FUTURE TUNNEL STRUCTURES IN THE CENTRAL PART OF THE PRAGUE RAILWAY NODE

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ABSTRACT: Growing demands in both passenger and freight transport inevitably lead to the gradual overloading and the inability to meet all long-term requirements of rail transport in Prague. The current arrangement has its limits; therefore, further development of suburban rail transport together with the integration of high-speed connections into long-distance transport urgently requires a new solution for the entire Prague railway node. To establish a concept for its completion, a feasibility study was developed between 2021 and 2025 and has been approved by the Central Commission of the Ministry of Transport upon completion. In accordance with the assignment, the study focused on variants of building new underground rail infrastructure in the central area of the city and on modernising the feeder lines in an effort to maximally satisfy the demand for transport defined by transport authorities based on transport forecasts.

1. PRAGUE AND THE RAILWAY

Coexistence between the city of Prague and the railway has lasted for nearly two centuries. The attractiveness of the then provincial centre attracted private railway companies to its outskirts, around whose station's industrial areas and entirely new city districts developed. These demanded increasing transport capacity but at the same time increasingly constrained the railway infrastructure and resisted the impacts of rail operations. More than a century ago, the nationalised railways initiated the first comprehensive reconstruction of the node by diverting freight traffic from the centre to the new Vršovice marshalling yard and to lines along the eastern perimeter of the then quarter-million city, which, however, was again absorbed about half a century later. A new comprehensive concept was approved in the 1960s and became the basis of the current layout of the node, where ten railway lines with a total track length of approximately 390 km enter the city.

The decline of heavy industry after 1989 led to a decrease in interest in freight rail transport, which from the 2000s onward was replaced by a steadily growing demand for passenger rail transport, both regional and long-distance. Already in the previous decade it became evident that despite significant partial investments, the Prague railway node as a whole does not have sufficient reserves for further development of suburban passenger transport, for stable operation and renewed growth of freight transport, and especially for a qualitative leap in long-distance transport in the form of high-speed rail—all while new urban development increasingly pressures railway land. The approval of the High-Speed Connection programme at the government level in 2017 was the final impetus for the creation of a new long-term development concept for the node. Správa železnic therefore commissioned the Feasibility Study of the Prague Railway Node including High-Speed Connections (= Rapid Services).

The work required the investigation of scenarios and options for eliminating the capacity limits of the node, taking into account all expected demands on the railway network in the long-term horizon of 2035–2050 with an extension toward 2070, i.e., after the completion of all railway projects currently under preparation. The assignment was finalised in 2019, and the contractor selection took place the following year.

2. PROCESSING THE FEASIBILITY STUDY

The contractor of the study, as of 7 January 2021, became a consortium of design organisations: AFRY CZ s.r.o., EKOLA group, spol. s r.o., SAGASTA s.r.o., and SMA (Deutschland) GmbH, led by Mott MacDonald

CZ, spol. s r.o. The tender procedure was based on the Best Value Approach / Best Value Procurement (BVA/BVP) method, in which the client grants the contractor significant space for creative innovation while reducing the pressure on the bid price. This made it possible to involve foreign experts with practical experience in designing S-Bahn systems in Western Europe, to prepare a specific working methodology suitable for managing a high number of potential variants, and to use a participatory approach that engaged all relevant stakeholders.

For managing the work and approving the outputs, a "Feasibility Study Committee" was established. Its members included representatives of the client, the Ministry of Transport of the Czech Republic, the State Fund for Transport Infrastructure, the JASPERS initiative, the City of Prague including institutions IPR Praha, TSK, and ROPID, the Central Bohemian Region including IDSK, the railway freight operators' association ŽESNAD.CZ, and the Czech Chamber of Commerce. A permanent working group followed the Committee's activities, consisting of experts from the involved institutions, including the client and the contractor. This group met on a regular two-week basis, providing sufficient time for effective involvement in all phases of the study, for gathering inputs and immediate feedback, and for finding compromises among differently perceived priorities as well as for understanding the proposed solutions and the selection of preferred options. Through a series of workshops, a broader professional public was also involved in the study. Their participation helped formulate answers to complex questions extending beyond the primary scope of the feasibility study.

3. THE CITY AND REGION DEVELOPMENT AND THE FUTURE SCOPE OF TRANSPORT

The forecast for regional development towards future horizons up to the year 2070 was prepared in cooperation with the Prague Institute of Planning and Development. The population of the capital city will increase from the current 1.3 million (2019) to 1.6 million, an increase of 21%. The so-called Prague metropolitan region, comprising the functional hinterland of Prague located in the Central Bohemian Region, will grow from 0.7 million to 1.0 million inhabitants, an increase of 42%, while the Central Bohemian Region as a whole will grow by an average of 34% to 1.9 million inhabitants. However, most new jobs will be created in the capital city itself; therefore, transport demand within Prague will increase by 25%, while transport demand to and from the region will increase by 85%.

A future operational concept for rail transport was prepared and optimised together with transport authorities. The concept is intentionally invariant so as not to influence the comparison of infrastructure variants, though it can be extensively modified if needed. Prague is planned to be served by 27 long-distance lines, each operating at a basic 60-minute interval throughout the day. Regional transport will be composed of 20 stopping services and 13 semi-fast services operated in a zonal pattern, interconnected as much as possible diametrically across the city centre. The peak interval of the core lines is 15 minutes, or 7.5 minutes on the Kladno – Benešov axis. On the main radial routes, lines are interlaced to create a combined 7.5-minute interval, and in the city tunnels the average interval is 3.75 minutes. Tangential urban rail lines are planned with a basic interval of 15 minutes. Freight transport follows the introduction of systematic freight train paths at 120-minute intervals, which must remain available even during the peak of passenger traffic.

