HOSTIVICE RAILWAY TUNNEL UNDER VÁCLAV HAVEL PRAGUE INTERNATIONAL AIRPORT: TECHNICAL CHALLENGES AND COORDINATION IN DESIGN AND PROJECT PREPARATION

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ABSTRACT: The Hostivice Railway Tunnel project is a key component of the planned rail loop connecting Prague Airport to the Prague–Václav Havel Airport–Kladno railway line. The 2,800 m long tunnel structure is partly situated beneath the airport terminals and crosses the RWY 12/30 runway, providing a link between the underground Prague–Václav Havel Airport railway station and the modernized Prague–Kladno line. At the time of writing, the project is at the stage of an approved project intent (concept design), while the adjoining section including the airport station has already reached a more advanced level of design documentation.

The tunnel design is significantly influenced by the operations of the international airport and the associated safety, technical, and organizational constraints. The structural design is atypical, primarily due to the requirement for a single track near the station and the complex track layout of the loop with a single-track branch toward Hostivice. The tunnel is therefore designed as a combination of single-, double-, and triple-track sections with a variable structural layout.

A fundamental challenge is ensuring safe construction beneath a fully operational airport, including maintaining uninterrupted aircraft movements, complying with protection zones, and limiting construction-induced seismicity, noise, vibration, and dust. The project is further complicated by the need to coordinate with the planned modernization of the airport terminals within the development projects of Prague Airport, as well as by the pressure to accelerate the preparation of the design documentation.

The paper summarizes the main technical, operational, and regulatory constraints affecting the design, compares alternative alignment and construction technology options, and assesses the associated risks. The aim is to demonstrate that, through systematic risk analysis and close coordination among all stakeholders, a safe and feasible solution can be achieved even under the exceptionally demanding conditions of an international airport.

1. GENERAL OVERVIEW, WIDER CONTEXT AND LINKS TO SURROUNDING INFRASTRUCTURE

The Hostivice railway Tunnel is one of three underground structures forming a continuous tunnel complex that provides a rail connection between the center of Prague (Masaryk Railway Station) and Václav Havel Prague International Airport. In the direction from the Prague-Veleslavín railway stop, this complex comprises the Aviatická Tunnel, the underground Praha–Václav Havel Airport railway station, and the adjoining Hostivice Tunnel. The common objective of the entire scheme is to create a high-capacity, operationally reliable, and fully through-running railway system serving the airport and the nearby areas (Železnice na letiště. 2026).

The importance of the Hostivice Tunnel lies primarily in ensuring operational capacity and traffic continuity. The tunnel enables the implementation of the rail loop concept, allowing trainsets to pass through the section from Prague-Veleslavín via the airport station further towards Jeneč, with the option of branching off towards Hostivice. Without the construction of this tunnel, the railway line in the airport area would terminate at a dead-end station, requiring train reversal and resulting in a significant reduction in line throughput and operational capacity.

From a broader perspective, a key coordination aspect is the planned expansion of the capacity of Prague Airport. The airport has been operating close to its capacity limits for a prolonged period, particularly during peak hours, which has led to plans for the extension of Terminal 2, modifications to aircraft apron areas, and the construction of a new parallel runway. These investment projects are being prepared simultaneously with the railway infrastructure and create a complex coordination interface between two independent investors: Správa železnic (the railway administration) and Prague Airport, a.s.

While Správa železnic has experience in the design and construction of underground structures, underground works represent a less common field of activity for the airport infrastructure investor. This difference in institutional experience is reflected in differing requirements for design solutions, scheduling, and operational constraints of the individual projects. The coordination challenge is further intensified by the fact that the railway tunnel complex and the above-ground airport structures are linked both spatially and functionally, and in some locations are in direct physical proximity or conflict.

Another significant risk factor is the temporal interdependence of individual investment actions. The modernization of the airport is planned with a completion horizon around 2033 (LETIŠTĚ PRAHA 2026) while, from an operational perspective, the construction of underground structures within the airport perimeter is a precondition for the beginning of subsequent above-ground works. For this reason, at least the key parts of the tunnel complex, including the advanced structures of the Hostivice Tunnel and the underground station, must be completed in advance.

