vehicles continue to dominate. For instance, the capacity of many highways is reached with conventional traffic control, so that an automated traffic control system would only lead to a modest decrease in physical space requirements. Further, consumer behavior still shows that safety, power, and comfort are the preferable features of a car, and not extremely low fuel consumption.

Alternatives from the basic principle of individually operated highway vehicles moving on major transportation arteries have been proposed. Railway trains for transporting cars and trucks theoretically enable fewer physical space requirements if the line is well used. With the operating schemes realized so far, the time-consuming and costly loading and unloading of trains and the low station density or, alternatively, low average speed because of frequent stops leads to low traffic volumes. Also, the energy savings of a train system is quickly absorbed if patronage is poor or if the travel speed is considerably higher than the typical road traffic speed.

An alternative solution is the convoy concept developed by Volkswagen during the 1980s for densely used freeways (1, 2). In this system, the driver enters the slow (right-hand) freeway lane and transfers control of the car to a computer by pushing a button. The car is steered to the passing (left-hand) lane and joins a platoon, so that the car forms the new front end of the platoon. Using sensors, the cars follow one another at a distance of 2 m (6.6 ft).

A. Steingröver, Nettlingskamp 20, 38120 Braunschweig, Germany. R. Krevet, Bammelsburger Str. 2, 38114 Braunschweig, Germany. R. L. Bertini, Department of Civil Engineering, Portland State University, P.O. Box 751, Portland, OR 97207-0751.

During the journey, additional cars join the front of the platoon. The driver requests an exit by pushing another button, and the car leaves the platoon toward the right lane. The driver then resumes control of the car. The gap remaining in the platoon is closed automatically by the vehicles following behind. With this system, freeway capacity is increased and air resistance in the platoon is diminished by 35 percent at 130 km/h (81 mph). Unfortunately, safety problems remain unresolved for this platoon concept. For instance, if a vehicle in the front section of the platoon has a flat tire and becomes out of control, the following vehicle will possibly be affected. Daimler-Chrysler has developed a similar concept for truck platoons. The energy savings are lower because the wheel friction is still high, which is a major component of a truck's total movement resistance.

Another proposed system uses dual-mode vehicles with conventional rubber tires for highway operation and an additional suspension system for track guidance. This type of system increases traffic density, but has little impact on energy consumption. A disadvantage is the need for specially designed vehicles, excluding conventional vehicles from the dual-mode traffic stream.

AUTOSHUTTLE CONCEPT

Maglev Vehicles

The safety problems of the platoons formed by automated highway vehicles are avoided if vehicles are transported by maglev track-guided cabins. Passengers may remain seated in their vehicles. Figure 1 shows a maglev vehicle. The car body and the hinged front exit door are transparent, whereas the two laterally hinged rear entry doors and the bottom part are opaque. Solar cells are mounted on the roof and afford cabin cooling if necessary. The front of the vehicle is streamlined, and the rear part of the cabin extends over the rear doors. During a convoy journey, the following cabin closes up directly behind the preceding cabin. Because the cabins fit together

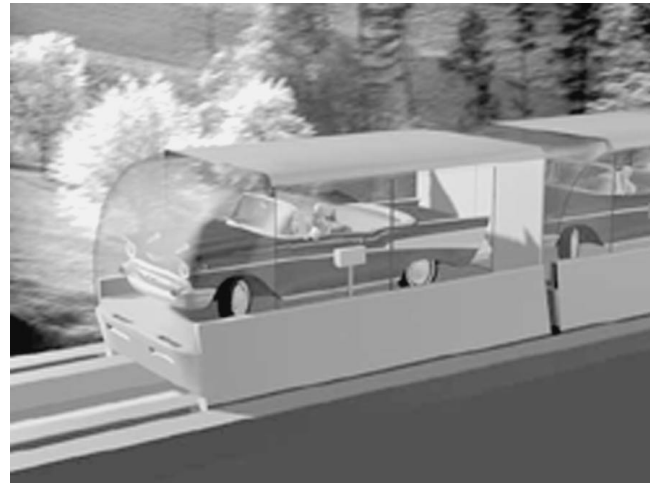


FIGURE 1 Maglev vehicle.

