Actual developments in Guideway Constructions at the Example of the TRANSRAPID Munich Project

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Keywords

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Abstract

This report provides a project and describes the track routing and the design of the guideway constructions for the TRANSRAPID project Munich Main Station - Airport. Standard solutions for the single- and double-track guideway for all guideways types as well as special constructions like bridges, tunnels, switches and protection measures are discussed.

1 Introduction

During the period 2001 - 2003 we have all seen the unprecedented successful realisation of the Transrapid Demonstration Line in Shanghai, China. Now the documents are prepared for the planning determination process for the approx. 38 km environmentally friendly Airport Shuttle in Munich, Germany with a travel speed of up to v = 350 km/h.

The route consists of at-grade and elevated double-track guideways. The track length of 37.7 km is divided in approx. 8 km elevated guideway, approx. 22 km at-grade guideway and 3 tunnels with a total length of approx. 8 km. The route is planned in collocation with existing tracks of railroad and federal highways.

Fig. 1: Overview track

2 Project Overview

2.1 Cause

Munich airport is expected to expand up to the year 2015 with an increase of the annual passengers from the current 23 million to approx. 48 million and an increase in airport staff of currently 20.000 to approx. 40.000. Today the airport is linked Munich by the interurban train lines of S 1 and S 8. The travel time of both the S 1 from the central station via the western suburbs with 12 stops and the S 8 via the eastern railway station and the eastern suburbs with 13 stops takes in each case approx. 40 minutes. Considering the growth evolution of the airport this railway link is inadequate in the long term. For the improvement of the traffic accessibility between the airport and the city of Munich a further rapid train connection with a maximum frequency and a minimal travel time is necessary.

In January 2001 the Federal Minister for traffic, building and housing instructed a planners team to carry out a feasibility study for a high-speed Maglev link between Munich Main Station and Munich Airport. Based on the results of this study the Bayerische Magnetbahnvorbereitungsgesellschaft mbH (BMG) was founded in the year 2001. The BMG had to practise the specification of the possible route variants according to the plan-legal and regional planning legal basic principles. They had to prepare and to carry out the plan regulation process with integrated environmental impact assessment.

2.2 Objectives

The main project aim is to improve qualitatively the accessibility of the airport to Munich central station link as well as to the city via public transportation. For this purpose the project is supposed to meet following traffic requirements:

- Short journey duration, from Main Station to the Airport in 10 minutes
- High frequency, as continuous as possible with 10-minute-service
- High reliability, low interference-risk
- Adequate travel comfort for flight travellers with baggage
- Convenient connections to the regional, national and interurban train networks at the central station by short route
- Connection to the subways at the central station
- Station at the airport located with minimal distance to terminal 1 and terminal 2

Furthermore the following additional traffic aims are pursued within the project:

- Implementation of a new transportation system with magnetic levitation technique
- Stabilization of the public passenger traffic between the city and the airport

2.3 Track routing

After the public hearing on land use planning procedures a decision was taken on the West Route (Fig. 1). Ecological and economic reasons speak for this route between Munich Main Station and Munich Airport through the north-west part of the city.

The track runs from the central station arranged above the railway tracks 11 and 12 in the main hall in high level in western direction, crosses the Paul Heyse underpass, falls then strongly off and underpasses the Hacker bridge in the first tunnel. The tunnel is double bore. Currently the alternativ approach of the track into the central station below the railway tracks 23 to 26 is checked.

The track in the tunnel continues along the railway axis south of corridor "Munich 21", bends then north and underpasses the entire track field to reach the Landshuter Allee north of Arnulfstrasse.

At km 4.8 the route emerges again, north of the Borstei residential area. From here the guideway continues north surface level parallel to the Landshuter Allee and the freight sidings and past the Lerchenauer Lake. In doing so, it crosses over the Georg-Brauchle-Ring at km 5.2 and Lerchenauer Strasse (km 8.1), passing a mixed urban landscape of residential areas, industrial buildings, community facilities and small garden allotments.

From km 8.5 until km 10.2 the route runs in a tunnel once more, parallel to the Munich-Landshut railway line, whereby it passes beneath the S-Bahn station and the underground station in Feldmoching at km 9.4. North of Feldmoching the route emerges west of the railway installations. At km 10.7 it crosses over or beneath the A 99 near the Feldmoching threeleg motorway interchange. Subsequently the route traverses agricultural land where the speed of the journey increases to around 350 km/h.

From km 12.8 on the route runs west of the A 92 and, closely following it, moves north-east, passing several trunk roads and the A 9 at the Neufahrn motorway junction (km 23.9). At km 28.3 the Munich-Landshut railway is crossed at km 30.9 the river Isar is crossed and at km 32.7 the A 92 motorway. In order to cross the Isar the guideway is elevated to the level of the A 92. From km 33.5 on the route follows the airport approach road and the S-Bahn track at at-grade level once again. At km 33.6 it passes beneath trunk road number 44.

From km 36.2 on the route enters a tunnel which takes it under the Terminal area directly to the Munich Airport Center between Terminal 1 and 2. Total length of the route: 37.7 km.

Track length	double track	37.7 km	
Parallel to roads / railways	approx.	2.9 km	
Overall tunnel length	approx.	7.2 km	
Elevated guideway	approx.	8 km	
At-grade guideway	approx.	22 km	
Track to the maintenance center	single track	1.0 km	
Stations		2	
Tunnels		3	
Average speed		222 km/h	
Max. Operation speed		350 km/h	
Travel time		10 min	
Minimum distance of the vehicles		10 min	
Daily operation time		20 hours	
Track centre-to-centre distance	minimum	4.40 m	
Min. / Max. Height of the space curve above ground		2.20 m / 15.00 m	
Guideway girder type I, L = 24.8 m	approx.	650 pcs.	*)
Guideway girder type II, L = 12.4 m	approx.	3500 pcs.	*)
Guideway girder type III in tunnels and on bridges, L = 6.2 m	approx.	2400 pcs.	*)
Substructures total for type I and II	approx.	2100 pcs.	*)
Low-speed switches, L = 78.4 m		3 - 5 pcs.	*)
Sliding platform over 5 tracks, L = 110 m		1 pcs.	*)
Pivoting girder, L = 145 m		1 pcs.	*)
Number of vehicles		5 vehicles with each 3 sections	

*) Planning status: may 2004

Fig. 2: Project data

2.4 Organisation of the BMG

In the year 2001 the BMG was set up with the goal of pressing ahead the realisation of the Munich Project. The company's main task is to prepare the planning for the Transrapid magnetic levitation train link from Munich Main Station to Munich Airport. This involves the provision of all the necessary documents for the public hearing on land use and the plan regulation process required under the regional and public works planning procedures. In addition, the BMG functions as the authority for the realisation of the required procedures, the public hearing on land use and the plan regulation process, and has the task of informing the public about the progress of the project.

Deutsche Bahn AG and the Free State of Bavaria are equal partners in the company, each providing one managing director. It is hoped that the State Capital of Munich, the Airport Munich GmbH, the Deutsche Lufthansa AG and other will at some stage participate in the company.

