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

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ABSTRACT: At this time the planners prepare the design planning for the guideways and the engineering structures of the double-track guideway for the TRANSRAPID project Munich Main Station to the Airport, which allows a specification of the project costs as basis for economic efficiency analyses. The following report is based on these planning activities.

1 INTRODUCTION

The annual passenger numbers of the Munich airport are supposed to duplicate from today to 2015 up to approx. 50 million. Today the Passengers going to or coming from Munich's airport need two things - a lot of time and a lot of patience. The trip by commuter rail takes a good forty minutes, almost as long as a flight from Munich to Berlin.

The journey time between Munich airport and city is hardly calculable anymore because the northbound highways from Munich are always hopelessly congested. The solution to solve this traffic problem can be the TRANSRAPID. This system is a contactless track guide and environmentally friendly system. This convenient connection to the airport needs only ten minutes journey time.

Recognise this solution 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. They 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. After finishing the first planning procedures a decision was taken on the West Route (Fig. 1).

Fig. 1: Airport link Munich (source: TRI)

2 PROJECT OVERVIEW

2.1 Track routing

The short journey starts in the basement of Munich Main Station. Under the transverse platform of the railway tracks 23 to 26 the magnetic train starts subterraneanly in western direction. The tunnel behind the station is double bore.

The track in the tunnel continues along the railway axis south of corridor "Munich 21", bends then north and underpasses the entire track field shortly before the Donnersberger Bridge with an angle of approx. 90° to reach the Landshuter Allee north of Arnulfstrasse.

With approx. 250 km/h the TRANSRAPID leaves the city tunnel in area of the Olympia Park at km 4.8, 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.

A tunnel of 2.5 km length underpasses the railway station Feldmoching. From km 8.5 until km 10.2 the route runs in a tunnel once more, parallel to the Munich-Landshut railway line, at km 9.4. North of motorway junction Feldmoching, after underpassing A 99, the route emerges to the surface. Subsequently the route traverses agricultural land where the speed of the journey near 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) is underpassed in a trough. Still the TRANSRAPID is on the way with his maximum speed of 350 km/h.

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 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 at km 37.8.

Track length	**double track**	**37.8 km**
Parallel to motorways / roads / railways	**approx.**	**21.6 km**
Overall tunnel length with at-grade guideway	**approx.**	**9.1 km**
Elevated guideway - double track	**approx.**	**5.8 km**
At-grade guideway - double track	**approx.**	**22.9 km**
Track to the maintenance center - single track	**approx.**	**1.3 km**
Stations		**2**
Tunnels		**3**
Underpass of roads		**19**
Overpass of roads		**5**
Overpass of railways		**2**
Special structures (bridges)		**3**
Low-speed switches, L = 78.4 m		**1**
Sliding platform over 5 tracks, L = 110 m		**1**
Pivoting girder, L = 145 m		**2**
Sound protection walls / ramparts	**approx.**	**4 km**
Track centre-to-centre distance	**minimum**	**4.40 m**
Min. / Max. Height of the space curve above ground		**2.20 m / 11.00 m**
Max. Operation speed		**350 km/h**
Daily operation time		**20 hours**
Number of vehicles		**5 vehicles with each 3 sections**

Planning status: May 2006

Fig. 2: Project data

2.2 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.

On the basis of the result of the regional planning procedure the plan determination process is commenced in 10/2003. The route has been split into five plan determination sections (PFA) (Fig. 3).

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.

