HIGH-SPEED MAGNETIC LEVITATION TRAIN TRANSRAPID, PLANNING OF THE FINAL DEVELOPMENT PROGRAM UNTIL 1995 AND PROSPECTS OF UTILIZATION IN THE FEDERAL REPUBLIC OF GERMANY

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Introduction

TRANSRAPID is a transport system of advanced technology, designed for speeds up to 500 km/h. TRANSRAPID vehicles are supported by electromagnets and propulsed by a synchronous long-stator motor integrated in the guideway.

Following a development period of approximately twenty years, Deutsche Bundesbahn (German Federal Railways) in 1991 confirmed a development status which allows the initiation of planning procedures for application routes without system risks and safety risks. The planning procedures for a first track will be conducted in parallel with the final development phase for economical reasons and in order to avoid time gaps between the completion of development and the start of construction. According to the time schedule the construction of the first route is to begin in 1995. Operational service is expected to start about 2000.

1. TRANSRAPID - characteristics and application fields

The electromagnetic forces which support, guide, drive and brake the TRANSRAPID vehicles, are transmitted - free of contact - over the entire speed range as controllable area loads. The power installation of the long-stator motor is accommodated in the guideway and not in the vehicle. The resulting advantages of this design permit efficient and ecologically reasonable operation throughout the whole speed range (fig. 1) :

TRANSRAPID routes can be constructed at reasonable cost and with an acceptable impact on the environment even in a difficult topography. In corridors with sufficient transport volume, the system can be operated economically at fares comparable to those of conventional railway systems. Additionally, environmental requirements can be adhered to even in the high speed range of 400 to 500 km/h. In sections through densely populated areas, where the noise emission has to be kept especially low, the operational speed can be reduced with only negligible effects on the travelling time. Studies of operational routes have confirmed these results.

Based on its characteristics and the requirements of the transport market, the following service profile is derived:

In cooperation - not in competition - with the conventional railway the TRANSRAPID can serve as a superimposed rapid transport system for corridors with high traffic volume over medium and long distances, primarily for passenger transportation but also for transportation of container freight; with close links to the wheel-on-rail system in existing central stations or in new peripheral stations, as well as with airports, highway junctions and public transit terminals. Further fields of application include the high-speed connection of adjacent urban centers and airport connections.

* Low wear and maintenance cost

* Low guideway loads

* Flexible routing parameters

* Minimum interference with the landscape due to easy adaptation of the route to the topography

* Economical operation due to short vehicle travelling time per cycle

* Comparatively low emission of noise and vibration, particularly in the speed range used for entering urban areas

* Comparatively low energy consumption because of low vehicle weight and complete aerodynamic fairing

* High acceleration and deceleration by virtue of low vehicle mass and high propulsion power in those sections of the track where it is necessary. As a result, a high average speed can be achieved even when there are short distances between stops.

* High payload, nearly constant over the whole speed range

Fig. 1: Specific characteristics of the TRANSRAPID sytem

The following contributions to the general objectives of transport research and policy can be obtained:

* Airports and air space can be relieved; domestic flights which account for a large portion of aircraft movements could be replaced by the TRANSRAPID. Flights from airports which are connected by TRANSRAPID may be combined, and therefore more economical airplanes with higher passenger capacity could be used.

* Highways will be partly relieved of the long-distance automobile traffic.

* Conventional railway systems in congested corridors will be partly relieved of the fast passenger transport volume so that the necessary capacity for regional traffic and freight traffic will be available. This is of primary importance in view of the drastically rising West-East traffic in Europe and the growth rates expected within the EC.

* The traffic volume on connecting railway will increase.

Energy consumption and CO_2 emissions can be reduced: the TRANSRAPID's energy consumption per passenger and kilometer is lower than that of the transport systems it will substitute. Given the same transport volume, CO_2 emissions will thus be reduced. Additionally, CO_2 emissions will be reduced if the electric power is not exclusively generated from fossil fuels.

In terms of passenger safety, TRANSRAPID offers the same or even more benefits than other modern railway systems, e.g. separate track, free from crossings, a signalling system which ensures safe headway, the possibility of automatic operation. In addition, the system is protected against derailment; trespassing on the guideway is impossible. A shift of traffic to the TRANSRAPID will, therefore, reduce the number of accidents - an important aspect in view of the alarming statistical data about traffic accidents.

Short travelling times, high ride quality and high safety combined with competitive fares and an appealing image play a vital role in a passenger's choice of a transport system. As the TRANSRAPID fully meets all of these criteria, it can contribute to making public passenger transport systems more attractive.