At the preparation of this paper, the individual components of the tunnel complex were at various stages of project development. The Aviatická Tunnel and the Prague–Václav Havel Airport railway station had been developed to the level of documentation for project approval (spatial coordination) (Novostavba železniční stanice Praha-Letiště Václava Havla. Železnice na letiště. 2026), whereas the Hostivice Tunnel was at the stage of an approved project intent (concept design). This discrepancy in the level of design maturity further increases the pressure on coordination and on shortening the design timelines.

Given the complexity of the interdependencies and the high level of systemic risks, a new comprehensive risk analysis was initiated during project preparation, treating the railway loop as an integrated whole. The aim of this approach is to identify risks arising from the interfaces between individual structures, schedules, and investors that could otherwise remain overlooked if the sections were assessed in isolation. This methodology reflects current trends applied particularly in large-scale infrastructure projects of Správa železnic, including high-speed rail projects.

1.1 DETAILED DESCRIPTION OF THE HOSTIVICE TUNNEL

The Hostivice Tunnel forms the final section of the underground railway complex running beneath the airport. It is a 2.8 km long railway tunnel that directly follows the underground Prague–Václav Havel Airport railway station and ends at portals located beyond the D6 highway. The tunnel is designed as part of the rail loop, enabling both through-running towards Jeneč and a branch towards Hostivice.

From a structural perspective, the tunnel represents an exceptionally complex underground structure, the layout of which is strongly influenced by numerous boundary conditions imposed by both Správa železnic and Prague Airport, a.s. These requirements result in a large number of transverse cross-sections and atypical transition zones that alternate along the tunnel alignment depending on the track layout and the operational functions of the individual sections.

A key requirement set by Správa železnic was the provision of a terminal (stub-end) turnback track immediately following the airport station. This operational concept requires three parallel tracks to be accommodated within a single tunnel profile, without internal dividing structures in the turnout areas. Consequently, the structural solution in this section involves a tunnel profile with a considerable span, placing increased demands on the design of the load-bearing structures as well as on the selection and optimization of the construction method.

Another critical boundary condition is the airport operator's requirement to maintain uninterrupted aircraft taxiing between the northern and southern parts of the airport. The tunnel alignment crosses two airport traffic areas: a taxiway in the vicinity of Terminal 2 and the RWY 12/30 runway. The airport requirements demand that at least one of these facilities must remain operational throughout the entire construction period, and that no construction activities may take place within their protection zones, including excavation works, site facilities, or access roads.

These operational constraints have a fundamental impact on the design of the construction phasing. In the longitudinal direction, the tunnel is divided into several technologically and structurally distinct sections that must be executed in a precisely defined chronological and spatial sequence. The phasing concept affects not only the construction process itself, but also the design of the waterproofing system, protection of the structure against stray currents, and the detailing of transitions between the individual structural types.

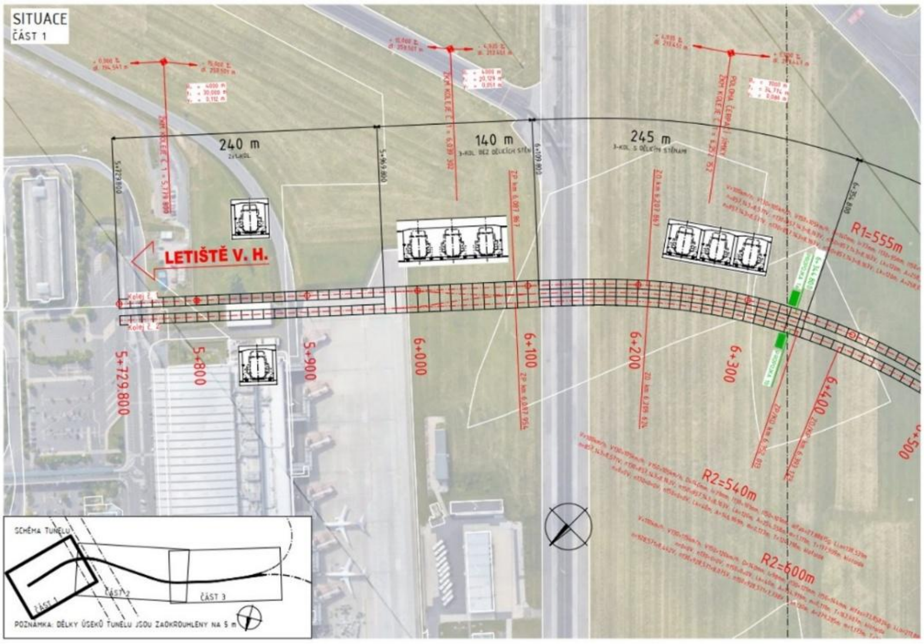

Figure 1a Situation of Hostivice Tunnel 1. part beneath the taxiway.