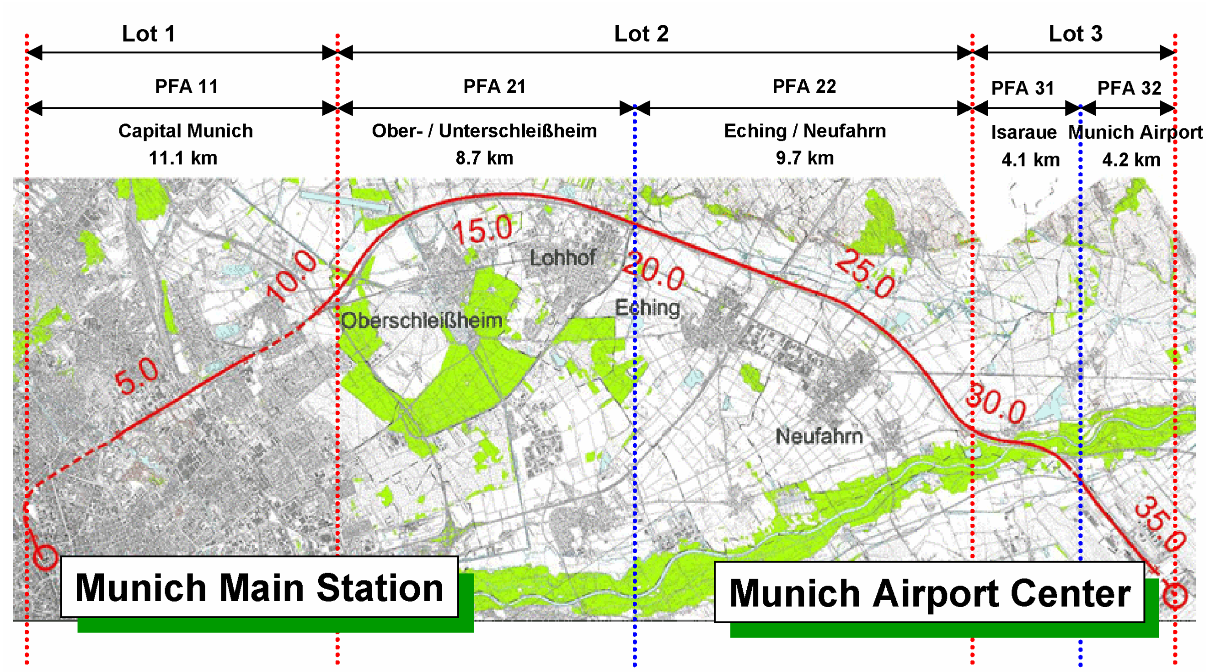


Fig. 3: Plan determination sections

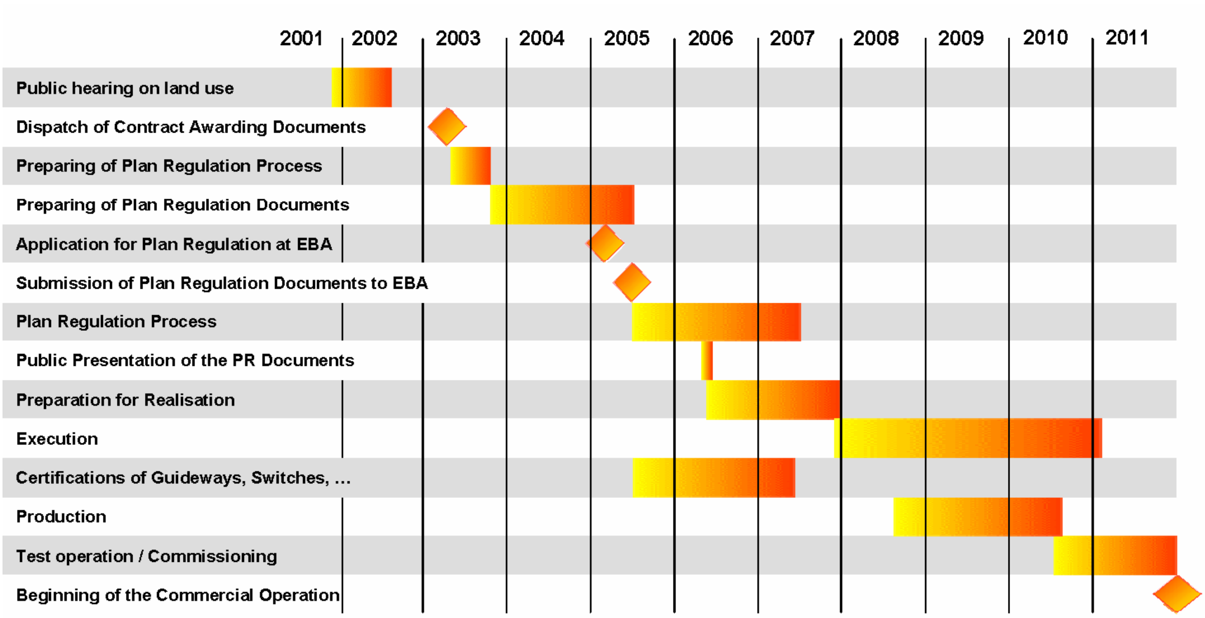


Fig. 4: Dates and Milestones

2.3 *Dates and Milestones*

The planning process reach a status that makes possible, that the construction of the first line sections is due to start in spring 2007 so that the TRANSRAPID can go into operation at the end of the year 2011. For this purpose the necessary public hearing on land use was carried out at an early stage.