2. STATE OF DEVELOPMENT

2.1 Overview of the first years of development

As early as 1930, Hermann Kemper from Nordhorn in the Emsland worked on the electromagnetic levitation principle. In 1934 he was granted the patent for a "Levitation system with unwheeled vehicles which is guided in a levitated state along iron rails by means of magnetic fields". Even though he was lacking modern electronic tools, he was able to demonstrate magnetic levitation by experiment.

In the mid-sixties the negative effects of large-scale motorization became evident and the development of rapid railway systems in wheel-on-rail technology and in new contact-free levitation technology was emphasized in several countries.

The German Ministry for Research and Technology has been sponsoring a comprehensive development program in the field of new transport technologies since1970. Based on the work of Hermann Kemper, the electromagnetic principle was the main line of development. In the first phase the numerous possibilites of magnet arrangement and linear motor versions were studied and the best combinations selected and compared with the competing technologies of levitation by permanent magnets, electrodynamic levitation and air cushion systems. The first positive results were soon to appear. As early as 1974, the TRANSRAPID 04 was presented, a vehicle with a capacity of twenty passengers and a maximum speed of 250 km/h.The KOMET, a component instrument carrier with a top speed of 400 km/h was demonstrated in 1976.

The selection process was completed in 1977. The electromagnetic levitation principle with separately controlled magnets for vehicle support and also for guidance and a synchronous long-stator linear motor with its active winding accommodated in the guideway combined with contactless supply of the on board electrical power by linear generators, proved to be the best choice. The basic TRANSRAPID concept was thus defined.

Already in 1979 the TRANSRAPID was presented at the International Transport Exhibition in Hamburg on a reduced scale, with a vehicle with a capacity of 70 passengers on a track of 1 km in length; more than 40,000 visitors opted for a ride on board the levitation train.

The selection of the TRANSRAPID concept has been confirmed by the experience gained in the meantime.

2.2 Testing on the TRANSRAPID Test Facility in the Emsland (TVE)

TVE development and construction started in 1979. This was the world's first MAGLEV test facility which enabled the full-scale testing of all principal components and of the complete system at high speeds and continuous operation. Main TVE components are the guideway, a high-speed straight section with loops on both ends, with an overall length of 31 km and with three switches; 2 vehicles, the TRANSRAPID 06 and 07, with a capacity of approximately 200 passengers each; the test center, power supply and the operations control system (fig. 2 and 3). The facility which was built by an industrial consortium started operations in 1984. One year later it was taken over by the Versuchs- und Planungsgesellschaft für Magnetbahnsysteme (MVP), a company founded by the Deutsche Bundesbahn, Lufthansa and IABG with the aim of testing the TRANSRAPID from an operator's point of view.

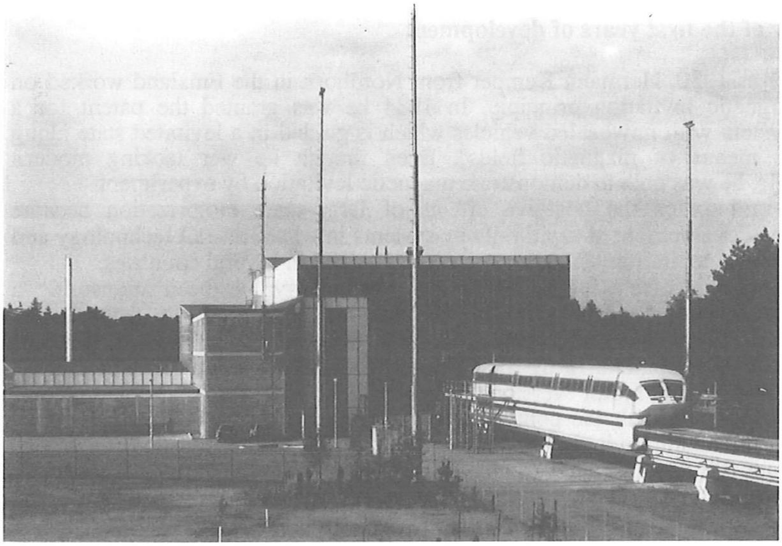

Fig. 2: TRANSRAPID Test Facility Emsland (TVE), Test center with vehicle TRANSRAPID 06

Testing was not without its technical setbacks, which, however, were almost never attributable to specific components of the magnetic levitation system. The objectives, however, were attained. Top speed could be increased from the design value of 400 km/h to 435 km/h. Extrapolations show that there are no limitations at this speed and that the system design is sufficient for operation at 500 km/h. In several endurance test campaigns, a total mileage of approximately 120,000 km was reached. The mileage record for a single day was about 2,500 km.