modularly, a streamlined, nearly smooth transition between the cabins with constant cross section is achieved. Figure 2 shows that the cabin sides pivot to form auxiliary doors so that passengers may leave the highway vehicle or the cabin in extraordinary circumstances. Remotely controlled ventilation windows are also provided. The cabins have a small cross section for passenger cars—2.2 m (7.2 ft) internal width and 1.7 m (5.6 ft) internal height—and a large cross section for trucks and buses—3.3 m (10.8 ft) internal width and 4.3 m (14.1 ft) internal height. Both cabin types are provided in different lengths—from 3.6 m (11.8 ft) to 5.6 m (18.4 ft) internal length for cars and from 6 m (19.7 ft) to 19 m (62.3 ft) internal length for trucks and buses. All vehicles ride on the same track and form convoys from cabins with identical cross sections. The typical operating speed is 180 km/h (112 mph) for all convoys. The uniform speed

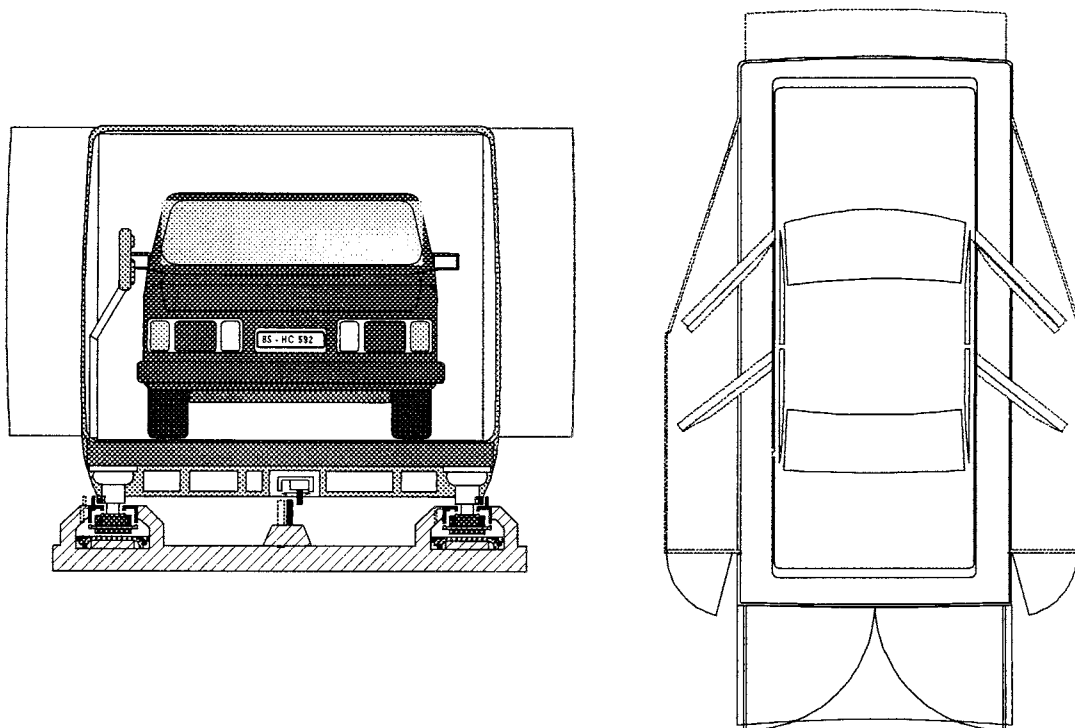


FIGURE 2 Cross section and bird's eye view of a maglev cabin.

yields an optimal line capacity. This speed is below what is technically possible, but is sufficient to clearly make Autosshuttle transportation faster than conventional road transit. At this speed, energy consumption is very low, noise is almost negligible, and relatively sharp curvature is acceptable (minimum radius of 1250 m). In extremely congested areas, a speed reduction is possible to combine Autosshuttle with the very sharp curves of an existing highway right-of-way. A gradient of 10 percent yielding short ramps can be traveled at a constant 180 km/h (112 mph). A flat, movable communications module is mounted on the driver's side inside the cabin. The module automatically moves toward the opened driver's window. The driver uses the communications module to enter the desired exit station by voice recognition or keyboard and pays by credit card. Alternatively, a mobile phone service can be used for this purpose. The type of highway vehicle is determined at the entrance station by a number plate identification system using a vehicle registration database. The fare is calculated on the basis of vehicle type, including type of engine and the corresponding operating cost. The fare is set at a point 15 percent below the average cost for driving the highway vehicle under its own power (i.e., cost of fuel, oil, wear and tear, and mileage-dependent depreciation determined for each vehicle type). The highway vehicle's dimensions are determined by light-beam detectors, so that a suitable cabin can be ordered. Further, a fast exit button for exiting at the next station, an emergency call phone, a power supply for the highway vehicle's equipment, and a cabin ventilation and window remote control are provided to the driver.