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. The following girder types are designed for the actual planning step and formed the basis for mass- and cost estimations to prove the economic efficiency of the project. This girder types are construction firm independent.

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. 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 separated 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. 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

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. The girder types can be manufactured in steel, concrete or as hybrid.

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.

For substructures such as columns or foundations, reinforced concrete is proposed. The substructures for the guideway girders consist of several components. These are, depending on guideway type and gradient height, the column heads with bearing supports, the columns, tie beams and intermediate beams and the foundation slabs. They are built onto the natural soil, soil with soil improvement and/or on piles.

The dimensions of the reinforced concrete substructures result from the high demands on the permissible deformations of the substructures.

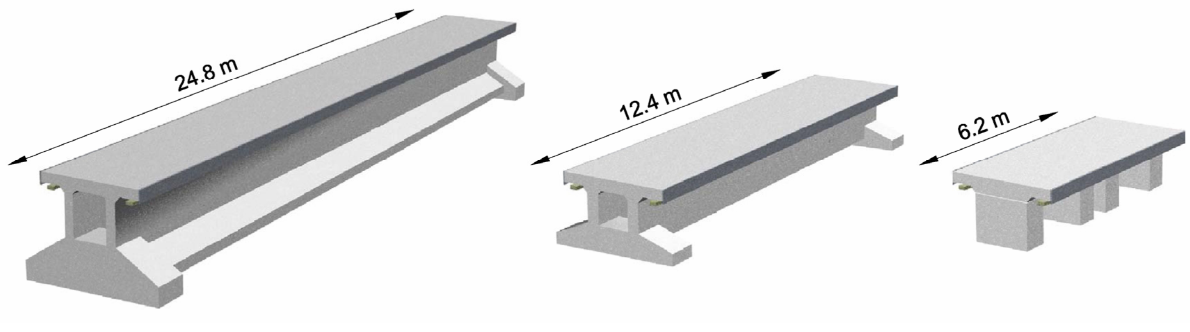


Fig. 5: Standard guideway types

4 SPECIAL ENGINEERING CONSTRUCTIONS FOR THE PROJECT MUNICH

A route planning of a Maglev line has 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 girders 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.