2.5 Planning Processes

According to the German planning regulations two major planning stages must be implemented consecutively one after the other:

- Firstly, the regional planning procedures for the public hearing on land use (ROV), which requires the definition of the complete routing of the track particularly in accordance with the environmental requirements.
- Secondly, the plan regulation process (PFV), which requires the detailed presentation of any works implementations in detail which may harm the existing environment and which therefore will have to be sympathetic to any existing rights as far as they deserve protection under the current legal standards.

2.6 Plan Determination Sections

On the basis of the result of the regional planning procedure the plan determination process is commenced in 10/2003 and is due for completion in 08/2004 in the course of a deepening planning for the West Route according to the Magnetschwebebahnplanungsgesetz. The route has been split into five plan determination sections (PFA) (Fig. 3):

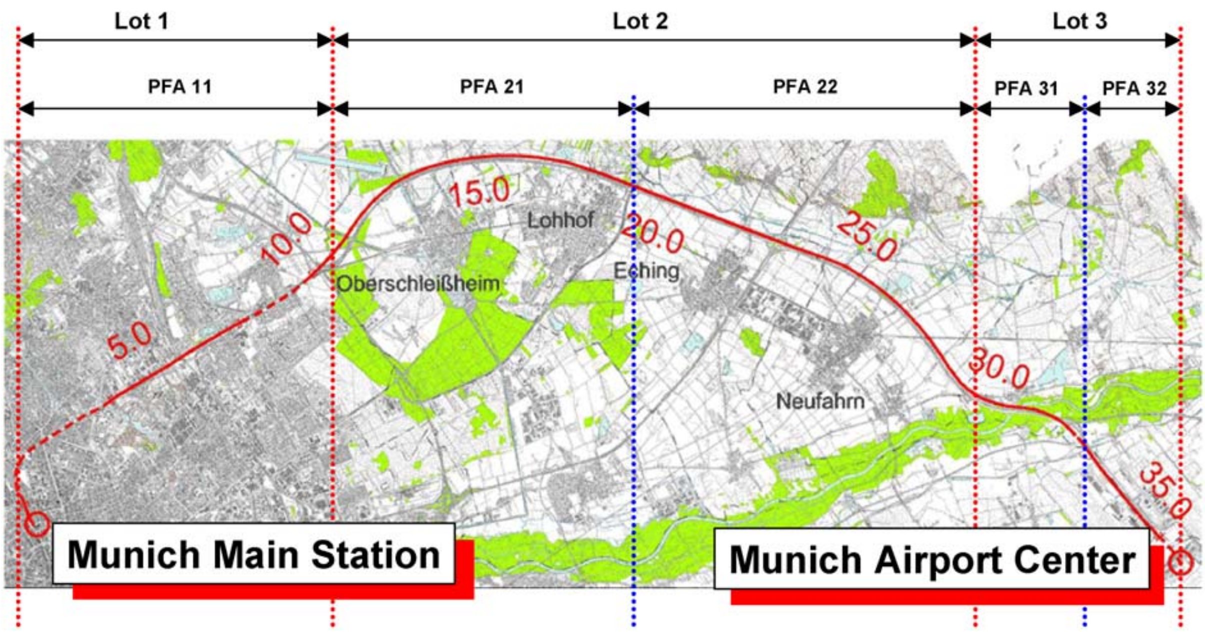

Fig. 3: Plan determination sections

The subdivision of the total route into plan determination sections has been done for procedural reasons, based on different problem priorities of the track and for better manageability and clear planning areas. So far as possible and reasonable, the rural district and municipality boundaries were considered during the formation of the sections.

PFA 11	Capital Munich	section length	11,1 km
PFA 21	Ober- / Unterschleißheim	section length	8,8 km
PFA 22	Eching / Neufahrn	section length	9,6 km
PFA 31	Isaraue	section length	4,1 km
PFA 32	Munich Airport	section length	4,2 km

2.7 Dates and Milestones

The construction of the first line sections is due to start in spring 2006 so that the TRANSRAPID can go into operation at the end of the year 2009. For this purpose the necessary public hearing on land use was carried out at an early stage. The preferred route derived from the public hearing on land use must now be examined more closely in order to arrive at the planning status necessary for the plan approval procedures. This is expected to take 18 months.

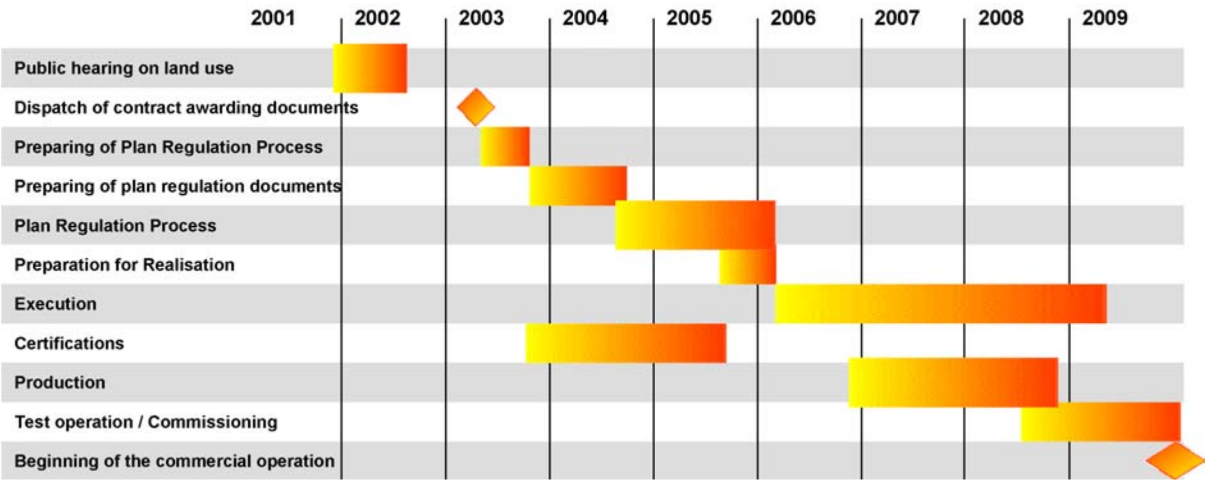

Fig. 4: Dates and Milestones

3 Standard Guideway Constructions

3.1 Type I, II,III with Modified Envelopes

In connection with the development of standard solutions for the single- and double-track guideway for all guideway types structural calculations and dynamic analyses were prepared before the project planning in Munich began. These formed the basis for mass- and cost estimations to prove the economic efficiency of the project for the first planning step.

The guideway girders may be classified under following aspects: the height of the guideway, the structural system, the length of the guideway girder and the type of construction. The type of construction is not defined, but based on from the experience of other projects the structural system and the span lengths for the standard girders are recommended. This concept is based on envelopes for the standard guideway girders type I, II and III with the main system lengths of 24.768 m, 12.384 m and 6.192 m. These envelopes are the basis for the required planning determinations process for the Project Munich. The aim is a free competition between the construction companies and cost optimized guideway girders.