Stations

Figure 3 shows a station plan. Stations are located at approximately 5 km (3 mi) spacing, on the order of freeway interchange spacing. Via a passive switch (Point 1 in Figure 3), an exiting cabin (Point 2) leaves the convoy (Point 3). The vehicle brakes on a 1-km (0.6-mi) deceleration track (Point 4), turns to the right at Point 5 and stops in an exit bay at Point 6, where the highway vehicle leaves the cabin through the front door under its own power. Thereafter, the cabin moves backward toward an entrance bay at Point 7, where another highway vehicle enters. As soon as a convoy, Point 3, has reached a reference position on the main track, the freshly loaded cabin accelerates, switches on to the main track, Point 8, via a passive switch, Point 9, and is swiftly caught by the convoy on reaching the operating speed. Cabins not wanting to exit pass the station at full speed. Average speed is therefore nearly 180 km/h (112 mph). The car convoys follow one another at 2-min headways, whereas truck and bus convoys have 6-min headways. The frequency will decrease during nighttime hours. Physical coupling of the cabins is, in principle, unnecessary; however, simple engaging couplers that uncouple using lateral motion are provided. The convoy need not be stretched when a cabin leaves the convoy at the passive switch. At interchanges, cabins can change Autosshuttle lines automatically.

Supporting and Guidance System and Passive Switch

Figure 4 shows the experimental mock-up of a maglev vehicle. Figure 5 shows the right-hand side maglev and guidance system from the front end with two L-shaped rails on each side of the cabin. The levitation bogies of the cabins enter between the two rails on each side and engage from beneath the rails. Symmetric magnetic circuits with minimized energy consumption are formed by a permanent magnet that is controlled by an excitation coil and the rails. The configuration of the levitation system enables the levitation function even when one rail per side is omitted. This is the case on some parts

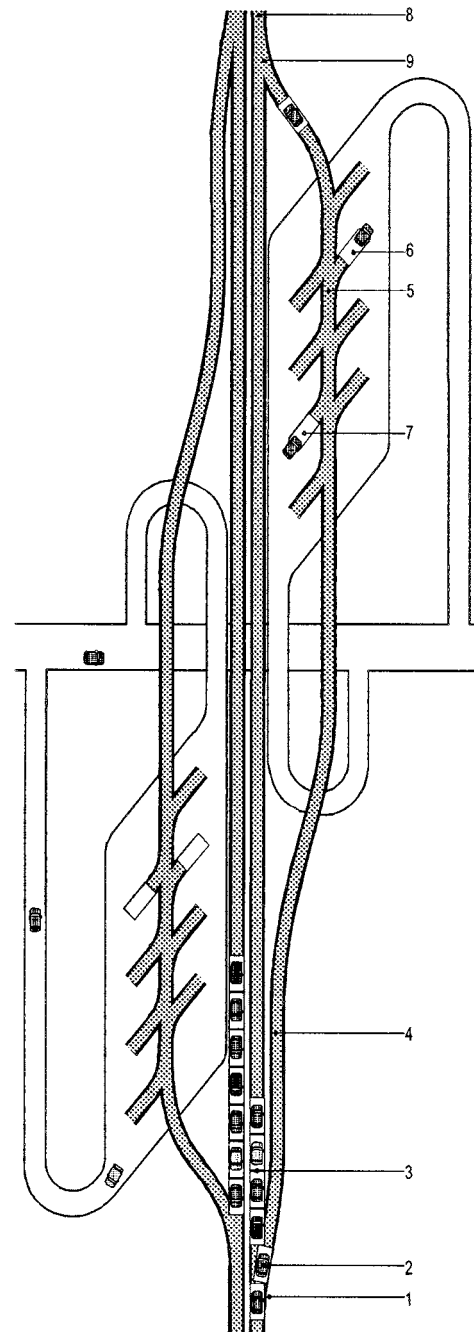


FIGURE 3 Principal sketch of a station.

of the passive switch, as shown in Figure 6. Also, lateral movement control magnets are provided, which are activated for short periods when entering a passive switch. For example, cabins turning to the left activate the control of the additional lateral movement control magnets. The cabin travels contact free by its onboard magnet along the right-hand branch of the passive switch.