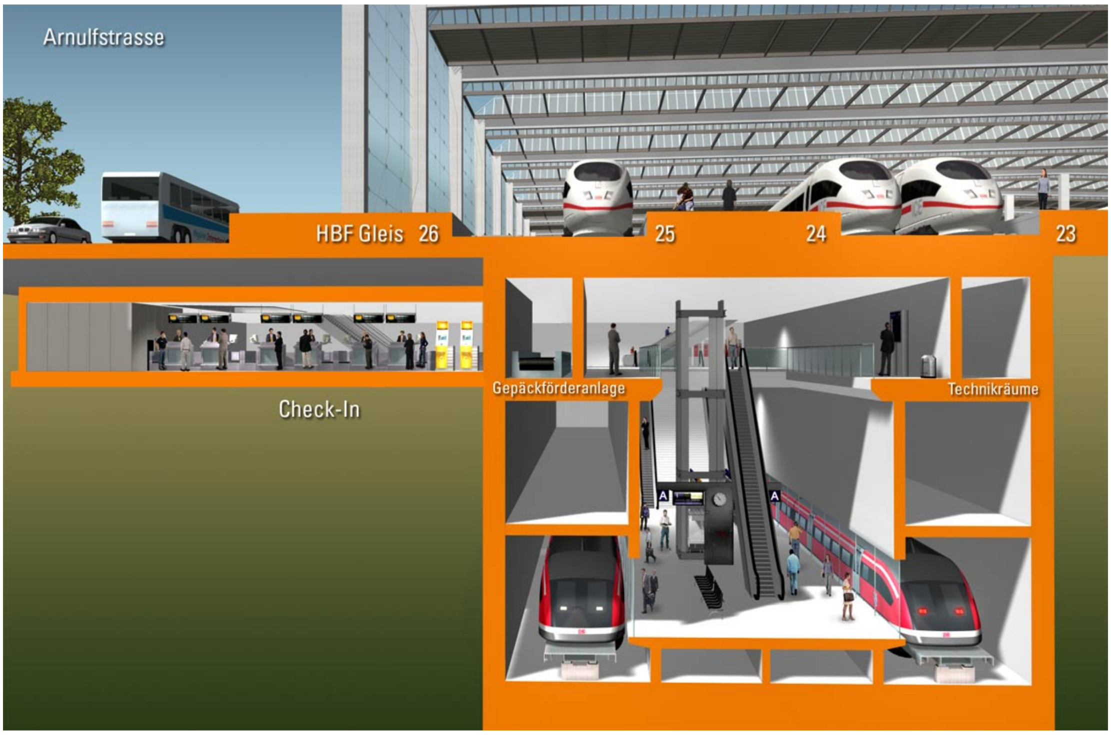


Fig. 6: Underground Situation of Munich Main Station

4.1 Munich Main Station

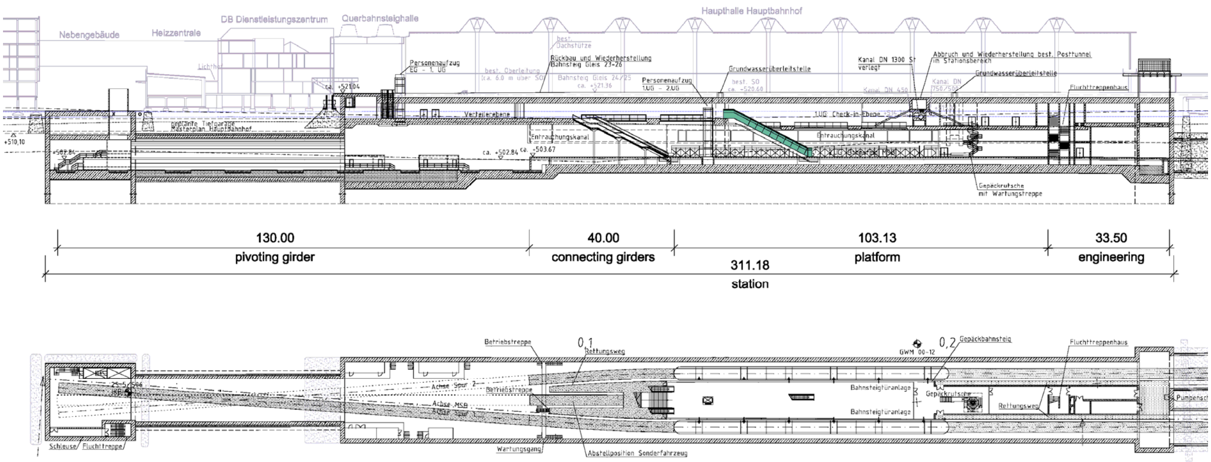
The underground station of the Transrapid is under the northern railway tracks 23 to 26 near to the main interurban train station. The Transrapid station will be arisen in cut-and-fill construction approx. 18 meter under the level of the platform (in comparison: the new interurban train stop of the second regular route will be in approx. 42 m depth).

In the intermediate storey, arranged above the station, existing trade areas of the neighbouring interurban train station should be extended. For the barrier-free crossing of the difference in levels escalators and lift facilities are available for travellers on both sides. In the intermediate storey are designated six check-in counters and six check-in automats, that are supplied with daylight by means of glass domes on the northern forecourt.

4.2 Pivoting Girder - Long Bend in the Main Station

Because of the given length of the track behind the building of the main station it can not be avoided that the vehicle be lowered onto the switch in order

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. 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.