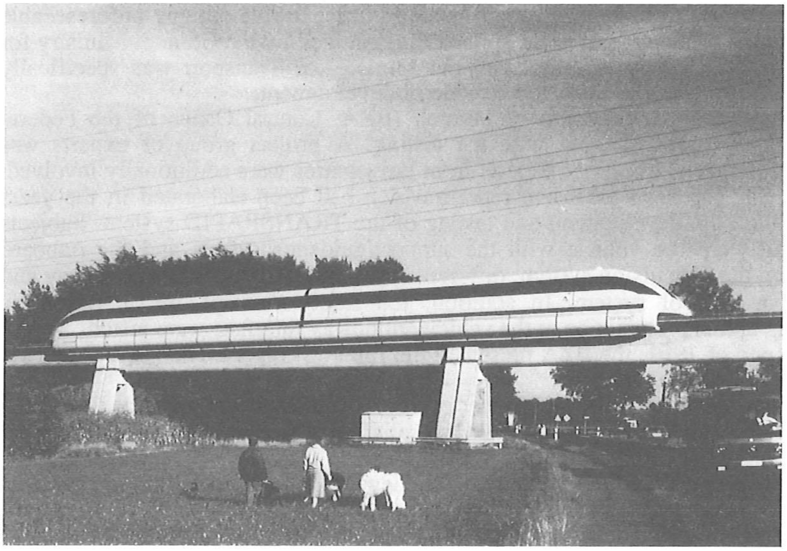

Fig. 3: TRANSRAPID Test Facility Emsland (TVE), vehicle TRANSRAPID 07

The tests included the qualification of the main hardware components of a complete new transport system in a prototype stage, in some cases in two generations. The mechanical and electrical designs had to be scrutinized. But also software concepts and procedures which are necessary to operate a tracked high speed passenger transport system safely and economically have been included into the testing as far as possible. Special importance was attached to the gaining of data which are relevant for an operator of a revenue system, such as verification of safety, investment costs, maintenance, energy consumption, aerodynamic behavior, riding comfort and noise emission.

The overall results were as follows: The principle advantages of the TRANSRAPID could be confirmed in full extent. Fundamental redesigns have in no case been necessary. All problems arising during the test phase could be solved satisfactory. A number of possibilities for further optimization could be brought to light. Continuation of the endurance testing is still necessary in order to complete and to corroborate the test results.

2.3 Qualification of readiness for application

The direct aim of the TRANSRAPID development is the construction and operation of a first application route. Experience has shown that it takes several years of planning procedures until construction go-ahead is given for a traffic route. To avoid large time gaps between the completion of development and the start of construction, the planning procedures for a first TRANSRAPID route have to be initiated in parallel with the final development phase. Before initiating the planning, the development has to be in an advanced state in order to rule out any unforeseeable risks. The testing of the readiness for application, initiated by the German Ministry for Research and Technology together with the Ministry of Transport was specifically designed to furnish proof of an adequate state of development.

The Bundesbahn Zentralamt in Munich (BZA, Central Office of the Federal German Railway), was charged with the testing. A project group of experts was established, for special questions experts from universities were additionally involved. The testing was based on extensive reports which had been elaborated in the years 1987 to 1990 on the development and testing of the TRANSRAPID system. Subjects of the testing were the vehicle with the support/guidance system and the onboard power supply, the propulsion system, different types and designs of the guideway and the operations control system. In addition, the safety concept, the aerodynamic dimensioning and the interaction at the vehicle/guideway interface were tested.

At the end of 1991, the BZA presented the final test report. The Central Federal Rail Office concluded as follows:

The criteria to be considered for technical readiness for application of the TRANSRAPID High Speed Maglev Train are satisfied. This means that

* the prerequisites for implementing the legal planning procedures are present;

* system risks and safety risks overall and in the subsystems are not present.

This also applies to technical solutions which have not yet been demonstrated for individual problems for which solution approaches exist and are being assessed.

Supplementary information and suggestions are given for the additional necessary development work with regard to application.

3. FINAL DEVELOPMENT PROGRAM

The BZA expertise has provided an exactly defined development state so that development work which has still to be performed could be specified.

In the negotiations of the coalition parties of the German Federal Parliament in January 1991, it was basically agreed to carry out the final development.

