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Traffic Infrastructure
Review
U. D. C.: 625.711.3:656.021.2
Accepted: Mar. 14, 2003
Approved: Apr. 28, 2003

AUTOSHUTTLE: CONCEPT AND COMMERCIAL EXAMPLE LINE

ABSTRACT

The transport system AUTOSHUTTLE integrates road and track guided traffic using and combining the specific advantages of each of these means of transportation. Conventional road vehicles are transported including their passengers and freight in individual cabins. The operational concept of AUTOSHUTTLE provides operation of the cabins without intermediate stops at almost constant travelling speed. During the journey convoys with low aerodynamic drag are formed in order to lower the energy consumption and increase traffic capacity. Approaching a station only those cabins that have reached their destination leave the convoy on a passive switch and decelerate on a brake track, while other cabins close the gap in the convoy and travel on at the usual cruising speed. This paper describes the planning and economical aspects of a proposed commercial line along the motorway A3 in Germany between the cities of Duisburg and Cologne as a typical example for many other applications.

KEYWORDS

rendezvous manoeuvre, passive switch, motorway

1. INTRODUCTION

The transport system *AUTOSHUTTLE* is a result of a consequent analysis of user requirements and requirements given by the state of the art, the economy and the environment.

The German Federal Ministry of Transport has predicted that the traffic volume on roads will still increase [1] in the next decades. There is still no indication that the maximum traffic volume will be reached. This refers to passenger and even more to freight transport. It results in the well-known situation on the motorways with daily tailbacks caused by high traffic density, accidents and construction works. Facing the predicted increase in traffic volume this situation will become even more critical in the coming years, since upgrading of the motorways in the most condensed areas is not possible or only with great expenditures. Expanding a motorway by an additional lane per direction is not possible in many locations. In some locations, expensive and not fully satisfying noise reduction measures or trench and tunnel constructions are necessary. This is true especially for congested areas, where the traffic density is the highest.

Traffic guidance measures such as for example electronic road signs or traffic situation dependent road toll can level the traffic volume. However, the effect is rather low. Although these new technologies have been considered in the traffic prognosis, the prognosis still does predict scenarios with frequent tailbacks and considerable economical losses. The prognosis also considers the traffic transfer from road to rail using huge subventions. However, rails will keep on having low share of the total traffic and will therefore have a low effect on decreasing the motorway's tailbacks only.

The user requirements for the new means of transport are short door-to-door travelling times, low cost, high undependability, safety, flexibility and simple use. Target value of each mentioned aspect is the best value realised in any of the existing means of transport. Only if all these target values have been reached or improved, can acceptance by the user and the entire population be expected. In this benchmarking very good values in one or more criteria cannot compensate for bad values in other criteria.

Instead of setting up concurrence to road traffic or trying to completely avoid road traffic, according to the requirements of the majority the unchanged road traffic vehicle is integrated in a very effective and environmentally friendly means of transport.

The synthesis leads to individual transparent cabins that transport road vehicles with their passengers and freight load. Thus, time-consuming and uncomfortable transfer processes of passengers and freight from the road vehicle to another vehicle are avoided. During the journey, convoys with very low aerodynamical drag are formed, so that the line capacity is increased, whereas energy consumption and transport expenses are reduced. Like on a motorway, there are stations about every five kilometres. An individual cabin stops there only if its user announced a corresponding wish at any time before or during the journey. This could be shortly before or at the beginning of the journey. Along with a constant travelling speed very low door-to-door travelling times are achieved. Track guidance and automated operation guarantee high levels of safety and reliability.

Preferably, *AUTOSHUTTLE* is built parallel to an existing motorway, since this yields the highest changeover rate from the road to *AUTOSHUTTLE*. At the motorway entries and exits there are *AUTOSHUTTLE* stations. Alternatively, *AUTOSHUTTLE* can be built at isolated locations like mountain ridge crossings in tunnels, which will profit from *AUTOSHUTTLE*'s safety, flexibility and environmental friendliness.

