National Road B 31 – The Realization of a Privately Financed Project

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Summary

One of the first privately financed projects in Germany was the national road B 31 East between Freiburg and Kirchzarten. This infrastructure project not only helps realize an efficient traffic concept but permits a further development of the infrastructure of the city of Freiburg as well.

As a direct result of the project, the overground East-West traffic is drastically reduced. This is achieved by directing the main traffic underground. Two double-cell tunnels (850 m and 1230 m) and two noise insulation galleries (275 m and 640 m) were planned. These have been built in the inner city part of the project. The outer city part of the infrastructure project consists of five bridges including a number of noise insulation walls.

The tunnels have been constructed using both the ‘cover and cut’ as well as the ‘cut and cover’ method. High security standards have been applied including a very sophisticated traffic control system. These aspects, which are of importance in densely populated areas, are outlined in the paper.

Keywords: privately financed project, infrastructure, concrete bridges, tunnels.

1. History

The national road B 31 is the most important East-West connection in the south-western part of Germany. It links the motorway A 5 (Karlsruhe – Basel) with the A 81 (Stuttgart – Singen / Schaffhausen). The road B 31 East, which passes through the city of Freiburg and continues to Donaueschingen, plays a significant role in the Black Forest region from the touristic point of view as well.

The idea of an efficient bypass through the city of Freiburg was born a long time ago. Since 1978 extensive preliminary designs for traffic concepts have been carried out.

The concept was to unite the conflicting goals of efficient traffic flow with an improved quality of life while at the same time respecting the environment. The finally developed traffic concept includes the following goals:

- Lessening of traffic
- Promotion of public transport
- Promotion of bicycle paths
- Traffic channelling into specific lanes
- Management of parking spaces

Due to the importance of the project, a very time-consuming process of authorization of the preliminary design followed. During this process the requests of several organizations as well as the concerns of the
residents had to be taken into account. This process went on for 15 years and in the year 1993 the final preliminary design was authorized.

The latest conception of the infrastructure project B 31 East not only realizes the stated goals but allows a further development of the infrastructure of the city of Freiburg.

For such a big project with a total length of 7.8 km (inner city and outer city part), the financing scheme presented difficulties. Due to reduced government resources new ideas had to be adopted. The new idea for such a big infrastructure project was to finance it privately. The government in Germany decided to use this financing mode for twelve traffic projects in total, one of them being the national road B 31.

2. Concept

2.1 Financing Concept

The federal investment program covering all infrastructure projects in Germany including bypasses of cities was about 600 million € at this period of time. A further 200 million € for the so called ‘future investment program’ was also made available by the federal government. However, these reduced resources were not nearly enough so the new idea was to finance big infrastructure projects privately. Applying this financing concept, infrastructure projects worth 2,806 million € were carried out. With these projects new strong impulses were given to the building and construction industry as well as to the labour market.

Without this new financing concept the B 31 project would probably have not got further than the drawing board! The total cost of the project reached a sum of 300 million €. A small part of the project worth 16 million € had to be excluded from this concept, because it did not fit in with the conditions of the financing concept. The main part of the cost of 284 million €, which fulfilled the given conditions, is listed in Table 1. The financial charges of the construction costs of 150 million € are 95 million €. They have been calculated on the basis of a constant level of interest over the financing period of 15 years. This amount of 95 million € is divided into several instalments, the first being 20 million €.

<table>
<thead>
<tr>
<th>Parts</th>
<th>Cost [€]</th>
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<tbody>
<tr>
<td>1 Construction</td>
<td>150 million</td>
</tr>
<tr>
<td>2 Financial charges</td>
<td>95 million</td>
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<tr>
<td>3 Acquisition of land</td>
<td>19 million</td>
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<td>4 Funding of the city of Freiburg</td>
<td>10 million</td>
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<td>5 Advanced Payment of the state</td>
<td>10 million</td>
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<tr>
<td><strong>Total</strong></td>
<td><strong>284 million</strong></td>
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*Table 1  Cost structure of the project*

2.2 Traffic Concept

The direction of the main traffic underground effectively reduces the overground East-West traffic crossing through the city of Freiburg. This was the most important aim of the project. Many other benefits result directly from this. Improved traffic safety is one of them. This is achieved by the channelling of traffic and by reducing the crossing of the traffic lanes. The main East-West traffic consists of four lanes. In the outer part of the project the lanes were designed for a speed of 100 km/h. Because of the tunnel solution there is no crossing of these lanes in the inner part of the city. The overground lanes are mainly reserved for resident traffic. The only main crossing is at the Lindenmattenstrasse, where the residential traffic crosses the North-South city traffic including a tram lane. Two foot- and bicycle-bridges complete this inner city concept.