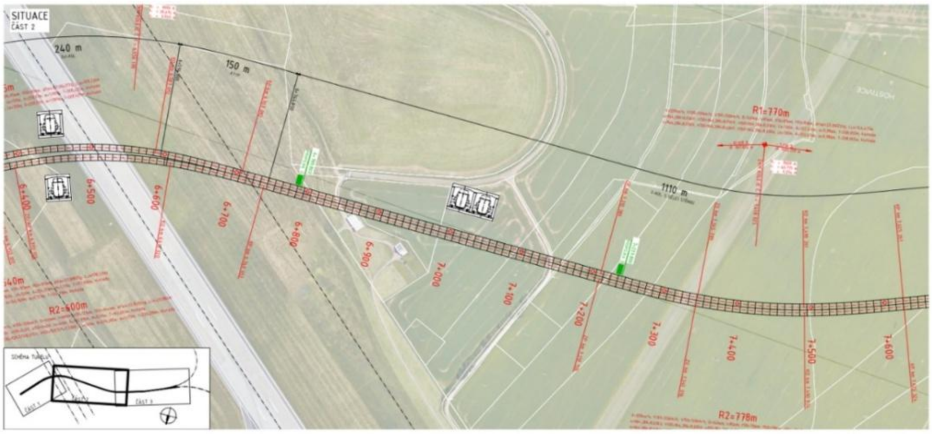

Figure 1b Situation of the Hostivice tunnel 2. part beneath the runway 12/30

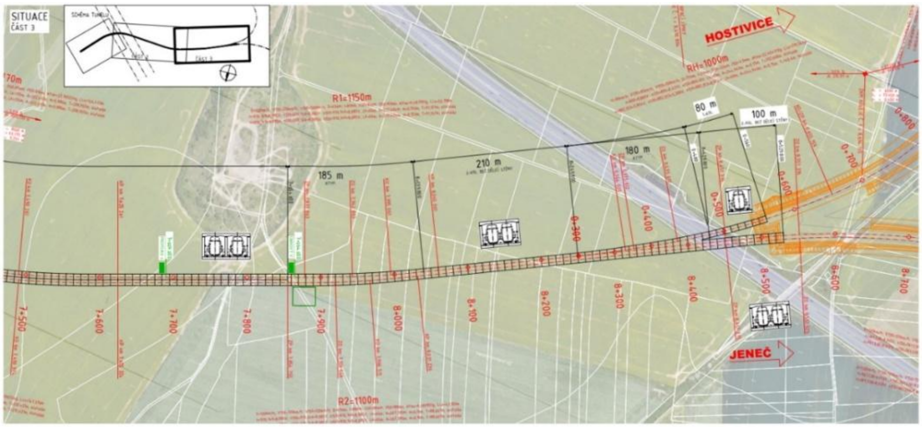

Figure 1c Situation of the Hostivice tunnel 3. part beneath the D6 highway.

In the longitudinal direction, the tunnel can be classified into five primary structural types depending on the number of tracks and the presence of dividing walls: single-track tunnel, double-track tunnel without a central dividing wall, double-track tunnel with a central wall, triple-track tunnel without dividing walls, and triple-track tunnel with dividing walls. Between these types, atypical transition zones are included to ensure a smooth change in geometry and layout. A detailed description of each section, including chainage and length, is provided in Table 1. From a risk perspective, the most sensitive areas are precisely these transition zones between structural types, where requirements for structural stability, construction methodology, waterproofing, and future operational reliability meet.