The guideway of the high-speed maglev system Transrapid consists of guideway superstructures and substructures. Depending on height the guideway is seperated in

- At-grade guideway — gradient height 1.45 m ≤ H ≤ 3.50 m
- Elevated guideway — gradient height H > 3.50 m

For the realization of the guideway all girder types can be used, for which a certification is guaranteed by the Federal Railway Authority (EBA) or which are suitable to receive a certification. Dependently on the gradient height of the guideway, the environment of the track and where appropriate dependent on the collocation situation with other location lines, the following standard guideways are used at this time:

- Type I: system length 24.768 m, girder height ≤ 2.50 m
- Type II: system length 12.384 m, girder height ≤ 1.60 m
- Type III: system length 6.192 m, plate construction, construction height ≤ 0.40 m

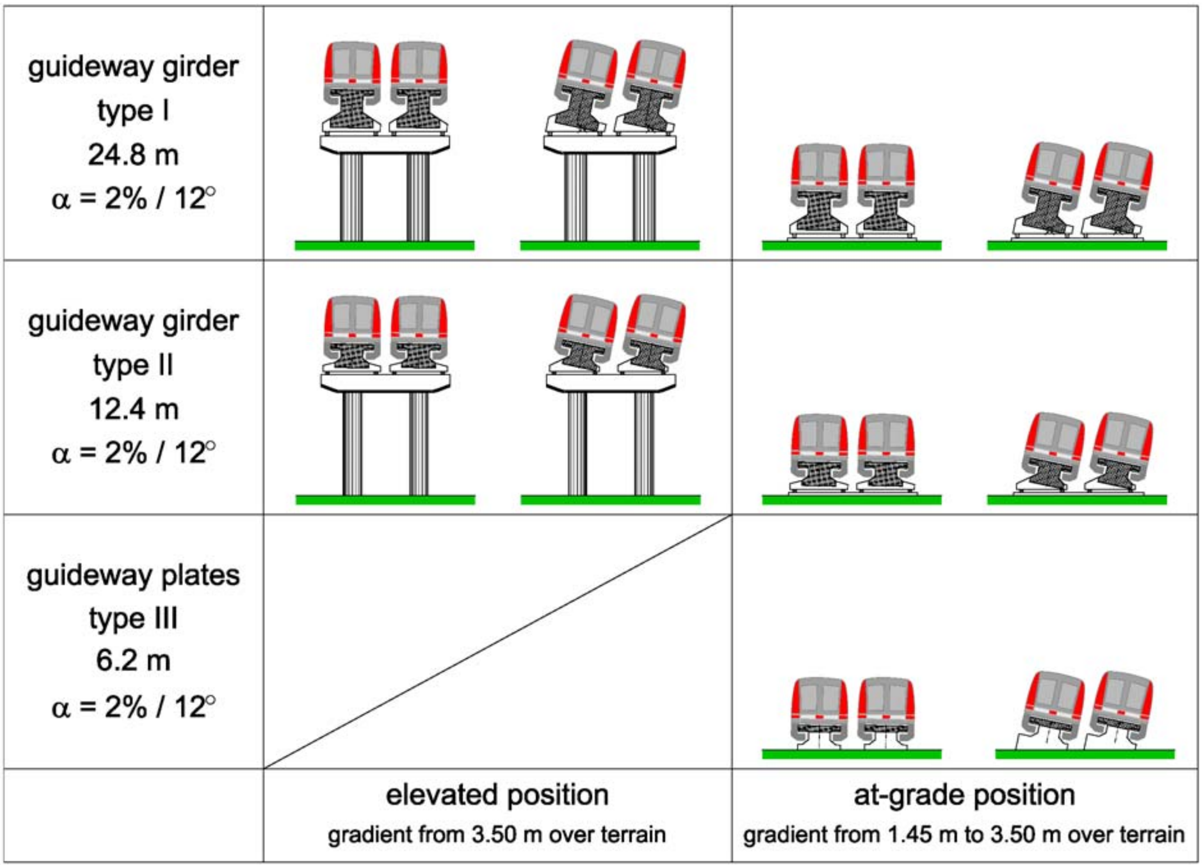

Fig. 5: Modified envelopes for the standard guideways in the project Munich

On an individual basis also guideway girders with special lengths are possible, which corresponds with a multiple of the system length of the stator packs of 1032 mm just as the standard guideway girder. In case of mainly at-grade routing of the track the standard guideway girder type II or type III are used.

Two girder types with different system lengths can be used for the elevated guideway at this time. The standard guideway girder type II has a system length of 12.384 m and the standard guideway girder type I a system length of 24.768 m. Both can be manufactured in steel, concrete or as hybrid. For sub-structures such as columns or foundations, reinforced concrete or steel are proposed.

The guideway height varies smoothly between 1.45 m and about 20 m. For greater guideway heights or span lengths larger than 40 m primary structures are needed in the form of conventional bridges.

For the alignment of maglev guideways a longitudinal inclination of 10 % and a transverse gradient of 12° should not to be exceeded for reasons of comfort and safety. The minimum horizontal radius shall be 350 m.

3.2 Switches

The low-speed switch is designed as a three-way-switch permitting the crossover between three different tracks. The operational speed for the straight position is 550 km/h, a maximum speed of 100 km/h is possible for the bending position.

The supporting construction of the switch is a solid-webbed continuous steel box girder over five spans of approx. 18.5 m and a total length of approx. 78.5 m. The box girder has vertical webs to reduce the lateral stiffness to permit bending of the switch. In connection with the bottom plate a parallel-flanged box is supplied with cantilevers to assemble the operational components. The cantilevers with the functional components are integrated in the construction analogous to the steel guideway girder.

Shifting of the switch in horizontal direction is carried out directly above the substructures. During shifting, the box girder is bent from the stress-free straight position along the vertical axis. The bending of the girder to the required form is achieved using switching drives at different locations. The route alignment of the switch in bending position is dependent on the maximum travel speed, the permissible acceleration and the permissible jerk. The horizontal displacement of the 78.5 m box girder is approx. 3.65 m in bending position.

4 Engineering Constructions in the Project Munich

During the route planning of a Maglev line fixed points resulting from the topography such as rivers, existing roads and residential areas as well as from special operator requirements can result in not being able to be implemented with standard or special girders. Here civil engineering constructions are necessary as a primary construction for the guideway.