To ensure the program's success, namely the construction of a first application route, negotiations with the major partners involved were conducted after the coalition agreement. The following results, which are interdependent and the prerequisite for the successful completion of the program were achieved:

* The German Federal Ministries of Research and Technology and of Transport are investigating suitable TRANSRAPID application routes in and together with the new German Federal States in a joint working group with the aim of including a line in the infrastructure plan which is to be passed in 1992.

* The German Federal Railway provides support required for the continuation of the program and is interested in taking over the revenue service of TRANSRAPID routes.

* The participating industries provide considerable contributions for the total financing of the development.

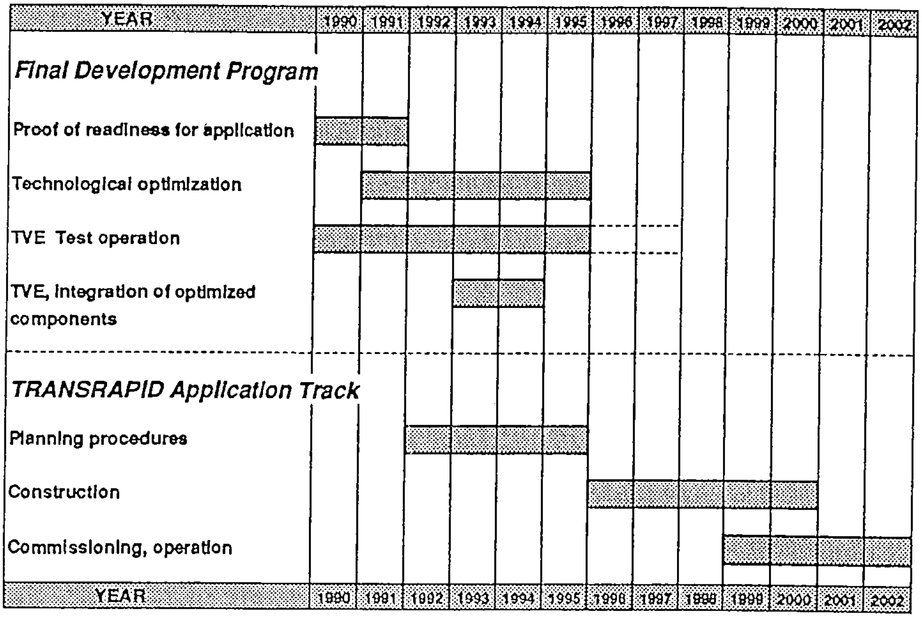

Fig. 4: TRANSRAPID, final development program 1991 to 1995, planning and construction of a first application track in Germany

As soon as these prerequisites had been settled, the final program was started. It will be executed in the 1991 to 1995 timeframe and consists of the main program parts (fig. 4):

* Final technological optimization with the keypoints high speed aerodynamics, utilization of the technological progress in electronics, further improvement of the availability and of the data which are relevant for environmental influences;

* Endurance testing on the TVE under all specified operating conditions, in order to gain more experience in operation and maintenance, with the aim to define and valididate the regulations and operation instructions for revenue lines;

* Employment and testing of optimized components, especially for the propulsion and signalling/control system and of auxiliary operation devices on the TVE;

* Basic research and companion studies and assessments.

4. APPLICATION ROUTES IN THE FEDERAL REPUBLIC OF GERMANY

4.1 Background

More than 20 years ago the Federal Government drew up a general traffic infrastructure planning which aims at developing the various means of transport so as to achieve optimum benefit for the national economy while giving consideration to aspects of technology policy, land use planning, environmental protection and regional industrial development. Each individual project is considered in terms of overall economic benefit versus the costs involved. A common evaluation procedure for all means of transport is used for such consideration. The catalogue of projects of high priority in this infrastructure planning is being revised and supplied at regular intervals. In 1992 the Federal Government will adopt the next version of the traffic infrastructure plan which will set up building programs up to the year 2010. In view of the German reunification this plan has to be extended to the New Federal States. With regard to the urgent need to improve traffic links between East and West, the congested railway corridors and airports, and following up recommendations of the parliamentary groups of the Coalition, it is intended to include suitable TRANSRAPID lines in the new infrastructure planning.

To identify suitable lines for a first TRANSRAPID application the Federal Ministry for Research and Technology and the Federal Ministry of Transport started investigations in and together with the new German Federal States in summer 1991.