Magnetic levitation technology is well suited for *AUTOSHUTTLE* in combination with a linear long stator drive. The specific advantages of this concept are fully exploited:

- High control accuracy – realisation of the rendezvous-manoeuvre with a wayside control and safety system (see [2] and [6]).
- Realisation of a passive switch – travelling direction on the switch is determined by the vehicle's actuators only.
- Very high traffic capacity combined with low specific space requirements – the high attraction and the resultant high traffic volume are achieved by the low convoy headways due to the rendezvous-manoeuvre and the passive switch together with an economically and ecologically advantageous uniform travelling speed of 180 km/h for passenger car convoys and lorry and bus convoys travelling on the same track.
- Almost no noise emission due to the moderate travelling speed of 180 km/h and use of a magnetic levitation system.
- Simple vehicles – the long stator drive is mounted wayside, an ideal solution for a concept with many vehicles. The suspension system and the cabin construction are very simple, since the passengers use the comfort systems of the transported road vehicles.
- Very low energy consumption – convoys formed by matching cabins with almost constant convoy cross-section yield a very low air resistance and low additional energy consumption by use of levitation and guidance configuration based on hybrid magnets in a transversal flux arrangement [2].
- Short door-to-door travelling times – due to very short times to reach the *AUTOSHUTTLE* station and to load the road vehicle as well as short times for unloading and reaching the final destination, *AUTOSHUTTLE* is, at only 180 km/h, the fastest door-to-door means of mass transport in a wide range of journey lengths.

AUTOSHUTTLE has been published in various media. A general survey on technology, usefulness and economy is given in [2], [3] and [4]. Safety aspects and approval aspects are dealt with in [5] and [6]. [7] describes details of the long stator synchronous drive. The present article gives an overview on *AUTOSHUTTLE* in Chapter 2 and a summary of a detailed application analysis for a commercial *AUTOSHUTTLE* line parallel to a motorway in Germany between Duisburg and Cologne in Chapter 3.

2. THE AUTOSHUTTLE CONCEPT

Figure 1 shows a convoy formed by magnetically suspended cabins for transport of passenger cars in the foreground. Oncoming is a convoy for lorries and buses. Passengers may stay seated in their vehicles.

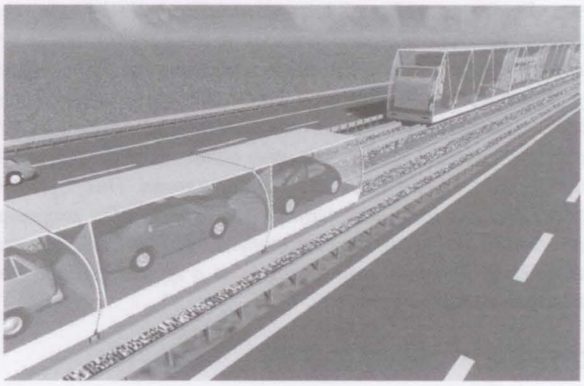

Figure 1 - *AUTOSHUTTLE* in the centre of a motorway

There are cabins with a small cross-section for passenger cars – 2.20 m internal width and 1.70 m internal height – and cabins with a large cross-section for lorries and buses – 3.30 m internal width and 4.30 m internal height. Both types are provided in different lengths – from 3.60 m to 5.60 m internal length for cars, and from 6 m to 19 m internal length for lorries and buses. All types ride on the same track and form convoys with vehicles of an identical cross-section. The usual operating speed is 180 km/h for all convoys. The uniform speed yields an optimised line capacity.

2.1. Cabin design

The cabin design is very simple. The sides and the front upside hinged exit door are transparent. The rear two laterally hinged doors and the fuselage are opaque. The front is streamlined. The rear part of the cabin extends over the rear doors at the circumference, so that it matches the front of the following cabin. During the journey in a convoy the following cabin closes up directly to the end of the preceding cabin. Since the end part is congruent to the front end of the following cabin, the flexible tips of the front cabin touch the following cabin so that a streamlined, almost even transition between the cabins with constant cross-section is achieved between the cabins. The cabin sidings are hinged and can form lateral corridors with auxiliary doors, so that the passengers may leave the road vehicle or the cabin in emergency situations. Further on, remote controlled ventilation windows are provided.

Inside the cabin, there is a flat movable communication module mounted at the driver's side. The module moves towards the opened driver's window as soon as the driver opens the window. At the communication module the driver enters the desired exit station by voice recognition or keyboard and pays by a credit card or via cellular phone. The type of the road vehicle is determined at the entrance station by a number plate identification system and an extract of the centralised road vehicle's register's databases. The fare is calculated with a table set up for each vehicle type including the motor type. The fare is slightly lower than the average fuel cost when driving the road vehicle by its own means. The road vehicle dimensions are determined by light beam detectors, so that a suitable cabin is ordered.

Furthermore, a fast exit button for exiting at the next station, an emergency call phone, a 12 V-supply for the road vehicle's equipment and a cabin ventilation and window remote control are provided. Since the cabin is always well ventilated the road vehicle may run the engine idle for operating the heating, air conditioning or other on-board equipment.