4.1 Munich Main Station - High level / Low level

Detailed investigations for the optimization of the position of Maglev station level within the main station show, that alternatives to the initial solution are possible under the transverse platform 13 m under ground. They lead to better connections with long-distance, regional and interurban train traffic and to shorter temporary ways for the passengers of the Transrapid. The following alternatives for the station level at the central station have been considered:

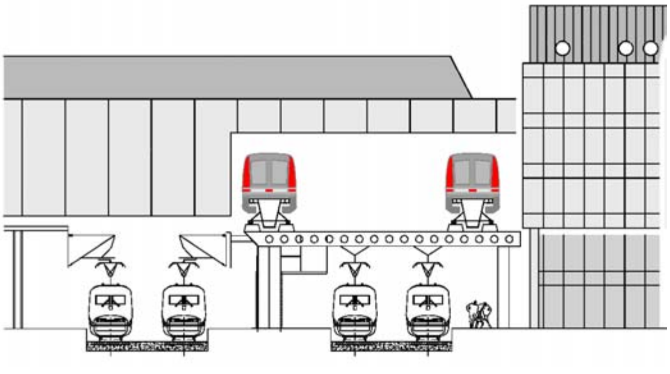

Fig. 6: Elevated platform solution in Munich Main Station

- For the elevated platform solution (Fig. 6) the station is approximately 10 m over ground level in east-west-direction directly above the railway tracks 11 and 12 and their platforms in the concourse. The maglev route runs at high level in a westerly direction, runs over the Paul Heyse underpass, falls then strongly off and underpasses the Hacker bridge already in the tunnel. For further routing information see chapter 2.3.

- For the low-lying platform solution the station is approximately 13 m under ground level under the railway tracks 23 - 26 and their corresponding platforms in east-west direction. The subsequent tunnel runs in a westerly direction and underpasses the Paul Heyse underpass. For further routing information see chapter 2.3.

4.2 Crossovers with Low-speed Switches

The crossovers are used for track changes on a multi-track guideway without break of the journey. They exist from a combination of bending switches with intervening lock blocks and combining guideway sections where appropriate. For the first time switches with a longitudinal inclination of 8 % are used in this project.

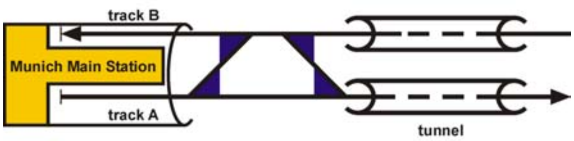

Fig. 7: Schematic presentation "V-crossover"

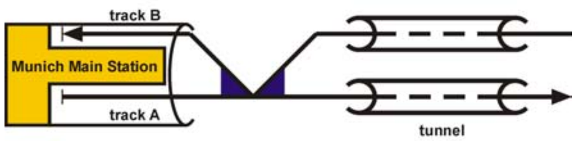

Fig. 8: Schematic presentation "K- crossover"

The V-variant for the crossover, with an overall length of approx. 450 m, is examined below as the first of three possible crossovers at the main station. The shown variation (Fig. 7) represents a combination of four low-speed switches, already employed and proven in the Shanghai project. The basic feasibility of this solution has been verified.

Advantages:

- The switches have assurance for type certification and are implemented and proven in Shanghai.
- The technical reliability is considerably higher than with a "X-crossover" since each switch works independently of the other switches.
- The service availability is also very high since in case of loss of one switch possibilities of a by-pass and/or the highest service reserves are available.

Disadvantages:

- Due to the length of the crossover and according to route, the driving time increases since the travel speed is limited on 62 km/h in bending position up to the last switch crossing.
- The space required is higher than with "X resp. K-crossovers". This means higher construction expenses, in particular since two of the switches are arranged for reasons of alignment in the tunnel.
- Reduces the entrance switches in the Holzkirchner railway station to one

As further solution a "K-crossover" is available (Fig. 8). This solution consists only of 2 switches with a length of approx. 156 m. Essential feature of the "K-crossover" is the single-track on the respective switch beginning.

Advantages:

- Most cost-effective variant
- Short design length for the alignment (without track renewal)
- The technical reliability of only 2 switches is comparably high
- Allows the entrance in the Holzkirchner railway station with 2 instead of only one switch
- Simple realization due to small space required.
- Relatively small travel time loss since situated near to the station.

Disadvantages:

- No continuous double-track guideway
- Least service flexibility, in the breakdown and in case of maintenance works can be up to 3 hours shut downs.
- According to breakdown of the corresponding switch a shuttle service with three or two vehicles and/or one or two tracks are possible.

4.3 Tunnel with Girder Type II and III

Special constructions are planned for route sections where it is not possible to erect the guideways using standard solutions. This is the case in the Munich project especially in the densely populated urban areas around the Main Station. The primary tunnel construction is a standard construction, as it is similarly used for railway and road constructions. It has only been adapted to Maglev-specific requirements with regard to loads, alignment, track clearance, displacements, mounting- and rescue concept. The primary constructions are built according to known planning and construction standards. The operational guideway components are integrated into the structure. Special attention is directed to the protection against vibration as well as the construction logistics.

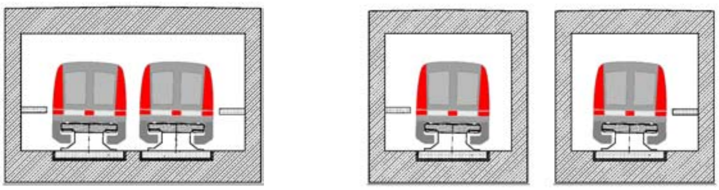

Fig. 9:
Tunnels in Cut and Fill Construction

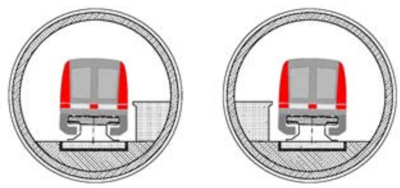

Fig.10:
Tunnel in closed construction

Tunnel types for Cut and Fill Construction:

Tunnels are usually planned as single-track, however in areas where the guideway axes are close together, a double-track as a rectangular cross section can be adopted (Fig. 9). In dependence on the lateral tilt results a clear height of the cross section between approx. 6.45 m (2% lateral tilt) and approx. 6.90 m (12°) including possible measures for structure-borne noise insulation. Without measures against mechanical vibration the cross section may be reduced around approx. 50 cm. For double-track tunnel frames without middle wall the distance is approx. 11.60 m - 11,95 m between the external walls according to lateral tilt and position of the flight and rescue way. The production of the tunnels occurs - so far necessary - in watertight excavations.

Tunnel types for closed construction:

The majority of tunnel routes are single-track tunnels using shield tunnelling methods. The circular cross section (Fig. 10) is equipped with a standard plate guideway type III resp. type II, L = 12.4 m and has a clear diameter of approx. 8.30 m. In this the project requirements from the clearance envelope and the guideway as well as a manufacturing-tolerance of 15 cm are considered.

Double-track tunnel in underground construction:

In areas where a small centre-to-centre distance not allows a construction of two single-track tubes as well as in areas, where the production of open excavations are not possible due to building density limiting conditions the underground cross section is used. In particular the switch construction, situated in the tunnel, is a determining geometrically limiting condition for the underground cross section. The cross section is carried out as basket arch section with a clear width from up to 20 m.