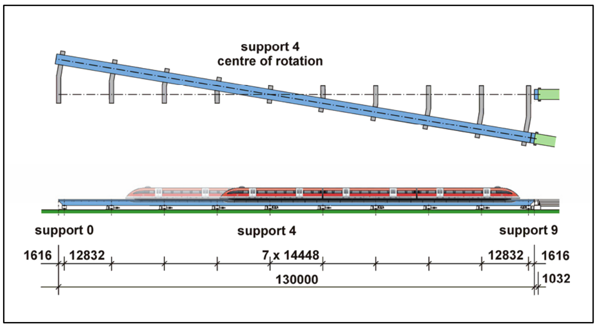


Fig. 7: Pivoting girder for 3 and 4-section-vehicle at Munich Main Station

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. Special attention is directed to the protection against vibration, aerodynamic situations as well as the construction logistics.

The advanced planning in the last years for the tunnels of the high-speed Maglev TRANSRAPID caused in substantial additions. So the situation of the tunnel entrance is supplemented by ventilation shafts on the first 100 m of the tunnel. To guarantee the travel comfort the tunnel cross section is widened from 42 m² to 52 m² (Fig. 8).

Because of these two measures concerning the tunnel construction as well as platform doors for aerodynamic decoupling of the platform area and air locks at the gates the pressure comfort criteria for the passenger can be optimized.

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.

Near to the surface of the ground the tunnel types will be built as cut and fill constructions as shown in Fig. 8 and 9. The majority of tunnel routes are single-track tunnels using shield tunnelling methods. The circular cross section is equipped with a standard plate guideway type III and has a clear diameter of approx. 9.10 m. In principle it is possible to order every girder type in the tunnel.

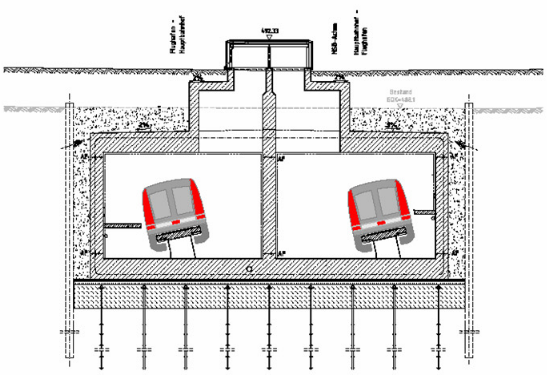


Fig. 9: Tunnel with ventilation shaft

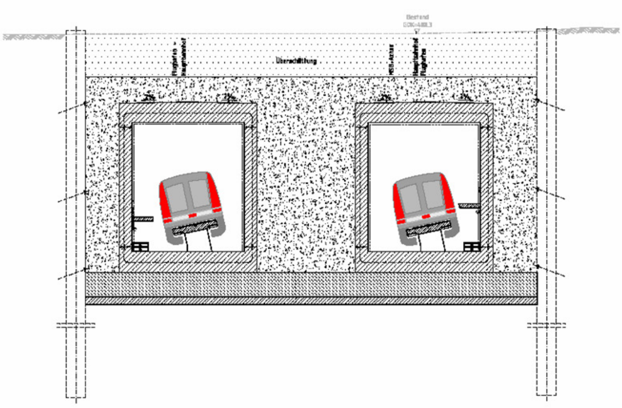


Fig. 9: Standard Tunnel Section

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

With short standard bridge constructions it is possible to cross existing roads. With the chosen constructions economic solutions are 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+89 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. The static favourable system allows a relative slender superstructure with a height of 3.10 m to meet the maglev specific deformation conditions. 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 standard girder type III is used on this bridge.