Table 1 Cross section types of the Hostivice tunnel

Chainage		Cross section type	Length
From [km]	To [km]		[m]
5,729 800	5,969 800	Two separate single-track tunnels	240,000
5,969 800	6,109 800	Triple-track tunnel without dividing walls	140,000
6,109 800	6,354 800	Triple-track tunnel with dividing walls	245,000
6,354 800	6,594 800	Two separate single-track tunnels	240,000
6,594 800	6,744 800	Atypical double-track tunnel	150,000
6,744 800	7,854 800	Double-track tunnel with a central dividing wall	1110,000
7,854 800	8,039 800	Atypical double-track tunnel	185,000
8,039 800	8,249 800	Double-track tunnel without a central dividing wall	210,000
8,249 800	8,429 800	Atypical double-track tunnel without a central dividing wall	180,000
8,429 800	8,529 800	Double-track tunnel without a central dividing wall	100,000
0,480 000	0,560 000	Single-track tunnel	80,000

1.1.1 Types and classification risks of the Hostivice tunnel

Risks associated with the design and construction of the Hostivice Tunnel cannot, as with most large-scale underground structures, be regarded as mutually isolated. Individual risk factors are interrelated and often accumulate at interfaces between structural, operational, and organizational requirements. In the case of the Hostivice Tunnel, this interdependence is further intensified by the location of the structure within the active perimeter of an international airport and by the involvement of multiple investors with differing priorities.

For the purposes of a structured analysis, project risks are divided into several fundamental categories reflecting both the project preparation phase and the subsequent stages of structural design, construction, and future operation.

The first category consists of design and conceptual risks. These include risks arising from the project brief itself, the subdivision of the project into individual sections, and the selected approach to managing the design process. The Hostivice Tunnel forms part of a broader railway loop that has, from the outset, been divided into several independently designed construction projects. While this subdivision enables phasing of design works and financing, it simultaneously increases coordination demands and introduces the risk of inconsistent design approaches in adjoining sections. A specific issue is the prevailing approach to risk analyses, which have largely been carried out on a project-by-project basis rather than at the level of the entire tunnel complex.

Design-related risks are directly followed by coordination risks. These are primarily associated with interfaces to bordering structures, differing levels of design documentation maturity among individual sections, and the presence of multiple investors. In the case of the railway loop beneath the airport, individual sections were prepared by different design teams, resulting in the absence of a clearly defined lead coordinator with oversight of the entire area. Moreover, during the early stages of preparation of the Hostivice Tunnel, no requirement was established for developing the documentation in a BIM environment, which further increased the risk of clashes and inconsistencies in subsequent design stages.

The third category consists of technical and structural risks directly related to the design of the tunnel's load-bearing structure. The Hostivice Tunnel is characterized by significant variability in cross sections and by the presence of atypical structural solutions, particularly in the area of the turn-back track, where the clear span of the profile exceeds 22 m. Structures of this scale impose high demands on structural design with respect to both ultimate and serviceability limit states. Substantial risks are also associated with the selected waterproofing concept, protection of the structure against stray current effects, and the design of transition zones between individual structural types.

Technical risks further include geotechnical and construction-related risks. These arise from uncertainties in the geological environment and from constraints imposed by the tunnel's location within the airport area. Although geotechnical risks are a fundamental part of any underground structure, in this case they are amplified by strict requirements to minimize surface deformations and to limit construction activities within the protection zones of airport roads. Construction risks are closely linked to the chosen construction method, the need for advance ground improvement measures, and the limited space available for site facilities.

The final category comprises operational and schedule-related risks. This group primarily includes airport requirements to maintain the operation of at least one transport route between the northern and southern parts of the airport, to minimize the duration of construction activities within the airport perimeter, and to comply with very strict deformation limits for the runway. A critical risk factor is also the potential conflict between the schedules of the two investors. While the airport modernization project follows a fixed timetable, the design preparation of the Hostivice Tunnel lagged other parts of the tunnel complex at the time of writing, creating significant time pressure on subsequent design stages as well as on construction itself.

1.2 KEY COORDINATION CHALLENGES

1.2.1 Links to surrounding structures.

Given the scale of the tunnel complex and its location directly within the premises of Václav Havel Prague International Airport, coordination with neighboring structures represents one of the key risks of the entire project. This coordination does not only concern individual railway structures, but primarily the parallel planning and construction of airport facilities, which are regulated by their own operational, safety, and scheduling requirements.