The forecast of transport demand response to the proposed service patterns was assessed together with the Technical Road Administration of Prague, which operates a detailed transport model of Prague and its surroundings. For more distant areas, the national transport model of the Ministry of Transport of the Czech Republic was used.

4. THEORETICAL AND PRELIMINARY VARIANTS

The study is based on a key assumption that by the year 2035, currently prepared projects—such as the Libeň grade-separated junction, the three-track Výtoň bridge, and the connection Prague – Airport – Kladno—will have been completed. However, even after these investments are finished, the node will still not be able to satisfy the full scope of the long-term transport demand described above. In addition to the overload of the track yards at the Main Station and Masaryk Station and all their feeder lines, all

level junctions within the node significantly reduce operational capacity. The line from Prague-Hostivař to Prague-Uhříněves and further southeast is inadequate, and after the increase in long-distance services towards Liberec, even the three-track line from Vysočany will not suffice.

The theoretical variants served to summarise experience from previous studies, to allow the design team to "get a feel" for the area of interest, and to generate new ideas as a basis for discussion within the working group. From nearly one hundred partial operational and technical proposals, a set of six preliminary variants was compiled.

One of these variants included high-speed rail in the underground and routing the RS4 line to Ústí nad Labem via the airport in Ruzyně. Although this connection may appear attractive, the number of so-called air-travel passengers within the rail system amounts to just over 20,000 per day and they already use the new conventional line to the airport. A direct high-speed connection would increase this demand by only a few thousand passengers, while its effect for hundreds of thousands of passengers in other segments would be minor and the costs high. For this reason, the connection of high-speed rail with air transport was not pursued further. The same applied to introducing long-distance services into the underground, routing regional transport via Žižkov, or constructing an underground bypass of the Negrelli Viaduct, all of which also failed economically.

The preliminary variants were presented in more detail at the previous edition of the conference in 2023.

By further combining the technically and economically promising outcomes of the preliminary variants—according to the preferences of the working group—the final proposal variants were developed.

5. PROPOSED VARIANTS

Before the approval process, the study presented the following three design variants, all sharing the common feature of relocating the regional rail service into underground tunnels.

5.1 PROPOSED VARIANT N1

This variant focuses on broad coverage of the city centre and on connections to the metro network. It consists of two new double-track underground lines for regional transport (so-called city tunnels) Smíchov – Karlín and Eden – Negrelli Viaduct in a cross arrangement. They intersect grade-separated within a shared, directionally arranged four-track section between Wenceslas Square and the Main Station, with one four-track, twin-aisle station located diagonally under the Main Station and another approximately beneath the Lucerna Palace. Additional new stations include Karlín, Florenc, Karlovo náměstí, Albertov and Náměstí Bratří Synků. The Wenceslas Square station must be located below Metro Line A. The Benešov branch therefore continues underground into Nusle, passing below Metro Line D and the Botič stream; it resurfaces only before Prague-Eden station.

5.2 PROPOSED VARIANT N2

This variant prefers fast access to central stations and lower investment costs by shortening tunnels and reducing the total number of underground stations. It consists of two completely separate double-track underground lines in a cross arrangement, Smíchov – Karlín and Vršovice – Negrelli Viaduct. The central area includes a new underground Main Station at level −1 (shallow position beneath platforms 1–3) on the Vršovice – Negrelli line, and a station at level −2 under the yard on the Smíchov – Karlín line, plus stations Wenceslas Square and Karlín. The shallow position allows the Benešov branch to pass above Metro Line A, climb on the Nusle side to the area between the 1st and 2nd Vinohrady tunnels and pass through Prague-Vršovice.

5.3 PROPOSED VARIANT N3

This variant builds upon solutions from previous studies with the Opera station. It uses two new double-track underground lines for regional transport, Smíchov – Karlín and Eden – Negrelli Viaduct, meeting grade-separated in a shared four-track, twin-aisle underground station arranged by direction near the State Opera, enabling line transitions. Central stations include Karlín, Florenc, Karlovo náměstí, Albertov and Náměstí Bratří Synků. Although Opera aims to improve the weak links between rail and metro via Muzeum A/C, it considerably lengthens transfers between regional and long-distance trains, which dominate at the Main Station.

6. APPROVED VARIANT AND ITS DESIGN CONCEPT

The study's authors recommended Variant N2 as the final solution, as it offers the best opportunities for interlinking lines through the city centre, provides the greatest reductions in passengers' travel times, and is significantly less financially demanding while still meeting the required economic evaluation thresholds for approval. At the initiative of the Committee members, Variant N2 was supplemented by adding a surface-level station Prague–Florenc and an underground station Karlovo náměstí, forming N2FK, which was approved by the Central Commission of the Ministry of Transport of the Czech Republic on 28 January 2025.