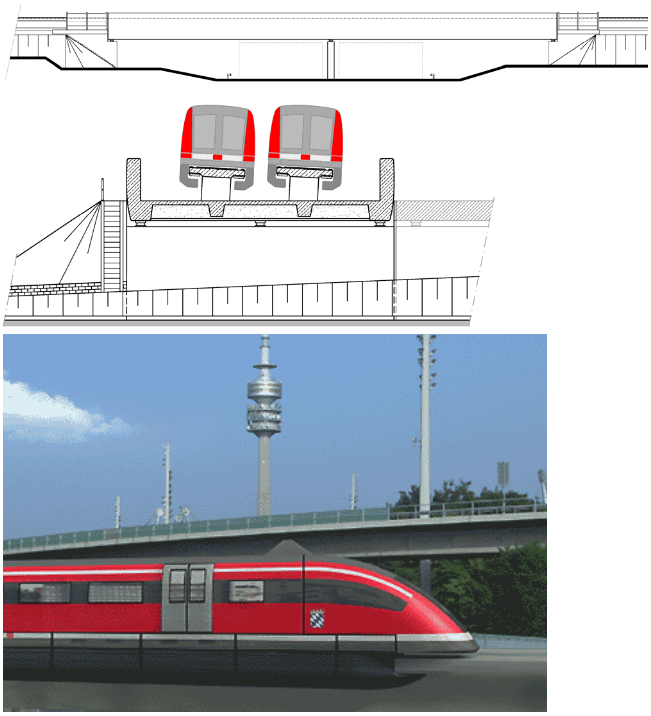


Fig. 10: Urban bridge construction - e.g. Georg-Brauchle-Ring

4.5 Protective Constructions - e.g. Olympic Center and Schittgabler Straße

Since optimization of the route protective constructions for noise reduction are necessary only for a few sections.

Depending on the planned type of guideway and the local situation various solutions of protection measures are proposed. 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.

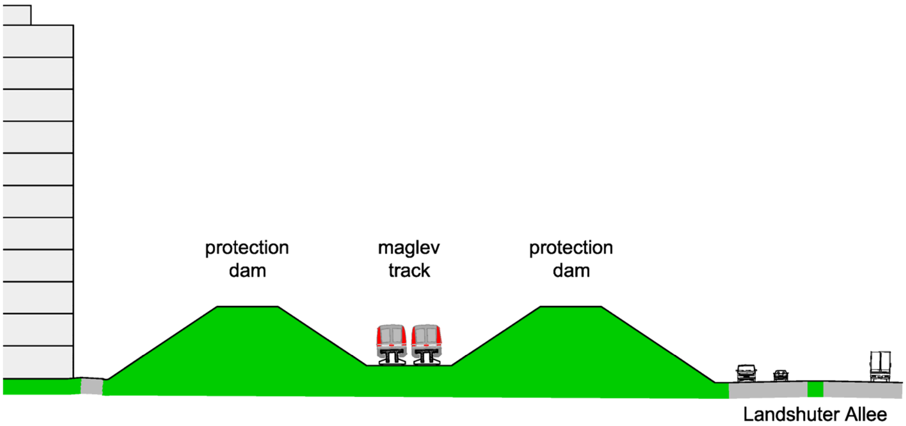


Fig. 11: Olympic Press City

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.

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. 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.