As an additional mechanical safety device, vertical guidance rails are mounted at the switch in the center of both the straight and deviating branches. Under the cabin at the front end, a guidance pin is opposing; this pin can move laterally. The cabin approaching a diversion point determines the intended direction before the braking distance of the switch is reached by activating the additional lateral motion magnet and moving the guidance pin in the



FIGURE 4 Experimental maglev vehicle.

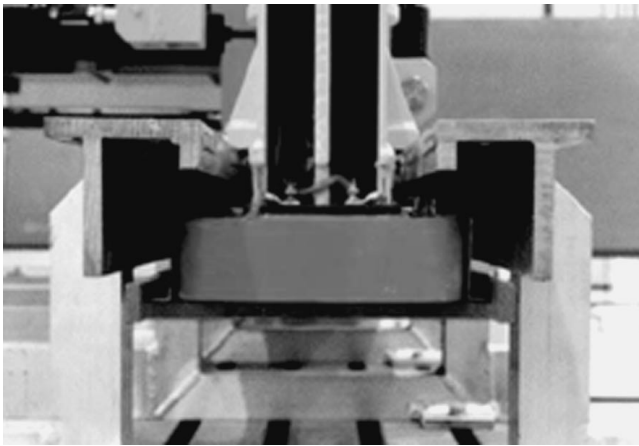


FIGURE 5 Front view of the magnetic levitation and guidance system.

desired direction. The pin is latched at the end position. An emergency brake is applied on failure. The guidance pin travels contact free laterally along the guidance sheets. Erroneous guidance is not possible, even in the case of magnet failure because of the presence of this engaging mechanical safety device. Therefore, the safety standard of this passive switch is at least as high as with conventional switches (dimensions of the passive switch are available at http://www.autoshuttle.de/A2_en.html).

Propulsion System and Rendezvous Maneuver

Autoshuttle has a long-stator, linear, synchronous drive with an iron-free stator winding placed beneath the rails on each side of the track (3). In track sections, where cabins move with very small distance from one another at different speeds, motor sections become shorter, down to 2.70 m (8.9 ft). Each short motor section is fed by a power inverter with corresponding pole position sensors and motor current control. The motor has a simple configuration and reaches high efficiencies because of the low power demand of the convoys at constant speed and the short motor sections during the accelerated motion. Power demand reaches 150 kW per meter (45 kW per ft) for accelerating a cabin containing a heavy truck. During travel at constant speed, the power demand goes down to approximately 4 kW/m (1.2 kW/ft) for a heavy truck cabin and 2.5 kW/m (0.75 kW/ft) for a passenger car cabin.

The rendezvous maneuver is enabled with the individual control of the short motor sections. The control principle becomes quite simple if predetermined curves for the movements of the approaching vehicles are used. Small deviations are corrected by the motor control. Only larger disturbances or defective motor sections require an adaptation of the predetermined curve.

Control and Safety System

A control center maintains control of the operations. Communications between the cabins and the control center are by radio or high

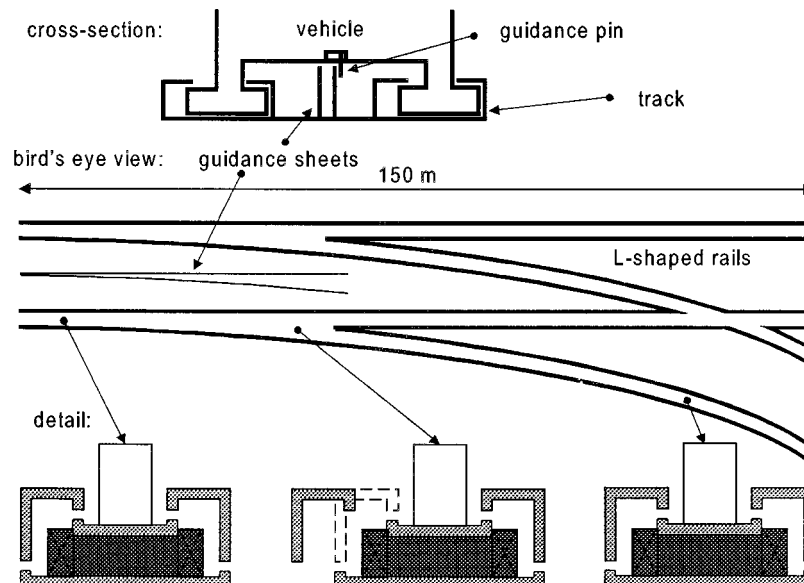


FIGURE 6 Passive switch.

frequency leaking cable in the track bed. The control center receives the following information from the cabins:

- Identification,
- Position,
- Desired exit station,
- Fare information, and
- Emergency and failure information.