In accordance with the Technical Report for the Safety Concept and the Guide for Building and Operation of Tunnels for the High-speed Maglev System by the Federal Railway Authority (EBA) emergency exits are to be arranged in the tunnel at least one emergency tunnel per track and tunnel. Next to every guideway a margin way with a width of 1.20 m and a clear height of 2.20 m is required. Analogous to the distances of the emergency exits used for the Munich under- / interurban train tunnels a maximum distance of 600 m is proposed. In the area of the emergency exits and the tunnel portals min. 1500 m² large rescue areas are arranged at the surface. These are linked to the public traffic network. They can be reduced in the area of urban emergency exits as long as public traffic spaces are available as setting down places for the rescue teams.

In principle it is possible to order every girder type in the tunnel. The present building logistics concept plans the partial placing of the guideway girders by means of specific erection portals. The necessary space for this purpose is to be kept in the tunnel cross section at least during the guideway erecting time. For later maintenance works a possibility of the dismantling and mounting of the guideway must be maintained.

During the dimensioning of the guideway substructures the measures for sound and vibration protection in the tunnel section are to be considered.

4.4 Urban Bridges - e.g. Georg-Brauchle-Ring

Crossing of existing roads is possible with short standard bridge constructions to overpass the track. This primary structure may be carried out as a trough bridge with guideway type III. With this chosen construction an economic solution is achieved, which meets all the different requirements from the construction logistics, nuisance, protection of underpassing traffic and installation of the track equipment are met simultaneously.

The maglev route crosses at MSB-km 5.1+58 to 5.2+20 the Georg-Brauchle-Ring, a multi-lane main road in Munich. For that the guideway is supported onto a primary structure with an overall length of approx. 70 m. The primary structure for crossing the Georg-Brauchle-Ring is planned as double-span prestressed concrete structure in trough form. At both ends of the primary structure the bridge plate is extended as a projecting cantilever. This is necessary in order to compensate the skew with the road and to extend the structural length to a system raster of the at-grade guideway girder. Additionally splashing-protection for the underpassing traffic route is integrated into the structure. To ensure the necessary height of the protective barrier a safety wall is added onto the side walls of the trough. The clear width of the superstructure is selected to permit margin ways and cables on both sides the double-track guideway.

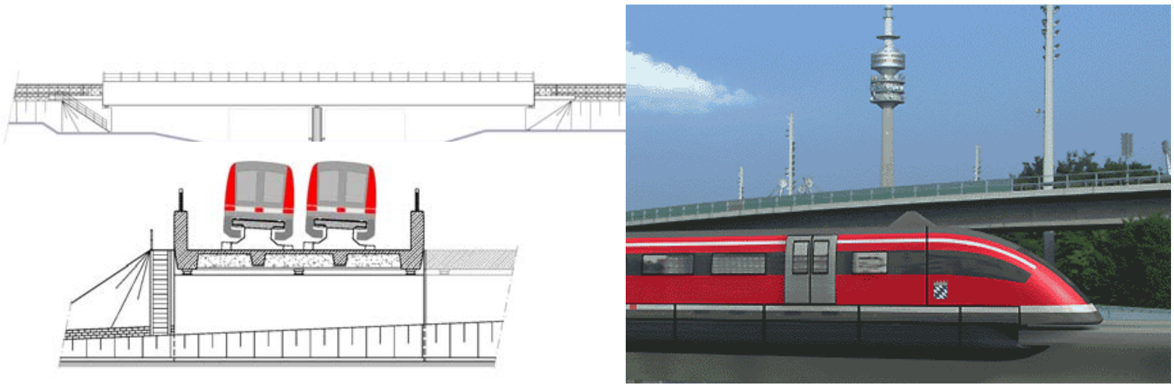

Fig. 9: Urban bridge construction - e.g. Georg-Brauchle-Ring

4.5 Protective Constructions - e.g. Olympic Center

With the optimization of the route the Bayerische Magnetbahnvorbereitungsgesellschaft (BMG) achieved important improvements for residents. By transferring and lengthening the guideways in tunnels, cut and cover construction was avoided in the residential areas.

The crossover initially planned in the area of the Olympic Press City was relocated so that the route can be extended a further 15 m out with the residential zone. Noise protection ramparts on both sides of the route deflect the noise influences from the traffic on the Landshuter Allee. The residents therefore receive better protection against street noise emitted from the Middle Ring road with the Transrapid route than is currently the case.

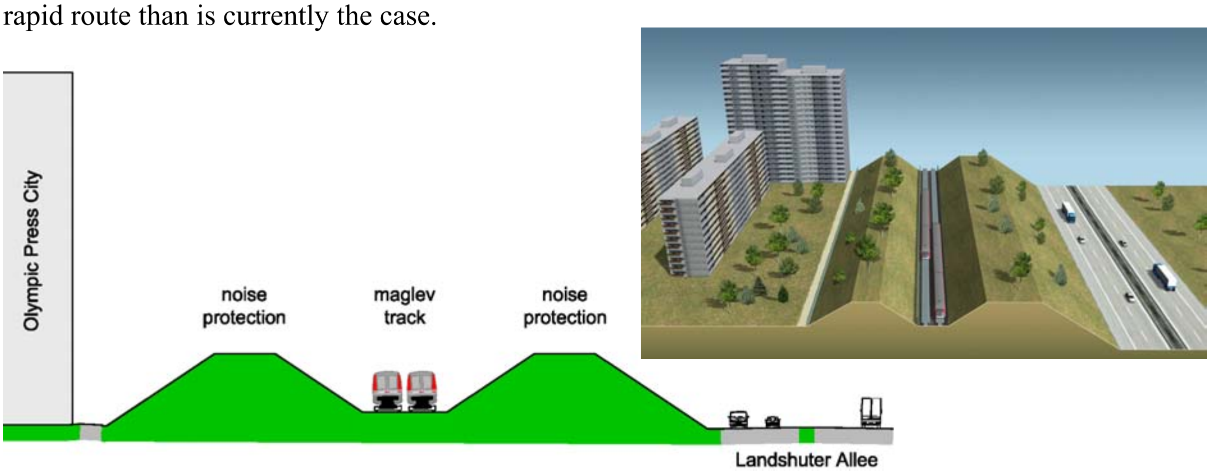

Fig. 10: Olympic Press City

The defined limiting values require the adoption of measures for environmental protection in certain sections of the route. Depending on the planned type of guideway and the local situation various solutions of protection measures are proposed.
The security concept requires every individual case to be checked, whether the standard measures, described below are necessary or rather sufficient. The condition and alignment of the road, the daily traffic volume, the quantity and kind of the heavy traffic as well as possible local special features are to be considered.

As standard protective measure an earthen bank with a height of 3.5 m above the road surface is proposed independently of the gradient height of the track as barrier between the road and the guideway. The development of the barrier occurs for example as ever green vegetation or as a screen fence. Depending on the collocation distance different measures are proposed.

In case of collocation with roads a barrier is planned up to a distance of 30 m. Its height depends on the distance of the maglev track from the other traffic. In the case of overpassing a road a barrier is planned 50 m from the lane edge. On road bends the values mentioned above are increased where appropriate. With gradient heights > 6.70 m and with a collocation distance > 25 m protective measures are not required.