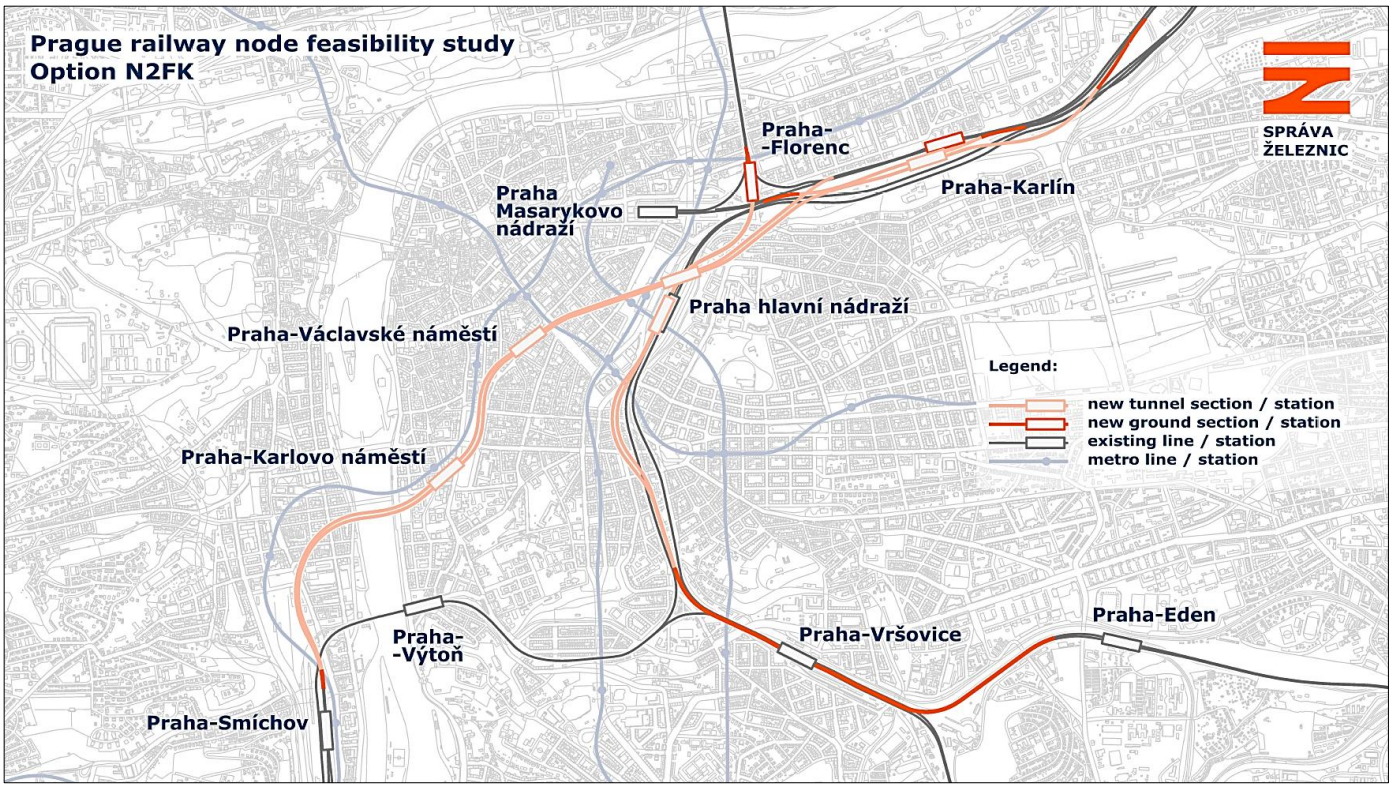

Figure 1: Graphic representation of N2FK variant in central part of Prague railway node. Source: Správa železnic, státní organizace.

City tunnels offer very high capacity (2×16 trains/hour/direction) and, if lines are not interlined, can carry most regional services. All variants retain Masaryk Station's operation for flexible scaling of the through-running model, but capacity is limited by level junctions at both approaches to the heritage Negrelli Viaduct. Demand differs little among variants: Kladno – Airport corridor ~90,000 passengers/day; Benešov axis ~80,000/day; regional total ~400,000/day; long-distance +240,000/day; trains handled at central stations rise from ~1,100 to ~2,400 per day; travel time Airport – Main Station will be 25 minutes.

The tunnel design for the central area was prepared to enable economic assessment and variant comparison within the feasibility study. Stations and tunnel sections are designed to be feasible but are not the only possible solutions, and specific geological conditions could not yet be reflected. In subsequent project phases, cross-sections and systems will be optimised with regard to traction type, passenger flows (terminating/interchanging), fire safety principles, etc.

Generally, technology will be located in station concourses, extended station tunnels, and below platform level. Forced ventilation is proposed, with an HVAC plant and one central ventilation shaft per station, an intake/exhaust duct above platform level, and dampers at both ends of the station. Each tunnel tube will be ventilated independently, and no intermediate ventilation shafts are needed between stations.

6.1 KARLÍN STATION

This is a combined station with two tracks at a surface stop and two tracks in an underground station. The underground part is designed as a mined, twin-aisle station at the foot of Vítkov Hill. The station tunnels are 250 m long with side platforms 220 m long and 4.6 m wide, interconnected by four

cross-passages. From the westernmost cross-passage (No. 1), a barrier-free exit tunnel is proposed to the existing Žižkov pedestrian tunnel, including two travelators. From cross-passage No. 3, an escalator tunnel leads to a connecting corridor and then to the station concourse located beneath the surface part of the station. From the easternmost connecting passage No. 4, a lift is proposed discharging into the transfer corridor, providing barrier-free access to the underground station platform.