4.2 Selection of routes to be analysed

In the selection process the following aspects had to be considered:

An established need for transport and a sufficient traffic volume; preferably, no selection of routes that already yield high gains within the existing railroad network; preferably, selection of routes with only a small or no effect on planned conventional rail links, prospects for subsequent extension, possibility of realising a TRANSRAPID track in successive construction phases; above all the TRANSRAPID should upgrade service in areas which so far have been underserviced.

With these criteria in mind the Federal Ministry of Transport proposed that the following links be analysed (fig. 5):

T1: Hannover - Halle - Leipzig

T2: Hamburg - Berlin

T3: Hamburg - Parchim Airport - Berlin

T4: Berlin - Berlin Süd Airport - Dresden

T5: Stuttgart - Nürnberg - Dresden

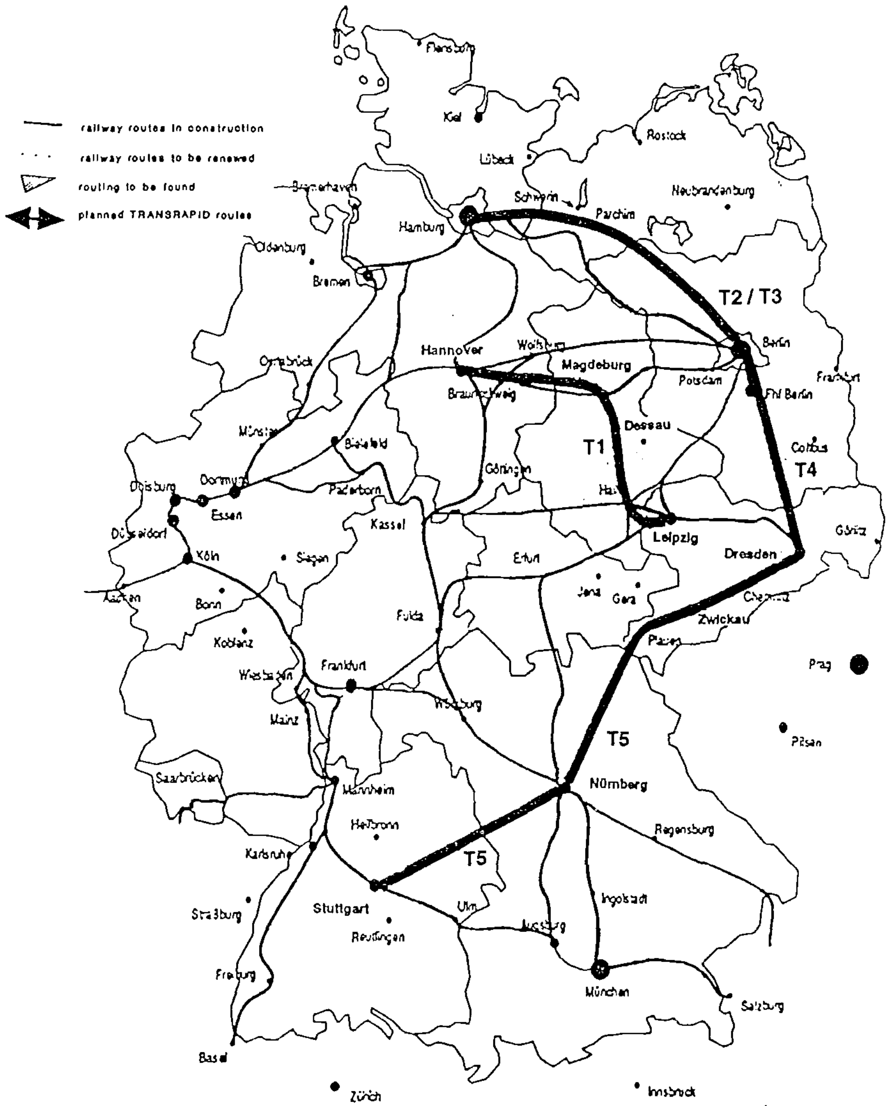

Fig. 5: TRANSRAPID links in investigation with regard to the German traffic infrasructure planning

In response to a recommendation by parliamentary working groups a link between Bonn and Berlin was also selected for detailed investigation (fig. 6).