Apart from the very important aspect of road and traffic design many other aspects like the economical, agricultural, forestry, tourism and ecological ones had to be considered. The problems of sound emission and exhaust fumes were dealt with as well. 165 variations of a scheme needed to be discussed and evaluated in the decision-making process. The residents were also involved in this process.

Parallel to the underground traffic, an overground train lane called ‘Hoellentalbahn’ serves as an
alternative to road traffic. The environmental aspects are also taken into account by promoting train, tram and bus in combination with the lessening of traffic. To emphasize this aspect, greenbelt areas of park-like character were designated over the tunnel. Traffic areas which became obsolete were also integrated in the landscape design. The design of all the green areas was included in the structural design process and was discussed extensively with the residents.

As a result, a very successful channelling of traffic is achieved and a dynamic infrastructure created, which increases not only the mobility of the residents but the quality of life as well.

During the period of construction works no interruption of the traffic was allowed. The main problem was the crossing at the mouth of the first tunnel at the height of the Schwarzwaldstrasse. The lanes of the main East-West traffic, the resident traffic as well as the tram traffic had to be designed and modified according to the building stages of the tunnel. To achieve this, one part of the traffic was allowed to run over the already built parts of the tunnel. Separate lanes for the site traffic needed to be designed as well. As mentioned before, crossings with other traffic lanes had to be avoided for safety reasons.

The choice of efficient, economical as well as environmental-friendly methods of construction is a notable aspect of the project.

2.3 Construction Concept

To realize the above traffic concept, an underground construction for the inner city part with a total length of 3.5 km became necessary. It consists of two double-cell tunnels (850 m and 1230 m) and two noise insulation galleries (275 m and 640 m). The cost of these underground constructions makes up the major part of the total cost of the project. Due to the high level of underground water a waterproof

Fig. 1 Aerial view of the structures in the inner city part

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concrete construction was chosen. Fig. 1 shows the aerial view of the structures in the inner city part; in this figure the main structures are marked. The tunnels were constructed using both the ‘cover and cut’ as well as the ‘cut and cover’ method. The first method was applied to avoid disrupting the traffic. At the same time the noise nuisance was reduced which benefited the local residents.

The outer part of the infrastructure project consists of five bridges - some being extremely skew - and a number of noise insulation walls.

The huge amount of material, which was gained from the excavation, was used for the road works as well as for the production of concrete. The on-site produced concrete was sufficient for the entire construction, thus no additional concrete from other places needed to be ordered. In this way not only the economical point of view was considered but the environmental as well. This kept budgeting costs low and was ecologically profitable.

3. Constructions

3.1 Tunnels

The Schuetzenallee tunnel has a length of 850 m. The main part of the tunnel, the first 700 m, was constructed using the ‘cover and cut’ method. Before construction work could begin, the foundation of many buildings running parallel to the tunnel had to be strengthened. This was achieved by applying jet grouting under their foundations. This proved essential because of the deep level of the building pit, which reached a depth of 13.0 m.

The typical cross section of the tunnel blocks is a double-cell one with a middle wall which separates the two tubes. The tunnel deck ground cover varies from 0.25 m to 3.0 m.