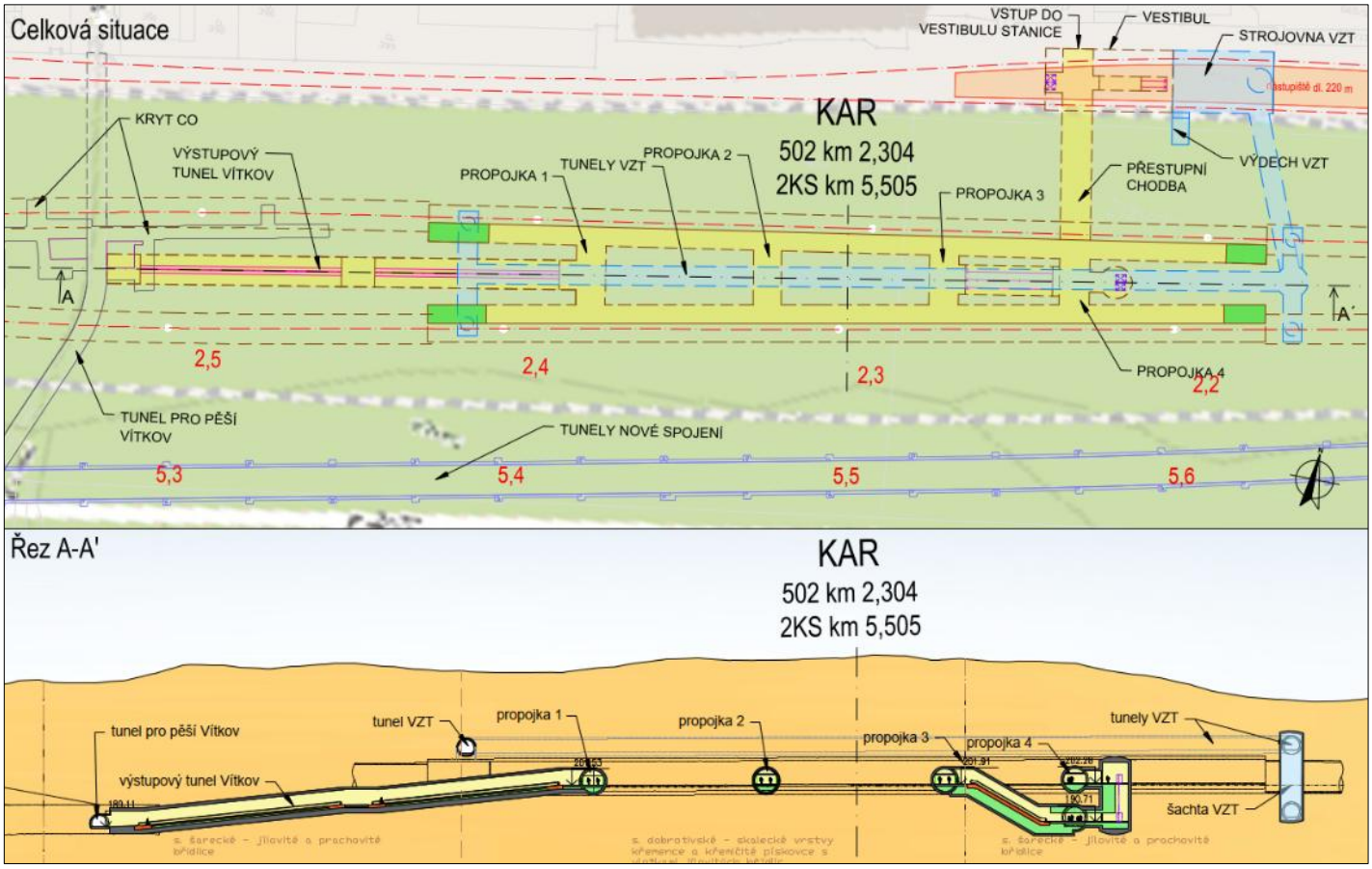

Figure 2: Layout and longitudinal plan of Karlín station. Source: Mott Mac Donald CZ, spol. s.r.o.

The station ventilation is provided by a subsurface HVAC plant room, connected to the station via ventilating mined tunnels and a shaft. The exhaust outlet is located behind the surface stop tracks at the toe of the slope. The technology installation is assumed to be located within the station entrance building and in the extended sections of the station tunnels. The surface part of the station (the stop), together with the entrance building and the HVAC plant room, will be constructed in an open excavation at the foot of the Vítkov hill slope. The underground part of the station will be mined using the NATM (New Austrian Tunnelling Method) through the running tunnel from the Karlín construction site facilities, or alternatively from the excavation for the station entrance building.

6.2 INTERCHANGE HUB PRAGUE MAIN STATION

Underground part of Prague Main Station hub was designed in two levels. The (lower) station on the Karlín – Smíchov rail track is designed as a single-aisle mined station 250 m long with an 11 m wide island platform. From the eastern end of the station cavern, an escalator tunnel leads into a transfer corridor, from which another escalator tunnel continues to the concourse at W. Churchill Square. To accelerate passenger movement, this transfer corridor includes a pair of travelators.

Approximately halfway along the station cavern, a transfer corridor located below the station level is proposed. This corridor connects to an escalator tunnel that leads into the transfer corridor under the track field of Prague Main Station. This corridor runs parallel to the tracks and connects the existing transverse underpasses of the station. Further westwards, another transfer corridor beneath the station links to an escalator tunnel that enters a new concourse of Prague Main Station. At the western end of the platform, a lift shaft is designed, which connects to a transfer corridor leading to the new concourse

as well. From the new concourse, two transfer corridors are proposed to Metro Line C: from the northern corridor (direction Metro C – Muzeum) an exit directly in front of the Main Station building with an interchange to the planned tram line Václavské náměstí – Bolzanova and a lift for barrier-free access; the southern corridor (direction Metro C – Florenc) passes through the current underground technical areas of the station, which will have to be relocated. From the new concourse, a dedicated exit corridor is also designed, leading directly into the historical station cavern.

For independent construction of the mined station, a 318 m long inclined access adit is proposed from a construction pit for the ventilation plant at the Seifertova Street worksite, broken out into a cavern perpendicular to the station cavern for excavation.