The cabins receive the following information from the control center:

- Indication of the direction to be chosen at the next passive switch,
- Specific fare of the transported highway vehicle, and
- Communications via the emergency phone.

The control center processes the information received from the vehicles and provides corresponding direction commands for the cabins. The track contains Hall sensors detecting the presence of cabins. If the sensors detect that a vehicle remains behind its intended position, all following cabins, which could come into a conflicting position with this cabin, will be braked after a tolerance interval. The control center calculates track occupancy after the passage of a passive switch according to the earlier direction indication of the cabins. Indications of desired exit stations are used to coordinate the empty runs required for dispatching the necessary number of cabins to each station. A daytime and calendar-dependent forecasting program also is used for this purpose. To save energy, empty cabins are dispatched with loaded cabins whenever possible.

ENVIRONMENTAL FRIENDLINESS

Energy Consumption

The Autos Shuttle's energy consumption includes cabin consumption from

- Air resistance,
- Eddy current losses in the rails,
- Inductive energy transmission for onboard equipment, and
- Infrastructure energy consumption.

Air resistance has been calculated by two methods (detailed calculations of the air resistance and resulting energy consumption are described at http://www.autoshuttle.de/A3_en.html):

1. Application of the air resistance formula for rail vehicles of the Deutsche Versuchsanstalt für Luft- und Raumfahrt (German Research Company for Air- and Spacecraft), and
2. Numerical analysis using aerodynamic similarity to the maglev vehicle Transrapid TR08.

Both methods yield an aerodynamic resistance coefficient $c_w = 0.69$ for a 177-m (580-ft) long convoy with 38 cabins for cars. This calculation assumes a 5.8 m² (62.4 ft²) cross section, average cabin length of 4.6 m (15.1 ft), and that an empty tail car with a streamlined form could be added at the end of the convoy; similarity calculations are based on Fürst (4) and Miller and Löser (5). The value diminishes for shorter convoys and reaches $c_w = 0.28$ for a single cabin. Eddy current

losses in the rails strongly depend on the choice of material and the distances between the cabin-borne supporting and guiding elements of each cabin traveling in a convoy. It is assumed that a convoy 177 m (580 ft) long bears a propagation resistance caused by eddy currents of 10 percent of the total propagation resistance. This value is doubled for cabins traveling singly.

Onboard energy demand is caused by the highway vehicle's equipment, air gap control of the levitation system, communications module, and cabin window control. The highway vehicle has a power demand for heating or ventilation and further equipment of approximately 1.5 kW. The air gap control requires 0.2 kW/t. With the vehicle's empty weight of 3 t and a load of 2 t, the gap control's demand is 1 kW. Further onboard equipment yields an average 0.2 kW. Average onboard equipment consumption therefore adds up to 2.7 kW.

A typical, realistic journey with the following parameters will be examined (detailed energy consumption calculations are available at http://www.autoshuttle.de/A4_en.html):

- Journey length of 35 km (22 mi);
- An acceleration phase with several cabins starting together;
- Exits located every 5 km (3 mi), at which every 10th cabin leaves the convoy; and
- Braking phase with individually traveling cabins.

Empty runs are included to dispatch the cabins (calculation of energy consumption considers empty runs). These empty runs have the following parameters:

- An acceleration phase as an additional cabin behind occupied cabins; and
- Other parameters as with occupied cabins, but no onboard highway vehicle energy consumption.

A station is located every 5 km (3 mi) there, each having a power demand for illumination, cabin door actuation, shunting movements, and optical recognition systems of 20 kW.

Efficiency from entrance to the substation and the motor air gap depends on the power demand of the motor section and the coverage ratio of the vehicle length to the length of the activated motor section. For typical journeys, efficiency varies between 70 percent for the short term during braking and 91 percent for traveling in the convoy at a constant 180 km/h (112 mph) on level terrain. Average efficiency from the power plant to the air gap is assumed to be 32 percent. Primary energy consumption is thus 24 kWh per average car per 100 km (62 m). This consumption corresponds to a comparison value (primary energy consumption contains 8 percent for refineries, infrastructure, and transport) of 43 km/L (102 mi/gal) of diesel fuel. Analogous considerations yield, for example, 7.6 km/L (18 mi/gal) for an 18-m (59-ft) truck. Assuming that electric power is furnished by coal, gas, or fuel oil power plants and that long distance heat supply is realized, the primary energy consumption is further reduced by 40 percent.