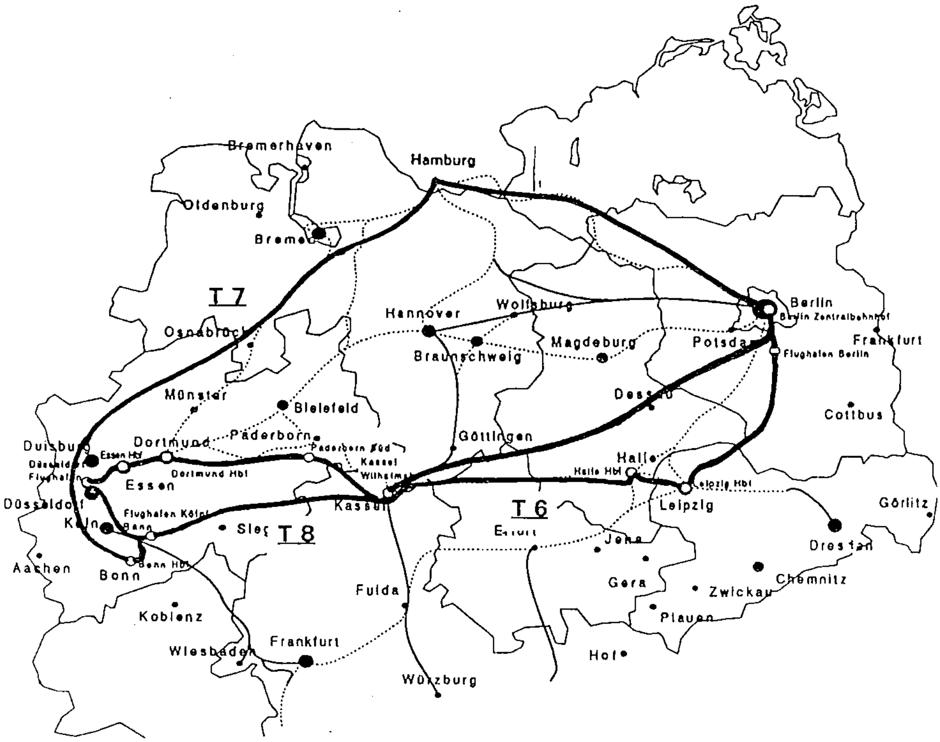

Fig. 6: Alternative TRANSRAPID routes Bonn - Berlin

4.3 Procedure

The proposed routes were studied in a step-by-step analysis according to the general evaluation procedure which has to be performed before infrastructure projects can be included into the general traffic infrastructure planning:

* environmental impact assessment;

* alignment;

* forecast of passenger transport volume;

* service planning;

* dimensioning of the infrastructure;

* calculation of investment costs;

* calculation of operating costs;

* determination of effects on the existing passenger and goods transport network;

* evaluation of the effect on the whole national economy;

evaluation of effects on the profitability of the German Rail.

The benefit/cost ratio resulting from these evaluations is decisive for the inclusion into the infrastructure planning.

4.4 First results of two selected routes

As the investigations are not yet completed at the delivery-date of this report some preliminary results are given for the following routes:

4.4.1 Hamburg - Berlin

The Hamburg - Berlin route is of particular interest from the transport and economic point of view. First and foremost, this intercity line is to link the two biggest German cities as a kind of metroliner.

The length of the Hamburg-Berlin link is 287 km; travelling time is around 55 minutes. At a fixed cycle of one TRANSRAPID train every 10 minutes, the service would comprise 95 four-section trains per day and direction.

The transport volume is estimated at 15.3 million passengers and 4.4 billion passenger kilometres per year. The increase in the capacity of freight trains on the existing railway lines was calculated to be some 430 million ton kilometres.

4.4.2 Bonn - Berlin

Three tracks for this link are currently being studied:

Bonn - Cologne/Bonn Airport - Düsseldorf Airport - Essen - Dortmund - Paderborn - Kassel - Leipzig - Berlin Airport - Berlin Central Station (710 km);

Bonn - western Ruhr area - Bremen - Hamburg - Berlin (750 km);

Bonn - Kassel - Berlin (direct route) (548 km)

Assuming a travelling time of 3 hours, a traffic volume of about 40 million passengers can be expected according to first estimates with respect to the first version of the Bonn - Berlin link. Version 3 would offer the advantage of the shortest travelling time of about 2 hours.

4.5 Time schedule for the implementation of TRANSRAPID application tracks

The inclusion of one or two TRANSRAPID tracks into the general traffic infrastructure planning can be expected in 1992. Subsequently the legal planning procedures can be initiated. In this case the construction work may start in 1995 and the commissioning of first sections can commence before the year 2000. If things go well, a promising new transport system which helps to avoid traffic congestion on the ground and in the air and which causes less damage to the environment than other transport means, can take up revenue service about the year 2000.