As active sound protection protective elements can be set up directly onto the substructures of the guideway (Fig. 11). To ensure uninterrupted views from the train the height of the sound protection walls should not extend above the level of the bottom of the windows of the train.

Additional protection is required for flyovers to prevent snow during snow clearance and icicles during train passage being expelled onto roads below.

The maglev route crosses the Schittgabler Straße at MSB-km 6,9+60 to 6,9+70. The crossing of the Schittgabler Straße is planned by means of type II single-span standard guideway girders with additional walkways for rescue purposes (Fig. 11). Noise protection measures are integrated into the protective side wall. The substructures are designed as the standard substructures. The column head is approx. 11.60 m wide and serves as plinth for the protective elements. The protective construction exists of single-span prestressed concrete beams arranged adjacent to the guideway. An additional safety wall is mounted on top of these as a noise protection measure. Between the guideway girders two steel girders are arranged, which transfer their loads via consoles onto the column head. As completion of the protective construction, prefabricated reinforced concrete plates are attached under the prestressed concrete beams and the flanges of the steel beams. The draining of the structure occurs in the longitudinal direction through the available inclination of the guideway. Water runs into drains in the area of the track.

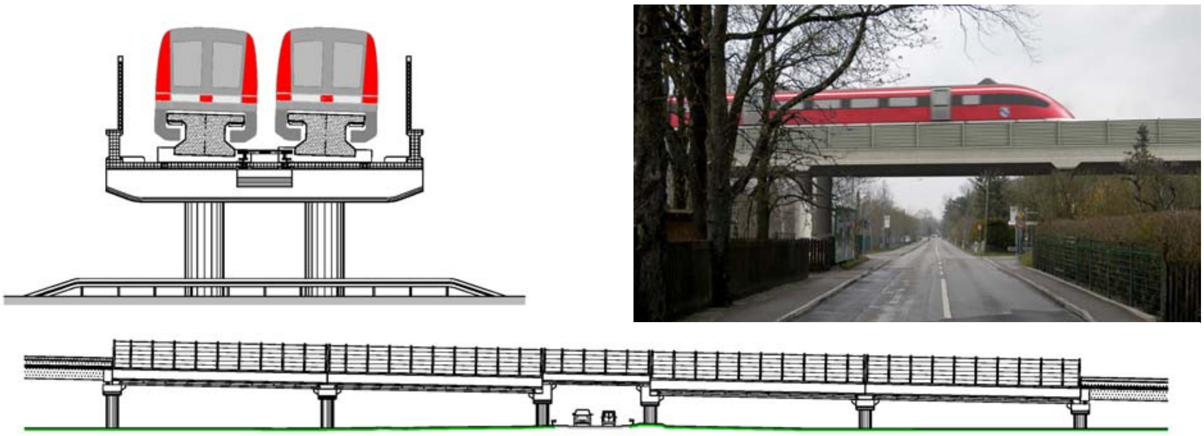

Fig. 11: Protective construction Schittgabler Straße

4.6 Special Solutions - e.g. Motorway Junction Feldmoching

At MSB-km 10.5 to 11.0 the maglev route crosses the motorway junction Feldmoching. Several options for the guideway are available for motorway junctions in case of a narrow collocation of maglev route and motorway. The public hearing on land use dictates the crossing of the BAB A 99 at Feldmoching junction in a 340 m trough construction in cut and cover. During subsequent planning stages the alternative to cross the A 99 in high level position was appraised and cost savings identified.

The planned maglev route crosses the Feldmoching junction at MSB-km 10.5 to 11.0. The high level option is planned in this area as elevated guideway, spanning the multi-lane motorway junction. In the course of this crossing the route passes across the feeder road North A 99, the A 99 and the feeder road South A 99. To protect the underpassing traffic a protective barrier is developed for winter operation of the Transrapid (see Ch. 4.5) and a screen is mounted on top.

The proposed geometrical parameters for the standard guideway including protective measures are different for the three necessary crossings. Below are the parameters for the crossing of the motorway A 99:

Maximum span length	approx.	2 x 24 m
Height of construction incl. protective construction		14.60 m
Clear width of protective construction		13.10 m
Gradient height above roads	approx.	7.80 m
Gradient height above existing ground	approx.	14.50 m
Track centre-to-centre-distance	approx.	7.30 m
Lateral tilt	α =	1.15°

The crossing of the motorway junction Feldmoching is planned by means of single-span standard guideway girders type I with additional protective measures including rescue walkways and space available for the cable-laying. Due to the different skew to the roads crossed and the existing spacing of the roads to each other it becomes necessary, to install in fields before, between and behind the crossing shortened girders type I in order to optimize the clear width for underpassing roads. The substructures are designed as the standard substructures. In the area of the crossing a greater track centre-to-centre distance is necessary due to the near by tunnel exit Feldmoching.

4.7 Rescue Walkway at the Standard Guideway

Basis for the functions supporting and guiding and starting point for the majority of all orders is the principle of the safe reaching of a breakpoint. The function of the safe reaching of a breakpoint ensures, that every vehicle in all loss and emergency situations within a safety route section does not run over a defined danger point and reaches the current stopping point levitating or braking. Risk-dependent boundary probabilities are valid for the occurrence of failure rates of subfunctions.

In the project Munich the design of the system occurs on basis of the described principle. There is not an expert confirmed proof of this functionality at this time and can not be produced probably before introduction of the plan determination either. From this basis the plan determination is introduced considering a relapse level. This relapse level plans the possibility to evacuate the vehicles at almost every point of the route. This is realized with suitable vehicle-sided exit aids and the installation of a drive concurrent middle footbridge at the elevated guideway. The necessary structural measures are contained in the results of the preliminary planning. It is however the aim to verify the secure reaching of a stopping point before start of building and to check the necessity of the relapse level again.

In order to guarantee both exit and evacuation of the passengers at every point of the route, different safety requirements must be fulfilled. With at-grade guideways passengers reach the ground directly using vehicle-sided exit aids. With elevated guideways vehicle-sided exit aids and walkways between the tracks, arranged approx. 2 m below the exit level are used. The walkways must meet following criteria:

- In order to guarantee the passability of the walkway after an exit or an evacuation, a minimum unrestricted transition width of 0.8 m is required.
- A transition width of 0.6 m is required adjacent to the activated exit aid.

At each walkway at least one departure is designated, about which the passengers are able to leave the walkway. The used vehicle-sided exit aid corresponds to the relevant regulations. This security measure was included not due to a calculated risk, but due to a prescribed safety aim by the client.

If it is foreseen that the service will not recommence within one hour, then the opposite track is closed in order to guarantee a secure exit of the passengers. In the case of collocation with the railroad it is furthermore guaranteed that the Deutsche Bahn AG stop their operation.

4.8 Primary Structure for Isar River Crossing

Classical bridge constructions were chosen for span lengths > 40 m. Steelwork bridges and bridges in prestressed concrete construction were designed to the clearance of the Transrapid vehicle and furnished with guideway plates type III.