A major coordination issue arises from potential clashes between proposed structures and technologies. Clash management constitutes a significant risk factor, particularly in situations where the design documentation is not developed in a full BIM environment. In the case of the Hostivice Tunnel, this requirement was not specified during the early stages of project preparation due to the low level of design development at that time. The absence of a central coordination model and a clearly designated lead coordinator therefore increased the risk of both direct clashes between structural elements and indirect clashes resulting from non-compliance with prescribed clearances, operational spaces, and construction tolerances (hard and soft clashes).

Coordination challenges are not limited to load-bearing structures alone. Within the tunnel complex, it is also necessary to unify the concept of internal tunnel equipment and technological systems ensuring safe and reliable operation. These include the type of railway superstructure, drainage systems, routing of cable installations, placement of fire-fighting dry mains, tunnel lighting, escape route signage, and related safety elements. The complexity of this coordination was further intensified by the fact that individual parts of the complex were at different stages of design documentation, resulting in varying levels of detail and design maturity.

A specific coordination issue concerns the interface between the Hostivice Tunnel and the underground railway station Prague – Václav Havel Airport. While the station had, at the time of writing, been completed to the level of documentation for development consent (spatial coordination), the Hostivice Tunnel was only at the stage of an approved project intent (concept design). This mismatch led to differences in design assumptions, particularly regarding internal equipment and technologies, and increased the risk of subsequent design modifications in later documentation stages.

An important aspect of coordination is also the harmonization of the approach to the protection of load-bearing structures. The investor should treat the tunnel complex as a functional whole and define unified requirements for waterproofing, protection against stray currents, and structural service life. An inconsistent approach to these issues increases the risk of problematic interfaces between individual structures and may result in detail that are technically feasible but difficult to construct or operationally unreliable.

In the case of the Hostivice Tunnel, a solution based on the use of watertight concrete was adopted. This decision was driven both by the requirements for phased construction and by the structural concept of the cut-and-cover tunnel sections with flat roof slabs. The selected approach reduces the risk of damage to waterproofing during temporary backfilling and subsequent re-excavation of the structure, while also simplifying the design of interfaces between individual construction stages. From a coordination perspective, however, this solution places increased demands on the quality of design, execution, and inspection of structural details.

1.2.2 Underpass beneath the Taxiway and Runway 12/30

The railway underpass beneath the taxiway and Runway 12/30 represent the most critical section of the Hostivice Tunnel in terms of both design and construction. This is the section where technical, operational, and organizational risks accumulate, while at the same time exceptionally stringent requirements imposed by the airport operator must be met. These requirements significantly constrain the choice of construction technology as well as the method of execution.

The primary limiting factor is the necessity to maintain full operability of the airport infrastructure. Requirements for zero technical seismicity, minimal dust generation, and extremely low permitted surface deformations of the runway far exceed standard limits typically applied to linear underground structures. Although adverse effects can be mitigated through appropriate selection of construction methods, organizational measures, and monitoring, they cannot be eliminated. Even construction-related traffic alone constitutes a source of vibrations and loading that is difficult to reconcile with the declared limits under conventional construction practice.

Another major constraint is the existence of protection zones associated with airport roads and operational areas, within which construction activities during airport operation are entirely prohibited. This significantly complicates not only the execution of construction works but also their phasing and scheduling in coordination with other airport projects. The risk of schedule conflicts in this section is higher than in other parts of the tunnel and has a direct impact on the overall construction duration. (Letecký předpis Letiště L14. 2025).

From a geotechnical perspective, this section is characterized by a shallow overburden and a variable ground profile. The geological conditions comprise a combination of soils and fill overlying more competent rock formations (R4–R3 classes) at tunnel invert level. Under these conditions, deformation control becomes a key design criterion, fundamentally influencing the selection of construction technology, structural dimensioning, and the extent of advance ground improvement measures.

Further significant risk arises from the need to coordinate construction procedures with the airport's safety regulations. Any unplanned deviations during construction may lead to operational restrictions or even suspension of airport operations, with not only technical but also economic and reputational consequences. For this reason, the selection of construction technology and the development of the construction schedule must be based on a realistic assessment of risks and must not rely on marginal assumptions regarding compliance with operational limits.

