1. Diverting the north-south Backbone Road underground

The North-South Backbone Road is the most important arterial route in the central area of the Czech capital, Prague. Up to 100,000 vehicles daily run along this road, which means that it is one of most trafficked roads in Prague. Due to the unceasing flow of motor vehicle traffic, permitted exhaust and noise emission limits are seriously exceeded, which fact significantly degrades living conditions of local residents and visitors to the capital, Prague. The population density in the given location is the highest in the city, reaching over 13,000 per square kilometer. Noise pollution value in Legerova Street amounts to 78.2 dB in the daytime, while the limit permitted by sanitary regulations is 50 dB. In the nighttime it reaches up to 73.5 dB, while the permitted limit is 40 dB. The air pollution situation is also very unfavorable. Permitted limits are permanently exceeded as far as dust emissions (PM10) and nitrogen oxide (NO2) emissions are concerned.

The fundamental system problem of the entire adjacent area is the at-grade intersection between the North-South Backbone Road and a part of the Prague street network, the west-east trunk road (Žitná, Ječná, Rumunská and Vinohradská Streets). The traffic situation at I.P.Pavlova Square, where the traffic coming from Ječná Street joins the 'dual-carriageway’ Backbone Road, is very critical. The situation in this location is further complicated owing to the crossing with one of most trafficked streetcar routes and the extremely busy pedestrian traffic flow, exceeding 27,000 pedestrians per day.

The above-mentioned major traffic problem originated in the 1960s and 1970s. The originally planned route of the Backbone Road in the section from the Nuselský Bridge to the Hlavní Nádraží railway station was planned lead underground. Blocks of houses between parallel Legerova and Sokolská Streets were expected to be demolished and, after completing cut and cover tunnels for the Backbone Road, be replaced by a new development. The effort to find a more economical solution resulted in the idea, which is very unfortunate from today’s point of view, to lead the Backbone Road on the surface, in the footprint of the above-mentioned parallel streets. Of course, the vehicular traffic volume was significantly smaller at that time. After the implementation of this project, the important Wenceslas Square dominating building, the National Museum, as well as the neighboring buildings of the Parliament and the State Opera ended up on an ‘island’ surrounded by multi-lane carriageways with very dense motor vehicle traffic on them (see Fig.1). With the automobile transport volume growing and the city regions which are connected by the Backbone Road across the city center developing, this problem has become more and more ominous not only from the transportation perspective but also, first of all, from the standpoint of quality of the environment for people living in this location.
2. Comprehensive proposal for a tunnel solution

While seeking suitable alternatives of this age-old and complicated problem, it is not possible to only improve the pattern of the city just in the upper part of Wenceslas Square. First of all, it is necessary to solve the totally unacceptable situation of most affected inhabitants who dwell or are present in the area between the Nuselský Bridge and Hlavní Nádraží Station. The proposal being submitted responds to the needs of the city for reducing traffic flow on the NSBR and diminishing other related ecological loads in the area between Hlavní Nádraží Station and the Nuselský Bridge.

First of all, it is necessary to eliminate the close link between the Backbone Road and the upper part of Wenceslas Square, and minimize negative impacts on the compact house-building system in Prague 2, above all along Sokolská and Legerova Streets and at the exceptionally highly trafficked node in I.P.Pavlova Square. The outcome of comprises the elimination of the unsatisfactory situation and subsequent humanization of the street space in the entire area.

Taking into consideration the above-mentioned facts, it is necessary to dispute the division of the project into stages, leading in the beginning to the reduction in the surface traffic volume in front of the National Museum in Wenceslas Square and only subsequently, in some more closely unspecified future, in the other section in the direction of the Nuselský Bridge.

It is therefore obvious that a major reduction in surface traffic, improving the conditions at signalized intersections, including more fluent passage of streetcars across I.P.Pavlova Square, can be only reached by diverting transit transportation within the entire area underground.

3. Construction sequence proposal – options for putting the Road into operation in stages

Construction stage 1: from Hlavní Nádraží Station to Anglická Street and Nuselský Bridge

With this section of Legerova Street totally closed to traffic and streetcar traffic eliminated, the excavation for the cut-and-cover stacked tunnels behind the National Museum will be carried out.
Both directions of traffic will be diverted via Žitná Street to Wilsonova and Mezibranská Streets, using two lanes in each direction. Descending access and ascending exit ramps will be established in the Čelakovského Sady Park. The descending access ramp will be built in the direction from Hlavní Nádraží at the end of stage 1.