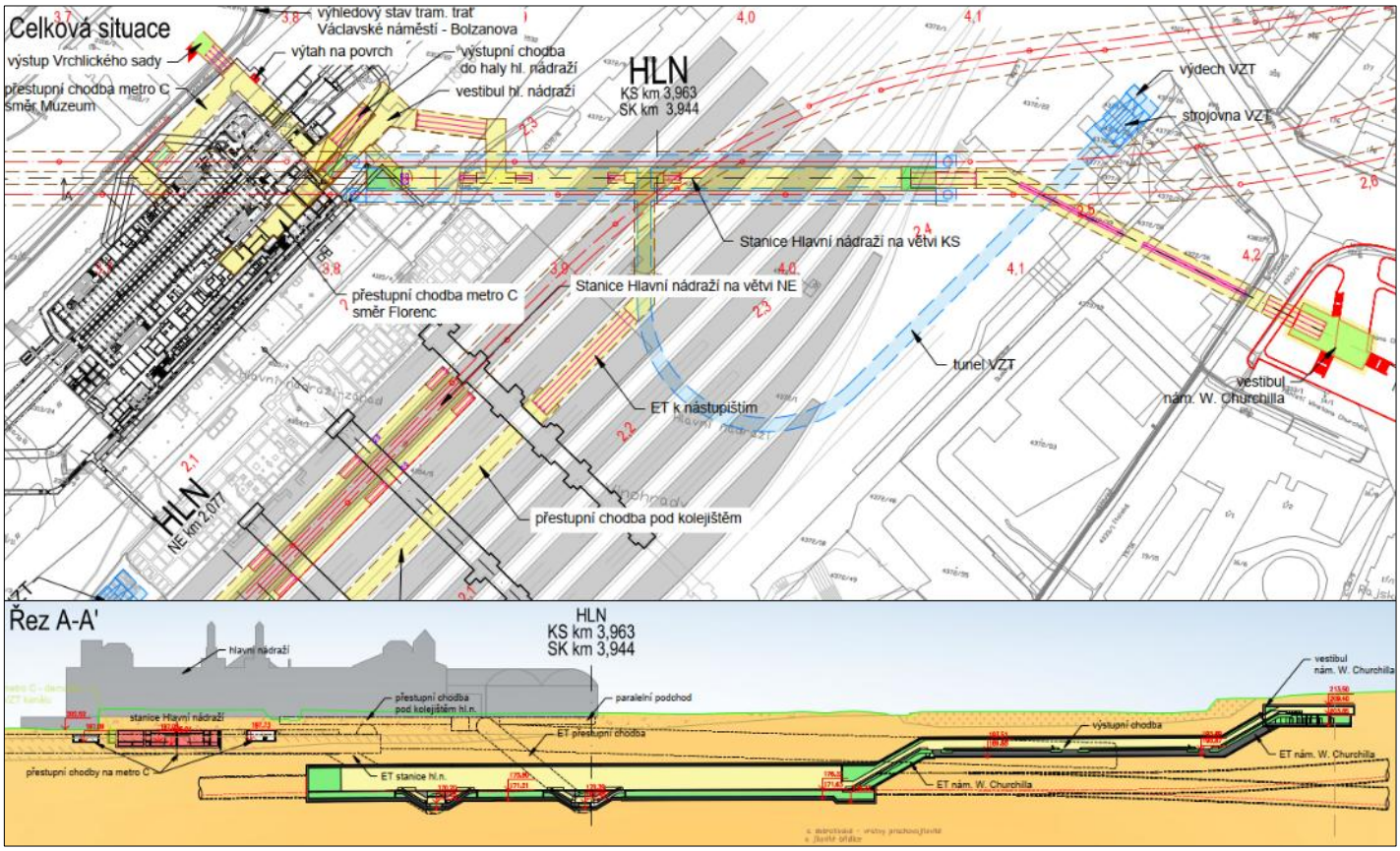

Figure 3: Layout and longitudinal plan of lower station at Prague Main Station hub. Source: Mott Mac Donald CZ, spol. s.r.o.

The (upper) station on the Negrelli Viaduct – Eden rail track is designed as a cut-and-cover station within an excavation aligned with Platform 2. It will have side platforms connected to the existing underpasses by six escalators and two lifts, ensuring barrier-free access.

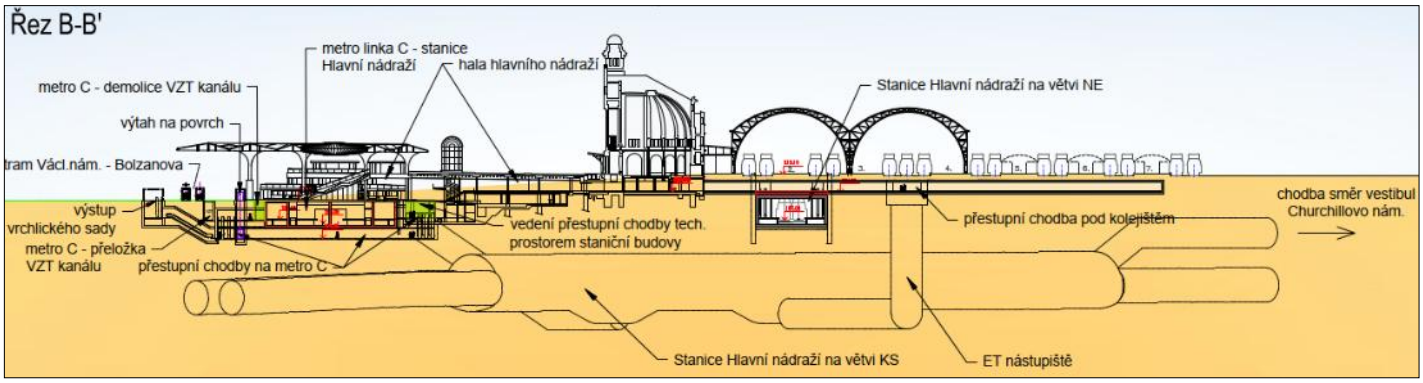

Figure 4: Cross section of upper station at Prague Main Station hub. Source: Mott Mac Donald CZ, spol. s.r.o.