The underpass beneath Runway 12/30 therefore cannot be regarded as an isolated structure, but rather as part of a complex system in which the technical solution of the underground structure must be subordinated to the priorities of airport operations. This fact fundamentally affects the assessment of individual construction variants and is one of the main reasons why none of them was evaluated as clearly risk-free.

1.2.3 Construction Duration

The construction duration of the tunnel within the perimeter of Václav Havel Prague International Airport represented one of the key evaluation criteria in the assessment of individual construction technology variants. The time aspect was critical not only with respect to minimizing restrictions on airport operations, but also as an essential input for the investor's decision-making regarding the selection of the structural and technological solution under conditions of parallel modernization of the airport infrastructure.

For the cut-and-cover variant, the construction duration was determined based on a detailed analysis of construction procedures, which significantly exceeded the scope typically applied at the project intent stage. A basic bill of quantities was prepared, covering individual phases of construction of the excavation pit, slope stabilization, execution of the tunnel's load-bearing structure, and subsequent backfilling. A simplified three-dimensional model was developed to quantify earthworks and structural volumes and served as a basis for time estimates.

Based on the calculated quantities and following consultations with specialists from construction companies, realistic productivity rates for individual activities were established. These values were subsequently verified with multiple entities in order to reduce estimation uncertainty. The result was a simplified construction schedule enabling a qualified assessment of the time requirements for construction in the critical section beneath the airport. To further reduce the overall construction duration, parallel execution of selected structural stages was considered, in particular the simultaneous start of concreting works at two working fronts.

Based on this analysis, the total construction duration of the cut-and-cover variant within the airport perimeter was estimated at approximately 2 years and 4 months. This period also included technological breaks resulting from concrete curing requirements and limitations on concreting during the winter season.

For the other assessed variants, construction duration was determined by expert judgment based on the volumetric parameters of the individual structures and on typical productivity rates of the respective technologies. The primary emphasis was placed on comparing time requirements in the most sensitive section beneath Runway 12/30, rather than on developing a detailed schedule for the entire project. This approach corresponded to the level of project preparation and to the nature of decision-making at that stage of the project.

In the final evaluation of the variants, construction duration was not assessed in isolation, but in combination with other criteria, particularly the level of technical risk, economic demands, and experience with the application of the respective technologies under comparable conditions. The time aspect thus represented an important, but not decisive, parameter in the selection of the recommended solution.

2. ALTERNATIVE CONSTRUCTION SOLUTIONS UNDER RWY 12/30 AND THEIR RISKS

The selection of the construction method for the Hostivice Tunnel within the Václav Havel Prague International Airport area is significantly constrained by the airport's operational and safety requirements. Key limitations include the necessity to minimize technical vibrations, control dust emissions, comply with strict deformation limits of runway 12/30, and avoid construction activities within the protective zones of operational roads. These conditions constitute a common risk framework for all design alternatives and affect not only constructability but also the safety and stability of airport operations during construction.

Another critical factor is the monitoring of surface deformations, which directly influences the structural design, the choice of construction technology, the extent of pre-emptive measures, and the ongoing monitoring during the construction process. Any exceedance of the permissible limits could lead to operational restrictions or temporary closures, which is unacceptable in the context of airport operations.

2.1 CUT-AND-COVER TUNNEL WITH ADVANCE WORKS

The cut-and-cover construction method represents a conventional and well-established solution for underground structures with shallow overburden, typically ranging from approximately 1.0 to 10.0 m. Within the Hostivice Tunnel project, this method was evaluated as the reference alternative for the underpass beneath the taxiway and runway 12/30. Structurally, it consists of a monolithic reinforced concrete frame constructed in an open excavation, with slope stabilization or temporary shoring as required, followed by backfilling.

From a risky perspective, the cut-and-cover alternative is most critically constrained by the operational requirements of the airport. Constructing an open excavation within the protective zones of airport roadways directly conflicts with the requirement to maintain continuous access along at least one route connecting the northern and southern parts of the airport. Consequently, construction must be staged, with individual sections of the tunnel structure executed in different time intervals. Even with staged construction and the use of advanced works, a significant risk remains of interference with the airport's operational schedule and with other simultaneous construction activities within its perimeter.