Concurrently with constructing tunnels in the – Hlavní Nádraží Station section, the double-lane tunnel designed to carry traffic toward the center of the city will be constructed from the Nuselský Bridge toward the Čelakovského Sady Park. First the construction trench for the cut-and-cover tunnel and an access ramp will be constructed in the space of Lublaňská Street and the adjacent park. Then the construction of the double-lane tunnel will proceed, with the major part following the footprint of Lublaňská Street, heading toward the portal of cut-and-cover tunnels in the Čelakovského Sady Park. Once the tunnel excavation is completed, the final lining of the mined tunnel and cut-and-cover tunnel will be installed, including the lining of the descending access ramp. All of these operations will run without restricting traffic on the Backbone Road. It will be only at the conclusion, within a short interval of time, that the two traffic lanes leading in the direction of the city center to the newly completed double-lane tunnel, will be connected to the Nuselský Bridge.

An underground service building will be constructed in Fugnerovo Square, using the cut-and-cover method, concurrently with the construction of the stage 1 tunnels, i.e. both the bi-directional tunnels in the Anglická Street – Hlavní Nádraží section and the double-lane tunnel ending at the Nuselský Bridge, which will carry traffic to the downtown. Apart from other services, the building will house the main ventilation plant. The service building will be interconnected with the mined double-lane tunnel via a mined service tunnel located under Koubkova Street. On the opposite side, a mined ventilation tunnel running under Apolinářská Street will be connected to the service building. A ventilation shaft evacuating polluted air will be built on the corner of Apolinářská Street and Ke Karlovu Street. It will reliably ensure the dispersion of polluted air in the atmosphere, in compliance with sanitary regulations.

When this stage is finished, the bi-directional tunnel section behind the National Museum, heading toward Hlavní Nádraží Station, and the unidirectional tunnel in the Anglická Street – Nuselský Bridge section will be opened to traffic.
4. Construction stage 2 – Construction of the Anglická Street – Nuselský Bridge mined double-lane tunnel

Now the double-lane section of the roadway between the Nuselský Bridge and Legerova Street will be operated in the opposite direction (from the center out). A diverted route will run from Sokolská Street through Wenzigova and Legerova Streets, to the Nuselský Bridge. A construction trench for the cut and cover tunnel and a descending access ramp will be excavated in Sokolská Street, in the section from Wenzigova Street to the Nuselský Bridge. Subsequently, the double-lane tunnel will be driven under Sokolská Street, toward the cut-and-cover tunnels portal in the Čelakovského Sady Park, which were built in the previous stage. When the double-lane tunnel driving is completed, the final lining of the tunnel will be installed. Naturally, the tunnel will be connected to the service building in Fugnerovo Square.
5. Structural design of mined double-lane tunnels

The basics which in principle have affected the tunnel cross-section design:
- the transverse ventilation system concept, allowing the air being exhausted to be cleaned if necessary at the service centre in Fugnerovo Square.
- the use of the ventilation duct under the roadway for escape of persons in the case of a tunnel fire (first of all during the first stage of the construction work).
- the tunnels are located under permanent ground water level, thus it is necessary to propose a closed profile of the final lining.

![Fig.5 The ventilation duct under the roadway for escape, The transverse ventilation system](image)

While adhering to the above-mentioned principles, the tunnel cross-section was designed to have a double-pass lining with intermediate waterproofing, suitable for the NATM (see Fig.6).

Recently, protests of Prague citizens against constructions of mined tunnels have been significantly increasing. Owners and users of surface buildings found above tunnel routes are afraid of possible damage to buildings and negative impacts of seismic effects during the NATM excavation.

![Fig.6 Cross sections variants - NATM and TBM](image)
These problems can be successfully solved by driving tunnels by means of TBM (see Fig.6). Modern Earth Pressure Balance or Slurry Pressure Balance TBM minimize the risk of damage to surface buildings and, at the same time, seismic effects during the driving are excluded. In the given case, the use of a TBM is even supported by the fact that the double-lane tunnels would be constructed in two stages. This system makes the deployment of only one tunnelling machine possible, thus this tunnelling technique becomes more effective. The total length of TBM driven tunnels would be 2010 m.