2.2. Operation principle

Figure 2 shows a simplified scheme of a station from above. Stations are located as densely as motorway exits along the line, i.e. about each 5 km. Via a passive switch 1 an exiting cabin 2 leaves the convoy 3. On an approximately 1.2 km long braking track 4 the vehicle decelerates, turns to the right on another switch 5 and stops in an exiting bay 6 where the road vehicle leaves the cabin through the front door. Thereafter the cabin moves backwards towards an entering bay 7 where another road vehicle enters. As soon as the convoy 3 has reached a reference position on the main track, the freshly loaded cabin accelerates, switches on to the main track 8 via a passive switch 9 and is swiftly caught up by the convoy 3 on reaching the operating speed. Those who do not want to exit will pass the station at full speed. The average speed therefore is close to 180 km/h. The car convoys follow each other in a 2-minute sequence, lorry and bus convoys in a 6-minute sequence. Frequency is reduced during nighttime. In principle, the coupling of the vehicle is not necessary. However, simple engaging couplers which uncouple on lateral motion are provided. The convoy 3 needs not to be extended when a cabin leaves the convoy 3 at the passive switch.

2.3. Levitation system and passive switch

The levitation bogies of the cabins enter between the two rails at each side and engage from beneath the rails, as shown in Figure 3. A magnetic circuit is formed through the controlled hybrid permanent and the rails. The energy consumption of the hybrid magnet is minimised. The configuration of the levitation system enables the levitation function even when one rail per side is omitted. This is the case at some parts of

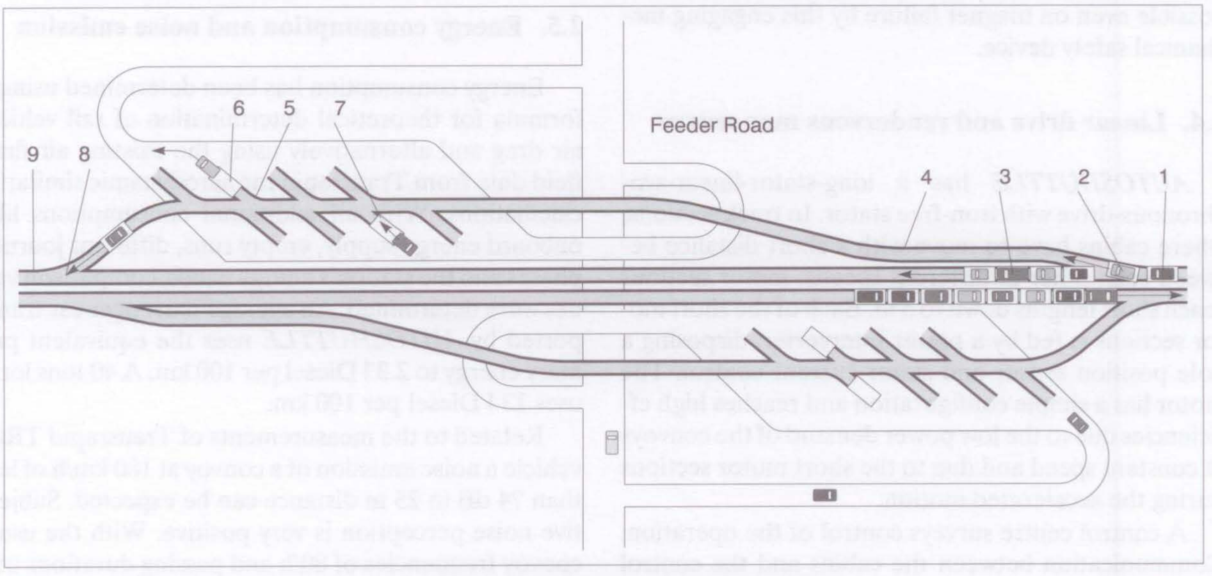

Figure 2 - Simplified scheme of a station

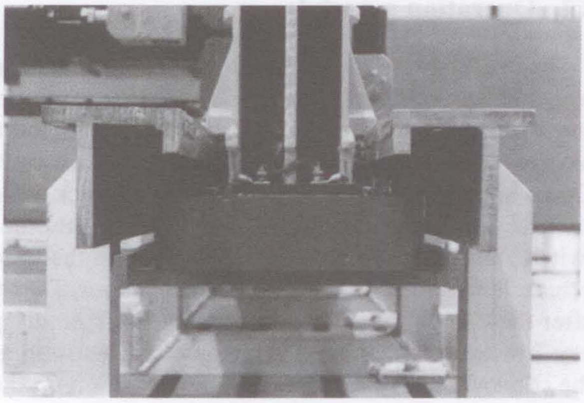

Figure 3 - Levitation and guidance system

the passive switch. Additionally, lateral movement control magnets are provided, which are short-term activated when entering a non-moving switch. For example, cabins turning to the left activate the left side control of the additional lateral movement control magnets. The cabin travels contact-free controlled by its on-board magnet in the desired direction through the passive switch.