When exceeding the maximal possible span of the standard guideway girders a primary structure is arranged as a bridge construction, on which the guideway is supported independently of the span length of the primary structure. The maglev flyovers are equipped according to the requirements with protective measures for the underpassing traffic routes and/or with noise protecting measures.

On bridges it is recommended, to apply the standard guideway girder type III due to lower dead load and the reduced height of the girder.

The maglev route crosses the river Isar directly north of the motorway bridge at MSB-km 31.3+53 to 31.5+11. The preferred option is to cross the Isar by means of a three-span prestressed concrete box-type structure with a total length of approx. 158.0 m similar to the motorway bridge (Fig. 12). The bridge is designed to match the neighbouring bridges of the motorway and interurban railway. The statically favourable system makes a comparatively slim superstructure possible. The supports are developed as columns and serve simultaneously as a support for the guideway girders. They are positioned perpendicular to the guideway axis. In order to minimize the span length over the Isar, the middle columns are located parallel to the embankment. This solution is current-technically favourable in the high water case. On the bridge construction are planned guideway girders type III.

Span lengths		**41.3 m + 75.3 m + 41.3 m**
Height of construction		**3.80 m**
Width of construction		**11.80 m**
Clear width about Isar river	**approx.**	**71.00 m**
Gradient height above Isar river	**approx.**	**15.00 m**
Track centre-to-centre-distance		**4.40 m**
Lateral tilt	**α =**	**3.91°**

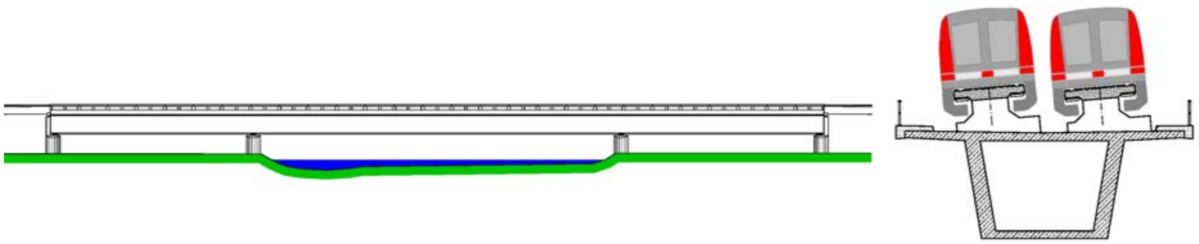

Fig. 12: Isar river crossing

4.9 Special Girders - Flyover to the Maintenance Center

Urban development considerations and possible cost reductions gave reasons for further review of the presentation of existing bridge design. With the development of the girder versions IX, X and XL with larger span lengths, the technical conditions to substitute the classical steelwork bridges and bowstring bridges are more favourable.

The maintenance center is connected by a separate track and a low-speed switch at MSB-km 34.4 onto the main track airport - central station. The maintenance track turns out due to the close proximity of the interurban railway in the north direction, rises with approx. 5.1% and crosses the maglev main tracks and the interurban train facilities with an approx. 186 m long, five-span special structure. The track then sinks again with approx. 4.3% in order to go with a height above ground of approx. 4,2 m into the maintenance centre.

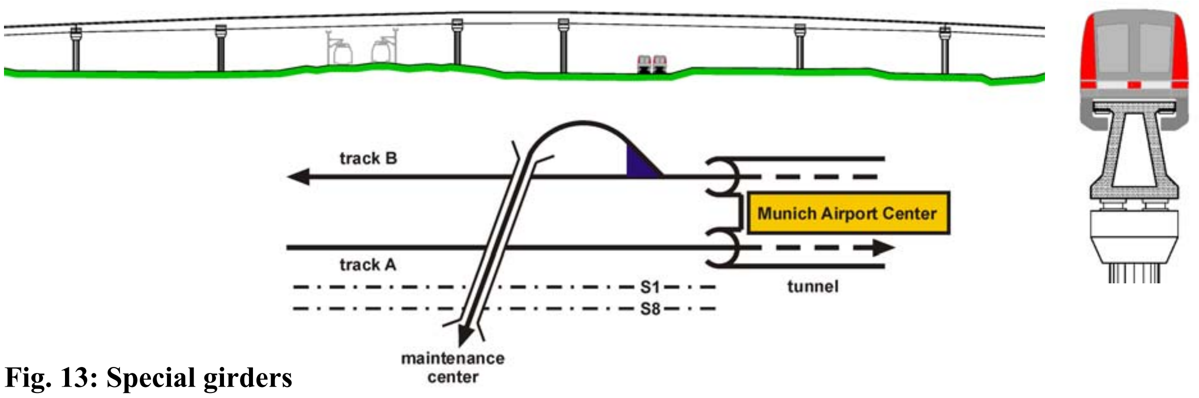

Fig. 13: Special girders

4.10 Troughs

In contrast to the alignment in the tunnel there are no aerodynamically optimal minimum cross sections in troughs. The build-up of snow banks within the trough is prevented by appropriate design or by setting up snow fences. For the disposal and defrosting of snow appropriate space with drains are provided outside of the clearance envelope in the trough. Additionally building logistics, maintenance and security aspects are considered during the planning of the minimum cross section.

Trough constructions are arranged at tunnel entrances and exits in order to take the guideway from the low level to ground level as well as for underpassing other traffic facilities.

The motorway A 9 runs on a 6 m high embankment at the crossing point with the maglev route. Since this height is not sufficient for an at-grade crossing and since the elevation of the A 9 should not to be altered, it becomes necessary to lower the maglev route in a trough.

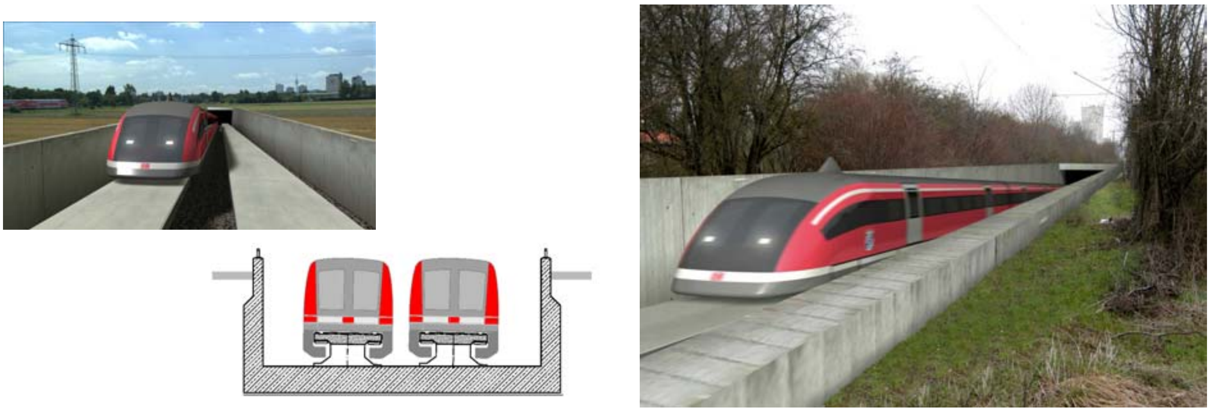

Fig. 14: Guideways in trough

4.11 Pivoting Girder - Long Bend in the Airport

Because of the given length of the partially available tunnel in the airport building it can not be avoided that the vehicle be lowered onto the switch in order to be pivoted with the switch to the opposite track. From this basis a solution to be redesigned and to be approved is designated as a so-called pivoting girder, comparable with the switch construction.