6.3 VÁCLAVSKÉ NÁMĚSTÍ (WENCESLAS SQUARE) STATION

The station is designed as a 250 m long single-aisle mined station with an 11 m wide island platform. From the eastern end of the station cavern, an escalator tunnel leads to the Můstek concourse, which will be extended in the direction of the National Museum. For a direct transfer to Metro Line B – Můstek, a transfer corridor is proposed that connects to the existing transfer passage between Můstek A and Můstek B. To avoid passenger stream conflicts, this corridor is supplemented with an additional branch that leads into the existing A–B transfer tunnels. To accelerate passenger movement, the transfer corridor is equipped with three travelators. West of the station centre, a transverse transfer corridor above platform level is proposed. From this corridor, a western passage leads to the Školská concourse and an eastern passage leads to lift access. From the upper level of the lift shaft, a transfer corridor connects to the technological building at Palackého 637, where a ground-floor lift concourse will provide barrier-free access. The exit to the Školská concourse is designed with two escalator tunnels and an intermediate transfer corridor. At the interface between the new transfer corridors and the existing ones in the A–B metro interchange, pressure doors will be installed.

The station ventilation is provided by a mined HVAC plant room located parallel to the station hall in the direction of Palackého Street. It is connected to the station by ventilation tunnels. For equipment delivery, a service adit from the station hall is proposed. The exhaust outlet is located in the mentioned technology building, where additional station equipment is also envisaged to be installed.

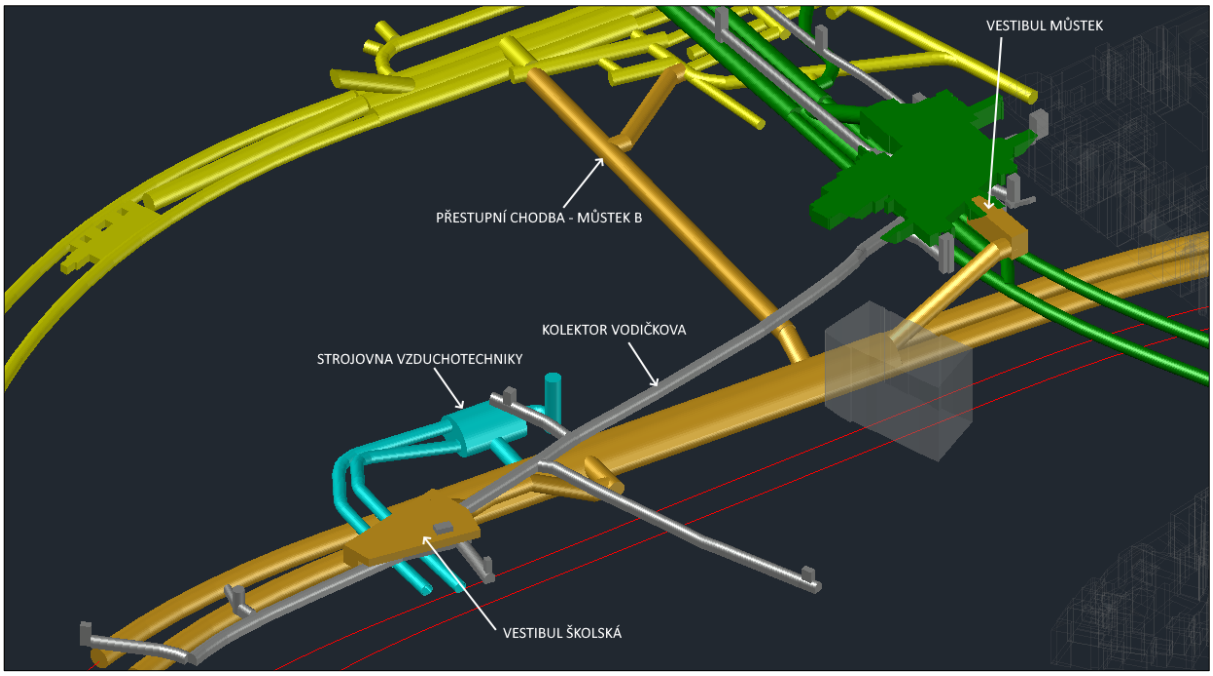

Figure 5: Visualization of Václavské náměstí station. Source: Mott Mac Donald CZ, spol. s.r.o.

For independent construction of the station, separate from the running tunnels, the station will be excavated through the escalator tunnels from the construction pit for the concourse at Wenceslas Square; a minimised separate construction of the concourse (and possibly the exit tunnels) is anticipated at the intersection of Vodičkova and Školská Streets. Together with the technological building, ventilation-related underground structures may also be excavated from Palackého Street.