Resource Consumption

The resources consumed in the construction and operation of Autos Shuttle have been estimated and compared with the results for an ordinary highway traffic system (see http://www.autoshuttle.de/A5_en.html). The conclusion is that the Autos Shuttle system consumes dramatically fewer resources than a highway traffic system.

Emissions

Table 1 shows the emissions resulting from passenger transportation. The results are compared with ordinary car traffic and the German Railways high-speed train ICE. Patronage is assumed to be 1.7 passengers per car for the automobile and for the Autosshuttle. For ICE, data from German Railways were used (6). The units for energy consumption in the second column are liters of diesel fuel per 100 passenger-km. The units for emissions are g/100 passenger-km. The calculations are based on German electric energy production modal split, with the caveat that no radioactive emissions occur, because the emissions values of the Autosshuttle and ICE were augmented assuming that no energy was produced by nuclear power plants. To conclude, Autosshuttle's emissions are much lower than those for cars and the high-speed train ICE.

Noise

Related to TR07 measurements, expected maglev vehicle noise emissions of a convoy at 180 km/h (112 mph) are less than 74 dB at 25 m (82 ft) distance. Thus, typical convoy frequencies yield a very low average noise level, making noise reduction measures generally unnecessary.

TRAFFIC CAPACITY AND LAND AREA REQUIREMENTS

At capacity, the main line is fully engaged by convoys except for gaps for entering cabins and safety tolerance intervals. Passenger car convoys operate at 2-min headways and truck and bus convoys at 6-min headways. The result is a capacity of 15,000 transported highway vehicles per hour per direction or 30,000 highway vehicles per hour on a double lane (details of the calculation of maximum traffic capacity are presented at http://www.autosshuttle.de/A6_en.html). This capacity corresponds to an equivalent capacity of 15 freeway lanes. The overall physical space requirements (i.e., for track, stations, and storage yards) is 3.6 times lower than those required for equivalent throughput on a highway (details of the space requirements calculation are presented at http://www.autosshuttle.de/A7_en.html). To handle the traffic of one six-lane freeway, the physical space requirements of the Autosshuttle are one-half those required for the freeway.

An initial scenario assumes a congested six-lane freeway that is being considered for expansion to eight lanes. This is a case for which Autosshuttle could be built instead of the expansion project. Figure 7 shows a combined four-lane freeway and Autosshuttle station. If the Autosshuttle generated substantial demand, its main tracks could be built on the freeway right-of-way, reducing the freeway to four lanes, which would be sufficient for the remaining lower traf-

fic volumes. The combined structure would consume the same space as a conventional eight-lane freeway. The vehicle-carrying capacity would equal that of a 10-lane freeway and could easily be increased. Station location would be flexible because highway vehicles could travel short distances to the next station. This scenario presents the interesting prospect of designing an Autosshuttle in a freeway median without widening the cross section of the combined facility at extremely space-critical sections. The loading and unloading capacity of a bay has been estimated on the basis of practical tests of the average time to enter a garage with dimensions similar to those of an Autosshuttle cabin. An estimated 109 cars or 63 trucks and buses could be loaded per bay per hour. Thus, the average station would be quite small with typically six loading bays and six unloading bays per direction. This configuration relates to a six-lane freeway with 10 percent of the traffic using the entrance. A large station (e.g., close to a stadium) would typically have 18 bays per direction and per type, with a total unloading capacity of 4,000 cars per hour. The same value applies to the loading capacity. Principally, cabins could be routed to adjacent stations in case of excessive demand. The affected cars would then be driven to the desired exit.

USER ACCEPTANCE

Potential user acceptance has been assessed by a preliminary, quite representative survey of 135 persons (survey details are provided at http://www.autosshuttle.de/A8_en.html). The question asked was, "Would you use Autosshuttle instead of an ordinary freeway?" Important parameters are as follows:

- Average fare is slightly lower than the vehicle operating cost when driving alone.
- Average speed is nearly 180 km/h (112 mph).
- A person can determine a desired destination during a journey.
- Convoy frequency during the daytime is 2 min for cars and 6 min for trucks and buses.