As an additional mechanical safety device, vertical guidance rails are mounted at the passive switch in the centre of either the straight and deviating branch. Centred under the cabin at the front end is a guidance pin, which is laterally moveable by about 10 cm. The cabin approaching the passive switch in diverting direction fixes the intended direction before the braking distance before the passive switch is reached by activating the additional lateral motion magnet as described above and by additionally moving the guidance pin in the desired direction. The pin is latched at the end position. Emergency brake is applied on failure. The guidance pin travels contact-free laterally along the guidance rails. Erroneous guidance is not possible even on magnet failure by this engaging mechanical safety device.

2.4. Linear drive and rendezvous manoeuvre

AUTOSHUTTLE has a long-stator-linear-synchronous-drive with iron-free stator. In track sections, where cabins have to move with a short distance between each other at different speeds, motor sections reach short lengths down to 3 m. Each of the short motor sections is fed by a power interverter, disposing a pole position sensor and stator current control. The motor has a simple configuration and reaches high efficiencies due to the low power demand of the convoys at constant speed and due to the short motor sections during the accelerated motion.

A control centre surveys control of the operation. Communication between the cabins and the control centre takes place by radio or high frequency leaking cable in the track bed. The control centre receives the following information from the cabins:

- cabin-id,
- position,
- desired exit station,
- information related to the received fare,
- emergency and failure information.

The cabins receive the following information from the control centre:

- indication concerning the direction to be chosen at the next non-moving point,
- specific fare of the transported road vehicle,
- communication with the emergency phone.

The control centre controls operation by processing the information received by the vehicles in corresponding direction commands for the cabins. A motor control unit at each long stator section converts the commands into respective motor currents and also controls the rendezvous manoeuvre via communication with the neighbouring motor control units. The track bears 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 brake after a tolerance interval. The control centre calculates track occupancy after the passage of a non-moving point according to the direction indication to the cabins issued earlier. Indications of the desired exit stations are used for the co-ordination of the necessary empty runs for dispatching the necessary number of cabins at each station. Additionally, a daytime and calendar-dependent forecast program is used for this purpose. In order to save energy, empty runs start only together with loaded runs whenever possible.

2.5. Energy consumption and noise emission

Energy consumption has been determined using a formula for theoretical determination of rail vehicle air drag and alternatively using the existing air drag field data from Transrapid for aerodynamic similarity calculations. With all additional consumptions like onboard energy supply, empty runs, different journey phases and the station's energy needs, comparison values were determined. An average passenger car transported by *AUTOSHUTTLE* uses the equivalent primary energy to 2.3 l Diesel per 100 km. A 40 tons lorry uses 13 l Diesel per 100 km.

Related to the measurements of Transrapid TR07 vehicle a noise emission of a convoy at 180 km/h of less than 74 dB in 25 m distance can be expected. Subjective noise perception is very positive. With the usual convoy frequencies of 80/h and passing durations of 4 s, this yields a low average value of 61 dB in 25 m dis-

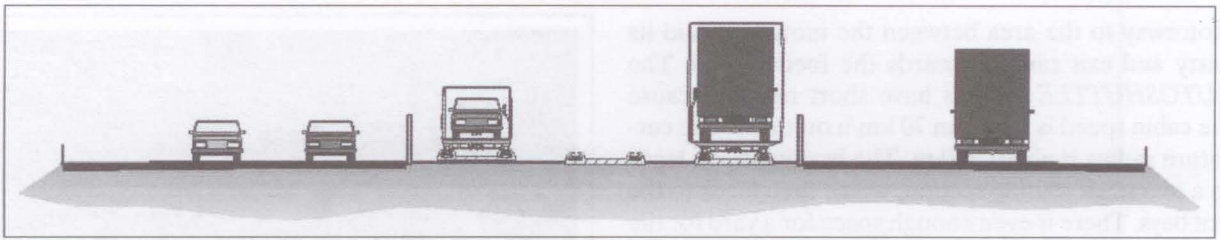

Figure 4 - Cross-section of a motorway with *AUTOSHUTTLE* in the centre

tance, making noise reduction measures generally obsolete. *AUTOSHUTTLE* may therefore be built through populated quarters without causing unacceptable noise annoyance.