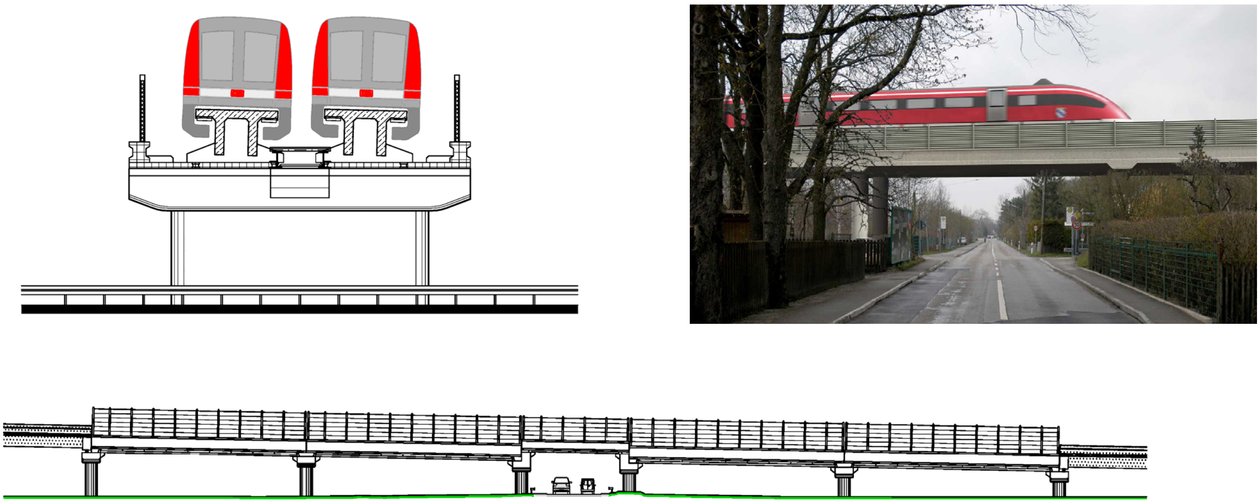


Fig. 12: Protective construction Schittgabler Straße

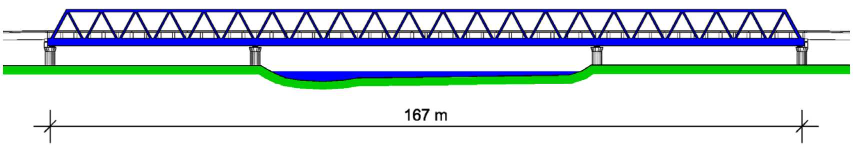
The maglev route crosses the Schittgabler Straße at MSB-km 6,9+66. The crossing of the Schittgabler Straße is planned by means of type II single-span standard guideway girders with additional walkways for rescue purposes (Fig. 12). Noise protection measures are integrated into the protective side wall. 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 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 additional 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.

4.6 Primary Structure for Isar River Crossing

In the opinion of experts there is an enhanced collision risk for some bat species where the TRANSRAPID at MSB-km 31,4+32 crosses the Isar river. This is mostly valid at the initial stage of this demanding traffic project. As reliable guide and barrier installation for an effective protection of the various bats a special protective installation is planned on both sides of the Isar bridge.

The three-span primary construction with an overall length of approx. 167 m is built as steel framework with a concrete composite slab. Dependent on the high external truss brace and the continuous longitudinal girder the distance between gradient and bottom level of the superstructure can be optimized. The abutments are formed as piers and serve as bearing pad for the adjacent guideway girders. Therefore they are arranged rectangular to the guideway axis. To reduce the span width of the central span the round intermediate piers are offset for one truss brace span.

Span lengths		**43.4 m + 78.7 m + 43.4 m**
Height of construction - steelwork girder		**8.40 m**
Width of construction between protection walls for bats	**approx.**	**12.00 m**
Clear height above HW 200 of Isar river	**approx.**	**6.00 m**
Track centre-to-centre-distance		**4.50 m**



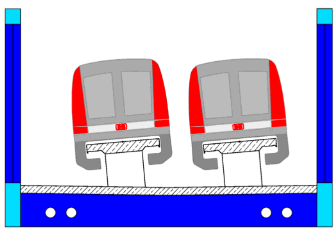


Fig. 13: Isar river crossing

By this the position of the piers can be adapted in a large degree to the course of the embankment, so that in the case of high water a favourable solution relating the flow exists. The bridge has fixing devices on one intermediate pier to minimize the horizontal deformation in longitudinal direction.

To avoid the collision with bats protective walls are arranged between the truss braces on both sides of the deck plate of the bridge. They consist of laminated glass with silk-screen print.

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.

4.7 Flyover to the Maintenance Center

The maintenance center is situated in the area of the airport link. In this section the double-track Maglev route runs parallel to the double track interurban train. To leave the main track to the maintenance center a low-speed switch is planned as two-way-switch. 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.

Since the bigger construction height of 2.85 m from the top of the bearing foundation the low-speed switch at MSB-km 34.4+44 (IHZ-km 0.0+00) must be arranged in a trough.

For crossing the interurban train and the Maglev track a primary construction with guideway type III is planned. A five-span prestressed concrete structure as curved continuous beam in form of a trough is the primary structure. Dependent on the favourable structural behaviour as continuous beam a construction height of 3.80 m is sufficient to guarantee the required stiffnesses. The columns are planned as round columns, partly with enlargements like capitals. Because of cramped space they are founded on pile trestles. The central columns are restraint in the superstructure.

4.8 Munich Airport

After changing to the underground solution for the platform of the TRANSRAPID at Munich main station the platforms, tracks and pivoting girder situation at Munich airport is not much different. The track change of the train is now identical in both stations. As cost advantage can be pointed out, that at this place an existing tunnel construction can be used.