Of those surveyed, 95 percent responded positively. Interesting aspects relating to sensitivity are the following:

- If the fare were significantly higher than the vehicle operating cost of driving alone, acceptance would decline more than proportionally compared with the price increase.
- Approximately 66 percent of the respondents assumed that the operating cost of the highway vehicle was only for fuel. After a short explanation, this group accepted that wear and tear and mileage-dependent depreciation should be included as well.
- Truck operators would even accept a higher fare than the truck operating cost, because labor costs would be reduced by using Autosshuttle and the faster transportation would directly translate into monetary profit.

TABLE 1 Emissions

System	l/100Plkm	CO ₂	CO	HC	NO _x	SO ₂
Car	7.1	17100	670	98	147	8.5
ICE train	2.5	6050	1.55	0.28	7.1	8.9
Autosshuttle car	2	4727	1.21	0.22	5.55	6.9
Autosshuttle bus	0.6	1418	0.36	0.066	1.67	2.1

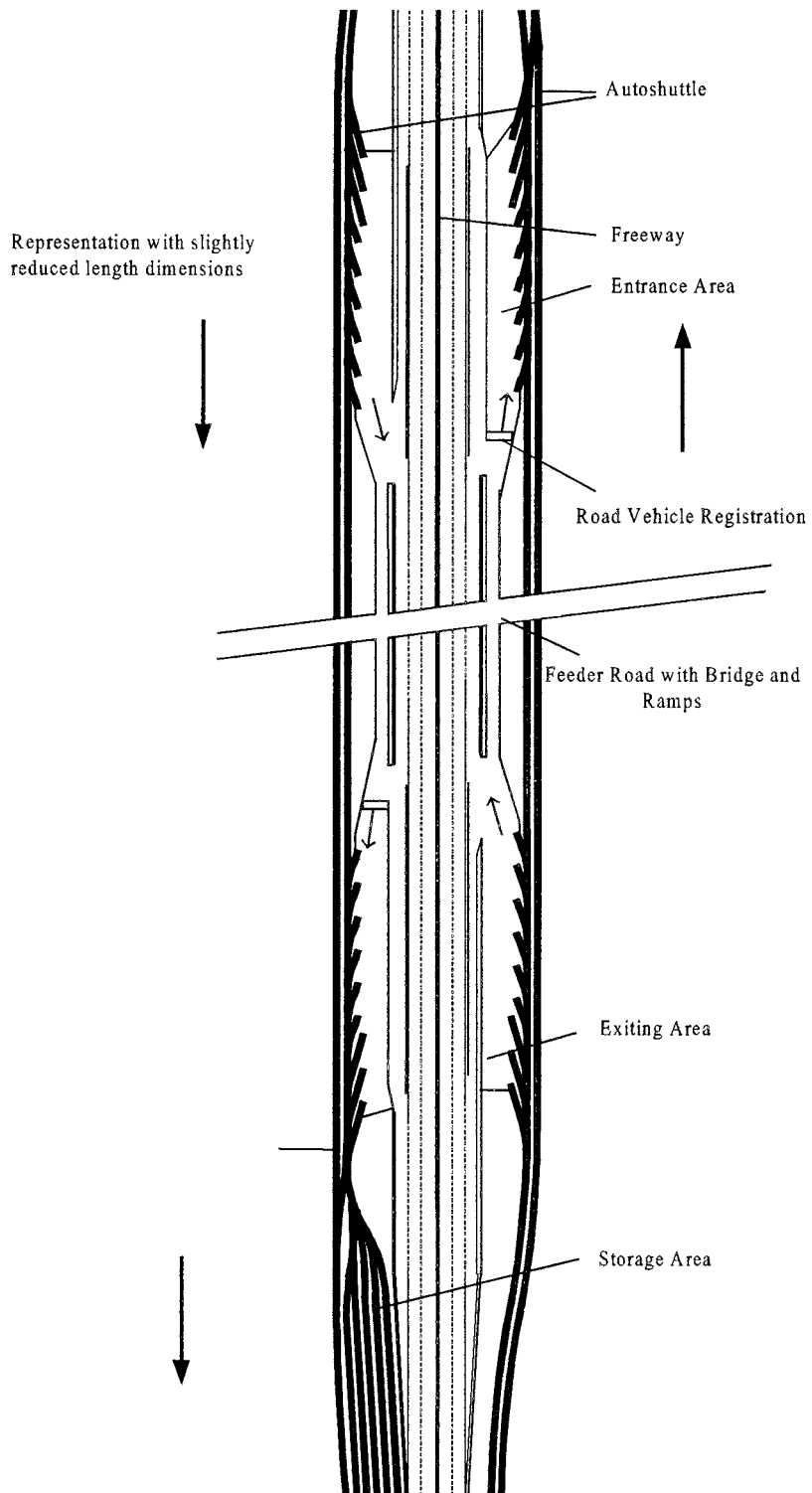


FIGURE 7 Autoshuttle station paralleling a freeway with integrated entrances and exits.