6.4 KARLOVO NÁMĚSTÍ STATION

The station is designed as a 250 m long single-aisle mined station with an 11 m wide island platform. From the eastern end of the station cavern, an escalator tunnel leads to the Karlovo náměstí concourse, which will be expanded from the existing metro B concourse. For a direct transfer to Metro Line B – Karlovo náměstí, a transfer corridor is proposed in the central part of the station. This corridor runs beneath the ventilation tunnel of Metro Line B and connects to the metro station's platform via escalators and lift. Barrier-free transfer is provided through a shaft and connecting corridor linking to the existing barrier-free access of the metro station from Václavská Street. From the western end of the station

cavern, an escalator tunnel leads to the Palackého náměstí concourse, which will likewise be expanded. For independent construction of the station, separate from the running tunnels, several access options are considered: a construction shaft from the worksite in Pod Slovany Street, or an access adit from the Vltava riverbank, or an access adit from the property of the Benedictine Monastery. To enable excavation of the station cavern, a transverse cavern is proposed in the western third of the station.

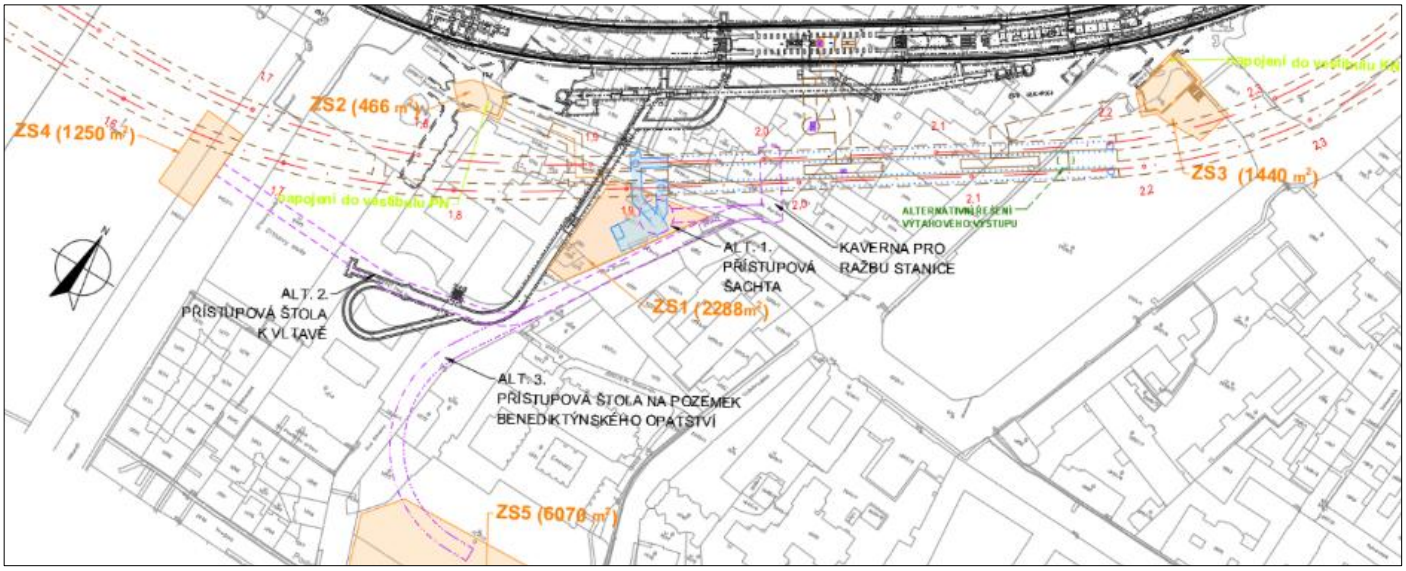

Figure 6: Layout of Karlovo náměstí station. Source: Mott Mac Donald CZ, spol. s.r.o.

6.5 TRACK SECTIONS

Single-track running tunnels will be constructed predominantly using TBM (Tunnel Boring Machine) technology. For mechanised excavation with TBMs, the key requirement is the placement of sufficiently large construction sites to launch the machines, providing space for storing segmental lining rings and removing excavated material. For this purpose, suitable areas have been identified near the tunnel portals in the Krejcárek, Pernerova, and Vršovice areas.

For the construction of the running tunnels on the west–east branch Karlín–Smíchov, the deployment of a single TBM is anticipated. The machine will be launched from the Krejcárek construction site and will drive the first running tunnel through the stations Karlín, Main Station, Václavské náměstí and Karlovo náměstí up to the Smíchov construction site. It will then be transferred to the Pernerova construction site to drive the second running tunnel.

On the north–south branch Negrelli Viaduct – Vršovice, TBM excavation is considered only between the southern throat of the Main Station and the mined junction between the Vinohrady Tunnels I and II. For both running tunnels, mechanical excavation will commence from the cavern and will be terminated in the cut-and-cover shaft at the southern throat.

The total length of TBM-driven tunnels in this variant is 10.087 km. Single-track tunnels that cannot be excavated by TBM due to the construction schedule, as well as all double-track running tunnels, junctions and crossovers, will be excavated using the NATM.