3. COMMERCIAL LINE EXAMPLE: DUISBURG-COLOGNE

A typical first application is the German motorway A3 between Duisburg Breitscheid Intersection and Cologne Königsforst. This is a 56 km long stretch currently characterised by very high traffic volume with almost daily tailbacks. The German Federal Ministry of Transport has predicted an increase of more than 15% in passenger traffic and more than 50% in freight traffic by the year 2015. Adding two further lanes to the currently six-lane motorway is very problematic due to close residential areas and the existing noise limitation laws.

There are many other sections of motorways with similar characteristics as the example line presented in this paper. Most of them are located in the condensed areas with their large amount of traffic. Principally, there is no need for a close network, as the cars, lorries and buses could easily continue their journey at the terminal stations of *AUTOSHUTTLE*.

3.1. Civil engineering

The *AUTOSHUTTLE* main tracks will be built at the centre of the motorway, which will be reduced from a six to a four-lane motorway in most sections. This is sufficient for the remaining conventional traffic, since the total traffic capacity of *AUTOSHUTTLE* plus the remaining motorway lanes is far higher than before the construction of *AUTOSHUTTLE* and having six lanes. Figure 4 shows a cross-section of the motorway A3 in the section Cologne-Leverkusen with two *AUTOSHUTTLE* main tracks and a braking track. The lateral limits of the right-of-way have not been affected.

The *AUTOSHUTTLE* stations are typically located at the entrances and exits of the existing motorway. Road vehicles approaching from a feeder road can directly enter an *AUTOSHUTTLE* cabin without using the motorway. Figure 5 shows the realistic con-

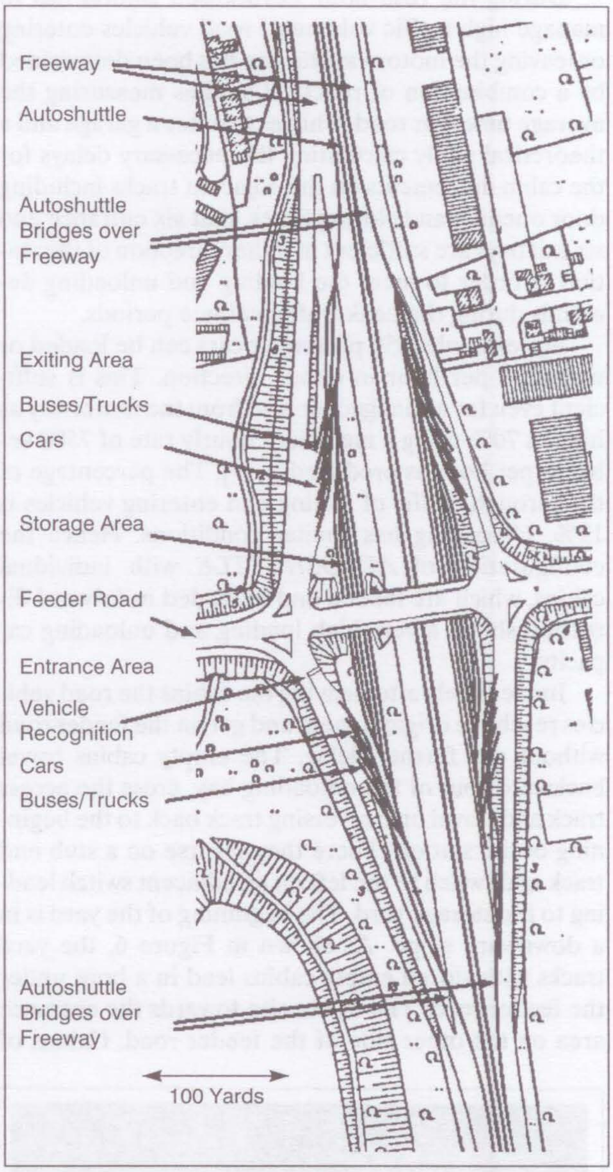

Figure 5 - Leverkusen station

figuration of the *AUTOSHUTTLE* station at the Leverkusen entrance and exit.