CASE STUDY: ECONOMIC ANALYSIS FOR A SAMPLE CORRIDOR

An economic study was conducted for the sample line between Duisburg and Köln (Germany). The line is 56 km (35 mi) long. The objective was to determine the minimum percentage of highway vehicles switching from the parallel freeway to Autosshuttle to produce a subsidy-free profit for the building and operating company.

According to the lowest prediction, an average of 124,000 highway vehicles would travel on this freeway every day in 2010, the assumed inauguration date of Autosshuttle (7–9). The fare for cars, trucks, and buses was set at a point 15 percent lower than the cost of driving on the parallel freeway for each vehicle type. Average fares would be 10 cents/km for cars and 31 cents/km for trucks and buses at the 2000 German price level (detailed calculations on what a car owner would save by driving 1 km less are provided at http://www.autosshuttle.de/A9_en.html). Expenses for constructing the line were estimated using the cost estimates prepared by Thyssen, Siemens, and AEG for the Transrapid-maglev line between Hamburg and Berlin, and cost tables for German Railways construction (a detailed description of the financial model is presented at http://www.autosshuttle.de/A10_en.html). Autosshuttle financing is entirely private, without public subsidy. Table 2 summarizes the financial analysis results.

The financial results represent a mode shift of 28 percent from the freeway to Autosshuttle. Considering the promising results of the preliminary survey, this mode shift could be exceeded. The cost coverage ratio could rise in ensuing years and reach 260 percent in the 26th year of operation. Autosshuttle could be operated on lower-volume routes as well.

This analysis is based on conditions in Germany. Adaptation of this economic study to the situation in the United States yields the following main differences:

- Fuel costs are lower but average vehicle size is larger in the United States.
- The daily traffic volume on many U.S. freeways is higher than on German freeways.

All factors combined yield a minimum changeover rate of the same order of magnitude. Autosshuttle therefore shows excellent financial aspects for a U.S. application as well. The total mileage of roadways worldwide where Autosshuttle could be built and operated without subsidies and with profit exceeds 60,000 miles.

CONCLUSION

The proposed new transportation concept—Autosshuttle—can mitigate the problems of abundant road traffic. Autosshuttle allows the use of conventional highway vehicles and is

TABLE 2 Financial Analysis Summary

Costs (first year)	
Financing cost (25 year term)	\$79 Million
Operating costs	\$34 Million
Total cost	\$113 Million
Revenue (first year)	
Based on daily Autosshuttle volume of 35,037 veh.	\$113 Million

- Very safe because of the effective derailment protection of the maglev configuration and the modern safety and control system.
- The fastest and easiest door-to-door means of transportation in a door-to-door range from 28 to 400 km (18 to 250 mi) for passenger traffic and from 22 to 670 km (14 to 420 mi) for freight (detailed estimates of door-to-door travel times are presented at http://www.autosshuttle.de/A11_en.html).
- Less expensive—fares 15 percent lower than the operating cost of a highway vehicle traveling on a freeway.
- More environmentally friendly—less energy consumption, less noise, fewer emissions, and fewer land requirements than for concurrent systems.
- A building and operating company that expects high profits without subsidies.
- A system on which users may simply go on to the next station in case of a temporary excess demand at one station.
- A relatively modest extension of existing maglev-technology. The levitation and guidance system has been tested in an experimental setting at the Technical University of Braunschweig, Germany, and the motor has been thoroughly investigated theoretically. The reliability of Autosshuttle is seen to be excellent. The frequency of service interruptions because of levitation and propulsion problems has been estimated (see http://www.autosshuttle.de/A12_en.html).

In conclusion, the new combination of features for this intermodal, track-guided transportation system includes

- Frequent stations combined with an average speed almost as high as the maximum speed;
- Individualized door-to-door-transportation without changing or load transfer;
- Fast loading and unloading of highway vehicles with individual cabins, loaded from behind and unloaded through a front door; and
- Ecologically and economically reasonable, uniform traveling speed of 180 km/h (112 mph) for cars, buses, and trucks, enabling maximum line capacity in mixed service for passengers and freight.

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