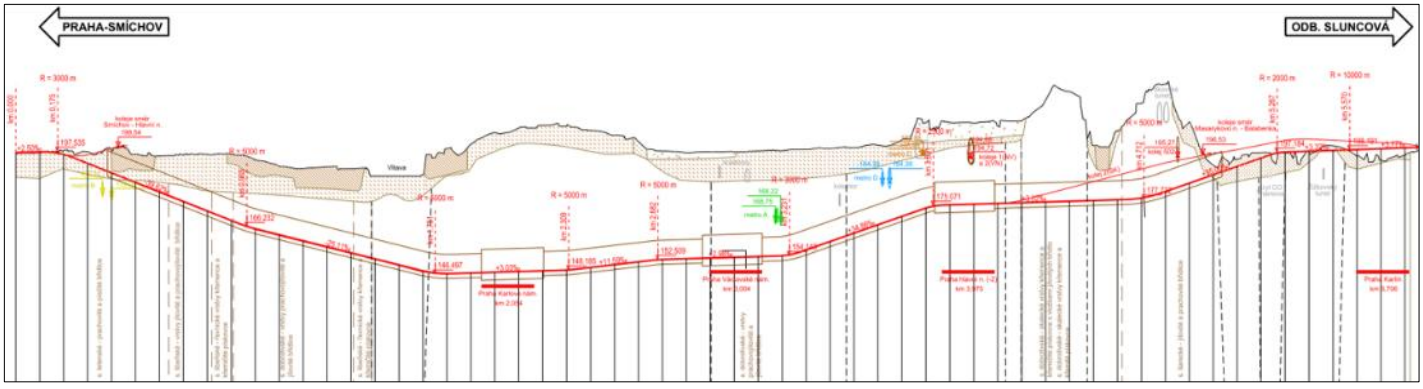

Figure 7: Longitudinal profile of the 1st track on Karlín – Smíchov branch. Source: Mott Mac Donald CZ, spol. s.r.o.

The total length of the tunnel section on the north–south branch (Negrelli Viaduct – Vršovice/Eden) is 2.5 km, while the west–east branch (Smíchov – Karlín/Krejcárek) measures 6.2 km. The total constructed length of all tunnel tracks amounts to 17.430 m.

6.6 SOLUTIONS OUTSIDE THE CITY CENTRE

In addition to the central area—which naturally attracts the most attention—the proposal also includes equally extensive enhancements outside the city centre, which are common to all variants.

The integration of the high-speed line RS 1 (Prague – Brno – Břeclav) along the route Zahradní Město – Vršovice – Prague Main Station (eastern group of tracks) – Balabenka, continuing further into the RS 4 high-speed line (Prague – Ústí nad Labem – Germany), must be understood as a single operational system and must eliminate train movements across level-crossing conflict points. To achieve high capacity at Prague Main Station, long-distance trains need to be placed in the optimal order already before entering the station, enabled by a series of grade-separated junctions in the Vršovice – Zahradní Město area, the complex arrangement of the Balabenka junction, and a grade-separated departure from the Malletova stabling yard into the heavily loaded southern Vítkov Tunnel.

A major capacity upgrade is required in the section Prague-Hostivař – Prague-Uhříněves – Říčany. This was addressed through the creation of the core of a new (conventional) line from Zahradní Město toward Benešov, including a connection to Říčany, and through the Hostivař grade-separated junction, which separates freight traffic (Malešice – Uhříněves) from passenger traffic.

The new urban tangential rail lines will significantly change the operating patterns of freight trains, which will need to run during regularly allocated time windows and will no longer be able to wait for a convenient moment to pass through conflict points. Even though the urban lines were optimised, a series of measures is essential for smooth freight operation. The most demanding among them is the so-called Malešice grade-separated junction at the northern throat of this critical station. Introducing urban lines onto freight corridors will therefore by no means be inexpensive. Using rail for urban goods delivery faces challenges such as the absence of a strategy for integrating modern city logistics with rail and the lack of market demand for such a system. The only sufficiently large development area suitable for this purpose remains the reserved land in Malešice.

In total, the scope of modifications associated with the expansion of the railway node covers approximately 72 km of lines according to track mileage and technically involves about 230 km of newly built or reconstructed individual tracks. Construction of the entire group of subsequent projects is planned for 2035–2047. In terms of environmental impacts and other protected interests, there are no significant differences between the variants, and the proposals appear to be acceptable.

7. CONCLUSION

The approval by the Central Commission of the Ministry of Transport of the Czech Republic in January 2025 established the feasibility study as a binding foundation for launching subsequent project stages. At the same time, the technical solution was incorporated during 2025 into the draft of the Prague Metropolitan Plan. At present, a coordinated effort is underway to align all known public and private development projects in the Prague Main Station area, including discussions on the parameters of the planning process. It will also be appropriate to elaborate the approved solution in greater detail within accompanying documentation or a technical study, particularly to further develop the design of underground stations and tunnels across the broad range of technical disciplines that could not be fully addressed within the feasibility study. The study assumes that until 2035, several other railway investment projects will be under construction within the Prague railway node. The implementation of the approved solution should follow directly afterwards. The construction of the entire system is expected to take 10–15 years, meaning the complete network could be fully operational around 2045–2050. The transport demand forecast considers a long-term horizon reaching 2070, approximately 20–25 years after completion of the project.

Figure 8: Visualization of single-aisle mined station with suburban regional trains. Source: Správa železnic, státní organizace.

8. ACKNOWLEDGEMENTS

This contribution was prepared in connection with the completion and unanimous approval of the feasibility study, which is the result of many years of work not only on the side of the client and the contractor, but also on the side of all participating institutions at every level. It is appropriate to express thanks to all those involved.

REFERENCES

Feasibility Study of the Prague Railway Node including Rapid Services. SP ŽUP Company without legal personality: MMD+AFRY+EKOLA+SAGASTA+SMA, 4/2025.

BABIČ, M., VANĚK, M., Feasibility Study of the Prague Railway Node including Rapid Services. Magazine Stavebnictví, 10/2024.

MAKÁSEK, P., Prague Railway Node – Central Part in Tunnels. Proceedings Railway Bridges and Tunnels, 1/2025.

MAKÁSEK, P.; BABIČ M. Prague Railway Node from the perspective of tunnel constructions, Proceedings Underground Constructions Prague 2023.

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