Approximately 1.2 kilometre before the station a braking track switches out of the main track in either direction. There are three tracks at the centre of the motorway in these sections as already depicted in Figure 4. The last section of the brake track is built as a bridge leading the brake track from the centre of the motorway to the area between the motorway and its entry and exit ramps towards the feeder road. The *AUTOSHUTTLE* bridges have short ramps because the cabin speed is less than 70 km/h on them. The curvature radius is about 250 m. The braking track leads to a two track waiting section, which then leads to the exit bays. There is even enough space for a yard for the storage of empty cabins during the off-peak hours of a day.

During the rush hour Leverkusen station has to manage high traffic volume of road vehicles entering or leaving the motorway. Its size has been determined by a combination of practical studies measuring the average times for road vehicles to enter a garage and a theoretical study calculating the necessary delays for the cabin movements on the adjacent tracks including door opening and closing times, that six entrance and six exit bays are sufficient in either direction of the station in order to meet the loading and unloading demands during the peak traffic volume periods.

For example, 650 passenger cars can be loaded or unloaded per hour in either direction. This is sufficient even for a changeover rate from the motorway as high as 70% using a maximum hourly rate of 7500 vehicles per hour as predicted in [9]. The percentage of the through traffic of exiting and entering vehicles is 12%. Unloading has similar conditions. Hence the configuration of *AUTOSHUTTLE* with individual cabins, which are loaded and unloaded in forward direction shows a very high loading and unloading capacity.

Immediately after leaving the cabins the road vehicles reach the original ramp and get on the feeder road without any further delay. The empty cabins travel backwards out of the unloading bay, cross the access track and travel on a reversing track back to the beginning of the station. There they reverse on a stub end track and switch to the left on an adjacent switch leading to the storage yard. The beginning of the yard is in a downward slope. As shown in Figure 6, the yard tracks with stored empty cabins lead in a bore under the feeder road. The tracks rise towards the entrance area on the other side of the feeder road. Cabins of each type, i.e. both cross-section types and each available length in either cross-section move via the stub end track towards the waiting track directly in front of the loading bays.

Figure 6 - Access to the Autoshuttle station

Figure 7 - Crossing the motorway towards the main line

On arrival and detection of a road vehicle it is then a matter of a few seconds until a convenient cabin has stopped in the bay which is signalled to the road vehicle driver and has its rear doors open. After loading, the cabin drives to one of the two parallel waiting tracks for small, that is, large cross-section. When a corresponding convoy has passed the reference position on the main track, the starting cabin or small convoy accelerates, crosses over to the centre of the motorway on a bridge, see Figure 7, and switches to the main track. About 1400 meters behind the starting position the cabins are caught up by the through convoy travelling at constant speed.

The terminal stations of the *AUTOSHUTTLE* line are much larger than the shown Leverkusen station since the main traffic on the motorway has to be loaded, that is, unloaded. These stations have 30 bays in each direction. Hourly loading capacity reaches for example 3270 passenger cars. When the *AUTOSHUTTLE* line is extended over these end points, the former end station will become smaller. Returning loops are located at the end points and at intermediate motorway intersections at Hilden and Leverkusen.

AUTOSHUTTLE can be built almost entirely on the existing motorway right-of-way and on the lost areas between motorway and ramps or within intersections. Contrary to the conventional concept of upgrading the motorway, *AUTOSHUTTLE* yields almost without need of new areas a far higher traffic capacity, average speed and drastically diminishes negative impacts like accidents, noise, jams, energy consumption and further emissions.

3.2. Construction strategy

In order to minimise constraints on the motorway traffic during the *AUTOSHUTTLE* line's construction, some of the intermediate stations will be omitted in the first commercial operation phases. Because of the long-distance journeys which already use

AUTOSHUTTLE then, the missing intermediate stations are built with lesser impact on the then reduced conventional traffic. It is economical to already start the operation on very short sections of the order of 15 km, to which further sections will then be added consecutively.

3.3. Financing

Building costs and operation costs as well as the revenues were calculated for the example line Duisburg – Cologne. In case of doubt due to low accuracy of the available data, conservative estimations were used. The result of this analysis shall be used for the following determination if the *AUTOSHUTTLE* line Duisburg – Cologne can be built and operated without subsidies. All the amounts in the following sections of this paper are indicated in Million Euro at a price level of the year 2002.