The following construction stages were planned for the ‘cover and cut’ part of the tunnel:

- Stage 1: The outer bored piles with a diameter of 90 cm were set. The layout of the pile wall overlapped, with a scheme of a reinforced concrete pile following a non-reinforced concrete pile. Temporary steel columns were placed every 2.5 m for the middle wall (see Fig. 2).
- Stage 2: The excavation was carried out till the bottom level of the deck. A sealing layer with transversal diaphragms every 40 m to 80 m was constructed.
- Stage 3: The tunnel deck was built on a sub-base. Between the tunnel deck and the sub-base a gliding film was placed. The top of the deck was sealed and the area over the tunnel-deck could be used by the traffic.
- Stage 4: Underground excavation. A system of ground water drainage for the rest of the ground water was installed. The piles of the outer walls as well as the columns of the middle wall were cleared of soil. A layer of shotcrete was sprayed over the outer pile walls.
- Stage 5: A sub-base for the sole plate of the tunnel was built and a gliding film was placed on top of it. The tunnel blocks were built taking into account the underground water pressure. For this reason, each tunnel block was cast in one piece without any construction joints.
- Stage 6: The road surfacing on the tunnel sole plate was built and finally the tunnel installation was carried out.

In total, 2,500 pieces of concrete pile of a maximum length of 26.0 m were drilled. A total number of 8,000 drillings were necessary for the 14,000 m² sealing layer.

The last 150 m of the Schuetzenallee tunnel as well as the whole Kappeller tunnel with a length of 1,230 m were built using the much easier method ‘cut and cover’. A Berlin-Type wall was used for the building pit, which reached a depth of up to 13.0 m. 900 m of the tunnel were constructed using movable scaffolding with a steel formwork. The casting of these tunnel blocks was done in one piece thus avoiding construction joints. The remaining 480 m of the tunnels were built in a conventional way using construction joints between the sole plate, the walls and the tunnel deck. A number of additional constructions were required before the tunnels could go into operation. This included underground control stations, emergency staircases, escape corridors with a maximum length of 300 m and utility
pipes of 2.0 m in diameter. At the mouth and tail-end of the tunnels, noise insulation aluminium elements were placed on the tunnel walls.

At intervals in the tunnel, emergency parking spaces and connecting gates between the two traffic directions were planned. These tunnel blocks required a special construction. The concrete decks have a form of a multiple T-beam cross-section and rest on the outer tunnel walls using bearings. Due to the double span of the system only prestressed concrete decks could be implemented. The deflection difference between the much stiffer double-cell tunnel blocks and the less stiff one-cell tunnel block was handled using waterproof transition joints.

In addition to the above mentioned constructions, sophisticated traffic control systems using computer-controlled cameras have been installed. So, for both tunnels, the Schuetzenallee and the Kappeller tunnel, high security standards have been applied. Finally, water reservoirs for the fire brigade were foreseen.

3.2 Noise Insulation Galleries

Two noise insulation galleries with a length of 275 m and 640 m are placed between the two tunnels. They break up the monotony of the tunnels by presenting interesting architectural elements. Only the north tunnel tube continues into the galleries with a concrete deck while the south tube is uncovered. Between these two tubes, the separating wall has been replaced by a row of diagonal slim columns (see Fig. 3). As a result, a transparency is achieved and daylight floods into the covered tube. At the mouth and tail-end of the galleries noise insulation aluminium elements are fixed on the wall.
The slim columns have a concrete joint at the top and are fixed in the sole plate at their base. They consist of steel tubes filled with reinforced concrete. In this way the dimensions of the columns could be minimized.

The two galleries are separated by an open space with a length of 505 m. Many types of sustaining wall separate the traffic from the surroundings. A concrete wall between the two traffic directions marks the entrance to the galleries. The wall has the shape of a triangle with a wide opening (see Fig. 3). The dimension of one side of the triangle was chosen taking into account the load case of a frontal vehicle impact. Two foot- and bicycle bridges cross above the galleries.

Fig. 3 Start blocks of the noise insulation gallery

3.3 Bridges

The bridges are divided into two categories; inner city and outer city.

3.3.1 Inner city Bridges

The inner city traffic crossing over the B 31 is achieved either over the tunnel decks or by two foot- and bicycle bridges (Hammerschmied- and Bergaeckerbridge) at the height of the noise insulation galleries.