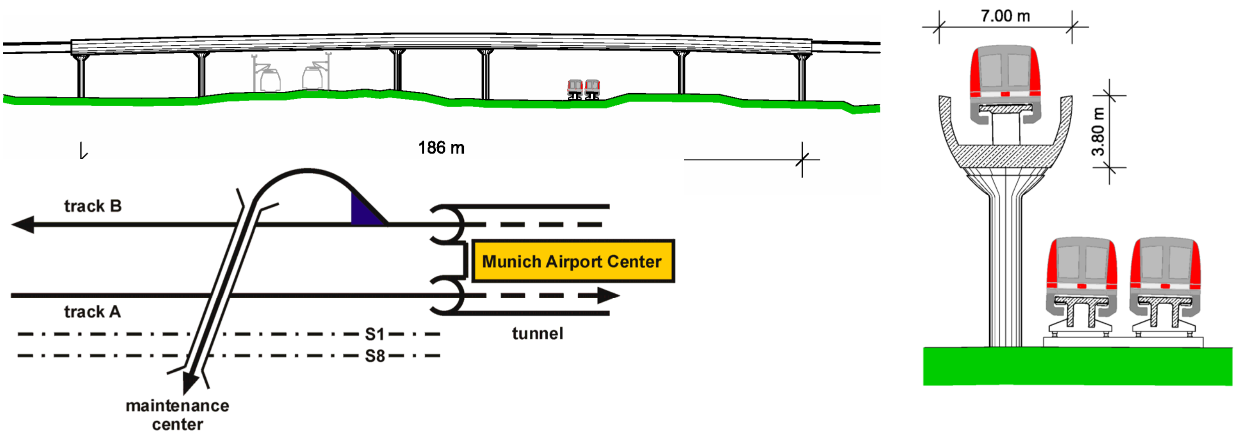


Fig. 14: Flyover to the Maintenance Center

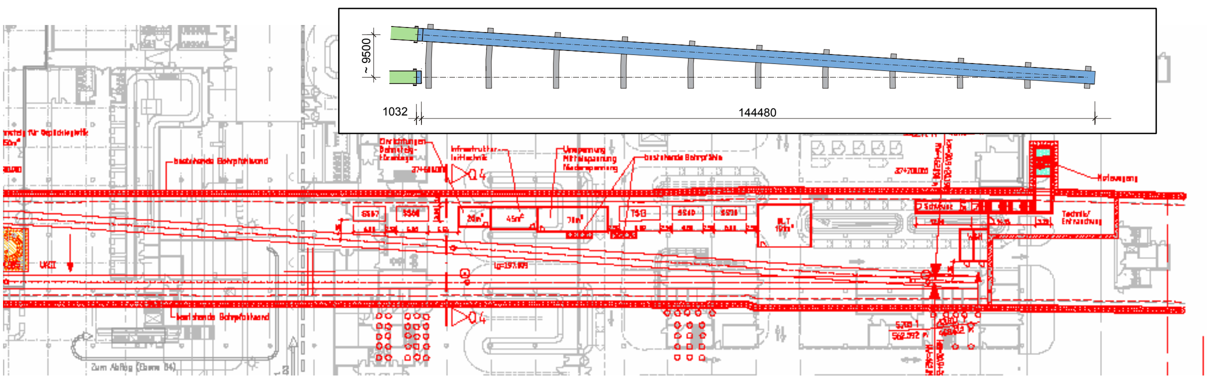


Fig. 15: Long bend in the airport (schematic presentation)

5 OUTLOOK

The project Munich links two important traffic turntables. The main station of Munich with more than 100 million passengers each year is the second largest station in Germany. Munich Airport with 27 million air passengers at present is the second largest German airport, its future aspects are favorable with high increase and existing possibilities to enlarge. Due to the attractive connection these two traffic turntables are linked in such a good way that they nearly fuse with each other. The travel line rail - Transrapid - airplane becomes more attractive than the corresponding traffic by car. It is proceeded on the assumption that in the year 2020 minimum 8 million passenger will use the Transrapid, from which 3 million are changed from car. The location favour of Greater Munich in international comparison is considerable improved by it.

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