3.3.1. Construction costs

The construction costs were calculated based on a detailed analysis of infrastructure construction projects of the German Railways - Deutsche Bahn AG. Track construction with sleepers as well as dams and cuts are very similar to classical railway lines. The load is lower, however, at about 4 tons per meter. Long stator drive, energy supply and operation system are based on cost indications for the former Transrapid line project Hamburg – Berlin [8]. The costs for some of the cabin's components like for example magnets, could be determined very accurately. Other components were estimated based on the road vehicle components due to similar production lots and construction methods. The following table shows a summary of the building costs. The line capacity is sufficient for the traffic volume as predicted and described in the following chapters.

Construction Costs	Mio. Euro
195 km track inclusive 1300 passive switches	103
58 bridges over roads	99
29 bores under roads	28
Long stator cable for 195 km track	47
Land purchase	26
Energy supply components	298
Buildings	65
Operation system	59
Planning, miscellaneous	79
1.862 cabins à 65.000.- Euro for a small and 570.000.- Euro for a large cabin	289
Total	1,093

According to the construction strategy described in Chapter 3.2 the line starts commercial operation being partly completed two years before the final completion. Revenues from this period will be used for the financing of the last section, which will get into commercial operation four years after the start of the line construction. At an interest rate of 7.5% and a credit period of 25 years, this yields annual capital costs of 112 Mio. Euro. Deduction will be financed entirely by profits as described below.

3.3.2. Revenues

The *AUTOSHUTTLE* line will be built and operated privately without any subsidies. Revenues result only from fares paid by road vehicle users who use *AUTOSHUTTLE* instead of the parallel motorway. Further attracted traffic can be expected but will not be considered in the following analysis. Traffic volume on the parallel motorway was determined based on [1] and [9]. The precondition for large revenues is high acceptance among potential users. A preliminary acceptance survey (see [2], annex A8) shows that *AUTOSHUTTLE* with its features

- transport of road vehicles in cabins on dense traffic motorways,
- fast, individual and flexible,
- safe, reliable and cheap,

corresponds to the requirements of almost all car travellers. For very short journeys however, the total travelling time is not attractive due to the time losses connected to loading and unloading, so that only low acceptance of changing over to *AUTOSHUTTLE* can be expected for such journeys. Starting from this, the changeover rate from the motorway to *AUTOSHUTTLE* has been evaluated based on a road vehicle, daytime and journey length dependent analysis. Input data include:

- comparison of total travelling times when using the motorway or alternatively *AUTOSHUTTLE*,
- changeover resistance towards *AUTOSHUTTLE*, which limits the percentage of *AUTOSHUTTLE* users even in the case of an advantageous *AUTOSHUTTLE* total travelling time,
- certain dislike of using the motorway during rush hours due to the tailback risk and during bad weather periods due to the increased accident risk.

For the time-dependent traffic volume on the studied motorway section the daytime and weekday dependent characteristics according to [9] were used. The distribution of the journey length on the motorway has been estimated as almost even with a small maximum at 35 km. The changeover rate mainly depends on the distance travelled on the motorway for each journey considered. For distances up to 6 km the changeover rate is zero. During night hours the changeover rate for passenger cars reaches only 36% even for the longest journey, i.e. 56 km.

However, further noise reduction laws would result here in an increase. Considering the other extreme, the changeover rate reaches 59% for passenger cars during rush-hour on the longest journey. The corresponding value is 79% for lorries and buses. They have a total travelling time of 24 minutes for the 56 km from entering the station including all waiting times until exiting from the final station. This stands against an average of 45 minutes when travelling the same distance on the motorway.

Summarising, the prediction shows that 32% of all journeys will change over to *AUTOSHUTTLE*. Since mainly long distance journey will be attracted, this value represents 40% of the vehicle-kilometre travelled on the motorway. The percentage of lorries and buses is 28% and thus much higher than on the parallel motorway, where it is about 14%. The remaining four-lane motorway will be used during peak hour by 1550 vehicles per lane and hour, thus somewhat less than currently so that the perturbation tendency will be diminished.

Using the *AUTOSHUTTLE* fare model as indicated above: "5% cheaper than the fuel cost and - if applicable – additionally the heavy weight tax", results in revenues of 183 Mio. Euro, out of which 62% result from lorries and buses.

3.3.3. Operational costs

The following table shows the annual operational costs. Deduction will be described in the text below.

Operational costs per year	Mio. Euro
Staff costs for 178 employees	10
Material costs for maintenance	14
Energy costs at 0,06 Euro/kWh	12
Insurances	5
Total	41

The low running costs of the cabins result from their simple construction with very few rotating or hinged parts. Furthermore, it is very cost-efficient for the operator to offer transport volume for road vehicles instead of seating capacity for passengers. Specific energy costs are very low due to the convoy operation with low aerodynamic drag per cabin at 180 km/h only and the minimised acceleration and brake phases.