Pivoting girders are sections in the guideway which enable the vehicles to change the track with a break of the journey. The vehicle goes onto the pivoting girder, is set down and then turned onto the other track. Pivoting girders are inflexible guideway girders whose length is larger than those of the vehicle and includes the length of the necessary connection guideway. They have a pivot around which the guideway girder is turned in the horizontal direction. There are different possibilities for the position of the pivot and fix point (Fig. 15). The length of the pivoting girder results from the project-specific vehicle length, supplemented around the so-called slip-trough-way. The process of displacement is planned by means of adjusting-engines, as employed for switches.

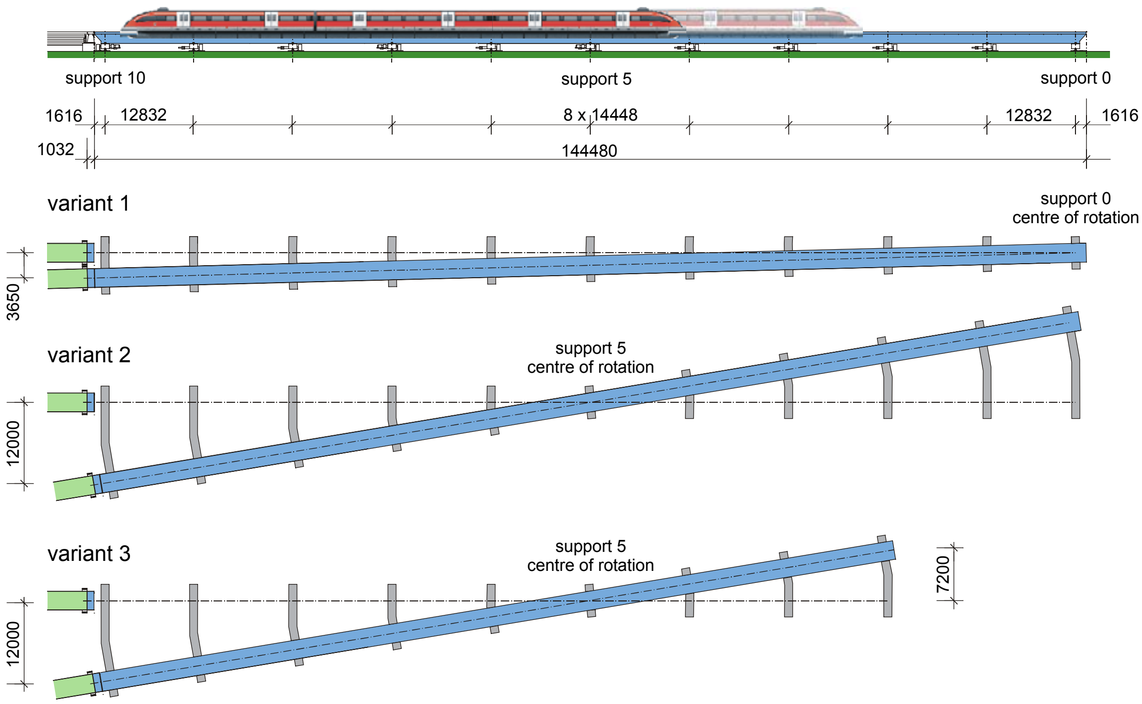

Fig. 15: Pivoting girder variants for 3 and 4-section-vehicle (schematic presentation)

The track changing of the vehicle in Munich Airport is carried out due to operation requirements as a long bend and ordered behind the platform inside an already existing tunnel construction. Alternative to the simple long bend it was examined, to integrate a parking track in the area of the track end. In total two switches are necessary for this purpose. In order to place this second switch it would be necessary to displace the platform in the direction of the main station. Such a parking track allows - in connection with increase investments in the drive - that a vehicle exchange can be carried out without loss of journeys.

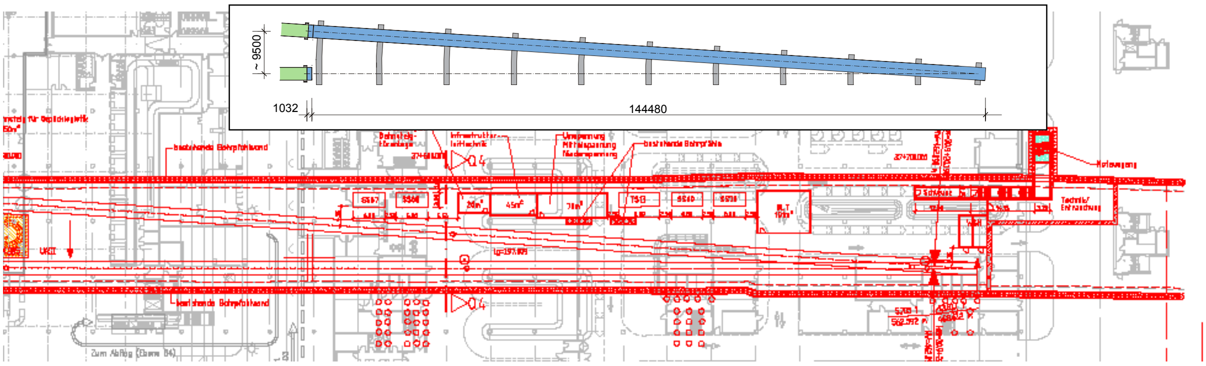

Fig. 16: Long bend in the airport (schematic presentation)

5 Outlook

In the year 2004 the eastern enlargement of the European Union occurred. So the catchment area of the Munich airport - today already the second-biggest airport of Germany and the number 8 of the European airports - enlarges also into the East European room.

In October 2003 the Transrapid route between the Airport Munich and Munich Main Station is included into the projects of the TransEuropean traffic networks (TEN). The EU commission classifies projects as priority, which create main- and intermediate connections, close gaps, complete long-distance links as well as connect different traffic carriers and consider the care of the environment. It is not intended to integrate the Munich airport into the long-distance traffic network of the German railroad company Deutsche Bahn AG. The TEN-conditions of the Bavarian Transrapid project are fulfilled.

The Transrapid combines with the Munich Main Station and the Munich Airport two important points of the TransEuropean traffic network. The Transrapid offers the ideal solution for the networking of the aviation net with the long-distance network at the Munich location with his design "In 10 minutes all 10 minutes".

Fig. 17: TEN-project - catchment area

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