The first bridge, the Hammerschmiedbridge, is a five-span bridge with a total length of 122.65 m. It crosses both the B 31 and the railway track of the ‘Hoellentalbahn’. The bridge was mainly cast in place. Only the middle part of it has been pre-fabricated in order to avoid interruption of the railway traffic during the construction period of the bridge.

3.3.2 Outer city Bridges

The B 31 East includes five outer city, concrete bridges. One of them is a bridge over a small river which was designed as a reinforced concrete frame. The width of the bridge is 61.50 m. Another bridge is the one over the river Krummbach. It has a similar cross section and is 32.0 m in width. The bridge to the golf club over the B 31 is a two-span prestressed bridge with a T-beam cross-section. The superstructure is rigidly connected with the middle column of the bridge. The middle column had to be dimensioned taking into account the load case of vehicle impact as well.

The most remarkable bridges of the B 31 East are the bridge of the road

Fig. 4 Bridge of the road L 121 over B 31
L 121 over the B 31 and the bridge over the river Brugga. Although the span of these bridges is rather small, the detailing of the bridges had to be carefully designed, because these bridges affect the layout of the surrounding landscape. One main architectural prerequisite of the design was that the construction harmonizes with the surroundings. The bridge of the road L 121 over the B 31 is a two-span bridge with a total length of 44 m (Fig. 4). The 73° skew superstructure has a plate cross section and is longitudinally and transversally prestressed. The bridge deck has a varying width (minimum width 11.0 m) due to an additional traffic lane which begins on the bridge.

The one-span bridge over the river Brugga has a length of 35.0 m. It consists of two parallel, 38° skew and 11.5 m wide superstructures. It has a double T-beam cross section. A prestressing in three directions was necessary. It consists of longitudinal tendons along the web of the T-beam, transversal tendons in the flange of the T-beam and straight tendons in the skew direction along the end cross beams. The bridge was cast in place using classical scaffolding. The two abutments of the bridge rest on the same foundation but are separated by a joint.

3.4 Sustaining Walls and further Constructions

Sustaining walls of a length of 505 m are built between the two noise insulation galleries in the inner city part of the B 31 East. The architectural layout was also of importance due to the inner city location of these constructions. For this reason different types of walls are used: a sustaining wall consisting of reinforced concrete pots with plants, a space frame wall which is also planted and a reinforced concrete wall. The combination of these construction systems avoids an abrupt transition from one system to the next. Fig. 5 shows the chosen systems.

In the outer city part, between the Kappeller tunnel and the bridge of the street L 121 over the B 31, the noise insulation structure consists mainly of noise insulation dams or noise insulation walls with acrylic glass or timber elements.

A number of further constructions were needed for the functioning of the B 31 East. Rainwater pipes, sewage canals and drain pipes were built along the entire length of the road. Water reservoirs for the fire brigade were also planned in the project.

Fig. 5 Inner city sustaining wall
4. Conclusion

One of the twelve privately financed projects in Germany was the infrastructure project of the national road B 31 East between Freiburg and Kirchzarten with a total length of 7.8 km. The primary concept was to combine the conflicting aspects of efficient traffic flow with those of an improved quality of life while respecting the environment. To achieve these goals a very time consuming decision-making process of 15 years followed. In this process the requests of several organizations as well as the concerns of the residents were regarded as far as possible.

The main concept was to direct the East-West traffic, which runs through the inner city over a distance of 3.5 km, underground. This concept involved the building of two tunnels and two noise insulation galleries. As a result, an effective channeling of the traffic is achieved by avoiding the crossing of busy traffic lanes. The outer city part of the B 31 East (see Fig.6) includes five concrete bridges, which were designed to harmonize with the surroundings. A number of further constructions were needed to ensure high security standards. Independent safety inspectors have since awarded the tunnel a distinction in the category of ‘Best Safety’.

The total cost of the main part of the project amounted to 284 million €. The financial charges of the construction costs of 150 million € are 95 million €, which have been calculated for a financing period of 15 years. The disadvantage of this long-term binding of state resources led the government to the decision not to apply this mode of financing for future projects. As a result, other modes which have been successfully applied abroad are currently in use for infrastructure projects in Germany.

Fig. 6 Aerial view of the structures in the outer city part