3.3.4. Net result

The *AUTOSHUTTLE* construction and operation company is profitable from the first year of operation on the full line and achieves a pre-tax profit of 23 Mio. Euro. This will increase in the following years due to constant capital cost and increasing revenues which are higher than the operational costs. Even if only 27% of the journeys, representing 33% of the road vehicle kilometres change over to *AUTOSHUTTLE*, full cost coverage is achieved.

The predicted changeover rate is 24% higher than this value. Deduction can therefore be financed by profits. Even if only 27% of the journeys change over, deduction can be financed before the end of the credit period by profits which in this case start in the second year of full line operation. If in later stages long *AUTOSHUTTLE* lines are connected to a complete network, the changeover rate will further increase, since mainly long distance journeys are attracted by *AUTOSHUTTLE*. Even lines with lower traffic volumes can be built and operated without subsidies.

The selected fare model partially offers extremely low costs for the user. The most economical Volkswagen Lupo or Audi A3 diesel compact cars would travel for example from Berlin to Frankfurt am Main for 13 Euro, the distance being 520 km. Door-to-door travelling time would be slightly more than 3 hours. In reality, most users would have to bear further costs when travelling on the parallel motorway like for example tyre use, mileage-dependent workshop costs and the mileage-dependent reselling value loss. Together with the fuel cost, this sums up for the example mentioned up to 26 Euro (see [2], Annex 9).

The preliminary survey in [2], Annex 8, shows that a very high percentage of the potential *AUTOSHUTTLE* users would accept it, if these additional costs were considered in the determination of *AUTOSHUTTLE* fares. Therefore, higher fares as used in the above Chapters are probably acceptable.

4. CONCLUSION

Construction of an *AUTOSHUTTLE* line results in a means of transport with very

- high safety,
- low door-to-door travelling times,
- high traffic capacity,
- high reliability,
- high individuality,
- low energy consumption,
- low noise emission,
- low space requirements which can be flexibly adapted to the circumstances,

and therefore fulfils all the criteria of a new means of transport. The example commercial line from Duisburg to Cologne shows that even with pessimistic assumptions, the construction and operation are feasible without subsidies. Due to the excellent *AUTOSHUTTLE* features there is high acceptance level among the users and the line residents, since this means of transport has many intermediate stops which will offer high speed service.

Additionally, *AUTOSHUTTLE* will result in a drastic reduction of the motorway traffic density and the corresponding nuisances. *AUTOSHUTTLE* can be economically constructed in mutually isolated short lines at the most critical spots. So, there is no need for a close network connecting all major cities. Even a short first line of only 50 km length yields profit already in the first year of operation. Thus, *AUTOSHUTTLE* solves one of the most urgent transport problems in a feasible and economical manner.

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ZUSAMMENFASSUNG

AUTOSHUTTLE: KONZEPT UND KOMMERZIELLE ANWENDUNGSSTRECKE

Das Transport System AUTOSHUTTLE integriert den Straßenverkehr und den spurgebundenen Verkehr unter Ausnutzung und Kombination der jeweiligen Vorteile jedes dieser Verkehrsträger. Konventionelle Straßenfahrzeuge werden einschließlich ihrer Passagiere und Fracht in indivduellen Kabinen transportiert. Das Betriebskonzept von AUTOSHUTTLE bietet einen Betrieb der Kabinen ohne Zwischenhalte mit nahzu konstanter Reisegeschwindigkeit. Während der Reise werden Konvois mit einem geringen aerodynamischen Widerstand gebildet um den Energieverbrauch zu veringern und die Verkehrsleistung zu erhöhen. Bei Annäherung an eine Station verlassen nur jene Kabinen, die ihr Reiseziel erreicht haben, den Konvoi über eine passive Weiche und verzögern auf einem Bremsgleis, während die anderen Kabinen die entstandene Lücke schliessen und mit der üblichen Reisegeschwindigkeit weiterfahren. Dieser Aufsatz beschreibt die Planung und die ökonomischen Aspekte eines Vorschlags für eine kommerzielle Anwendung entlang der Autobahn A3 in Deutschland zwischen Duisburg und Köln als ein typisches Beispiel für viele andere Anwendungen.

SCHLÜSSELWÖRTER

Rendezvous-Manöver, passive Weiche, Autobahn

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