Another major risk of the cut-and-cover method is compliance with the exceptionally strict surface deformation limits of the runway. The maximum allowable vertical deviation of 3.0 mm over a 3.0 m length imposes extreme demands on the design of excavation support, the structural capacity of the tunnel frame, the selection of backfill materials, and the methods of placement and compaction. Any underestimation of these factors could lead to unacceptable surface deformations and, in extreme cases, to operational restrictions or temporary closure of the airport. One mitigation measure is the selection of appropriate backfill materials, or the localized use of concrete as backfill immediately adjacent to the structure, which would reliably meet settlement requirements.

A further specific risk relates to the staging of construction. The assumption of constructing part of the structure in advance, temporarily backfilling it, and subsequently re-excavating imposes additional demands on the design of the waterproofing system and on the protection of the structure against mechanical damage and degradation during temporary operational loading. These aspects increase both the technical and organizational complexity of execution. For this reason, a watertight concrete structure, sealed with internal waterstop strips, was selected as the preferred waterproofing solution.

Overall, the cut-and-cover alternative can be assessed as technically feasible and structurally well manageable. However, it carries a high level of risk regarding construction coordination, time requirements, and operational constraints at the airport. Its implementation therefore requires close cooperation with the airport operator and strict adherence to the construction schedule and monitoring throughout the project duration.

2.2 TUNNEL EXCAVATION USING NATM

The bored tunnel alternative, based on the principles of the New Austrian Tunneling Method (NATM), was evaluated within the Hostivice Tunnel project as an alternative solution that allows minimizing surface interventions at the airport and potentially shortening the construction period within its perimeter. The method is based on an observational approach, which utilizes the interaction between the rock mass and the primary lining, with design and construction procedures continuously optimized based on geotechnical monitoring results.

A critical risk factor for this alternative is the very shallow overburden, which, in the most favorable sections, is equal to the tunnel profile height. Under these conditions, the ability to control surface deformations is severely limited, and in extreme cases, local instability of the excavation cannot be excluded. Moreover, the geological environment is highly heterogeneous: higher-quality rock masses (R4 to R3) are found at the foundation level, whereas sandy soils and anthropogenic backfills occur near the tunnel top heading, which are significantly less favorable in terms of stability and deformation.

The primary risk of the NATM alternative lies in the ability to reliably maintain the exceptionally strict surface deformation limits, particularly beneath runway 12/30. Despite the potential application of extensive advance measures, such as micropile umbrellas, pre-excavation grouting, or local rock mass stabilization, achieving the required deformation limits remains subject to substantial uncertainty. Extreme stabilization measures, such as creating a massive jet grouting block or implementing compensation grouting, are technically feasible but time-consuming and costly, with significant potential impacts on the project schedule and budget.

The method's risk is further compounded by the wide tunnel span in the area of the turning track combined with limited overburden. Under these conditions, the cut-and-cover solution or a three-vaulted bored tunnel appears technically more robust. In subsequent project stages, it would therefore be necessary to optimize the geometric track alignment (GTA) to meet both the horizontal and vertical requirements of the chosen technology while minimizing geotechnical risks.

A further critical aspect is the high execution complexity of tunneling beneath an active airport. This requires continuous geotechnical monitoring, immediate interpretation of measured data, and the capacity for rapid response to any deviations from the design assumptions. In this context, even a minor anomaly may lead to operational restrictions or temporary closure of the airport, with direct implications for construction economics and, in extreme cases, passenger safety.

Additional specific risks are associated with the transition zones between bored and cut-and-cover tunnel sections. These areas represent structural and technologically sensitive locations where demand on structural performance, waterproofing, and operational safety are concentrated. The NATM alternative therefore offers potential advantages in terms of minimizing surface interventions but comes at the cost of increased technical, temporal, and operational uncertainty under geologically and operationally challenging conditions.

2.3 TUNNEL EXCAVATION USING A TBM

Excavation using a Tunnel Boring Machine (TBM) represents the most technologically advanced alternative considered for the Hostivice Tunnel underpass beneath runway 12/30. Its primary advantage is the continuous and highly controlled excavation process with minimal disturbance to the overlying strata, which theoretically allows airport roadways to remain operational throughout construction and significantly limits direct interventions in surface structures.

From a risk perspective, however, the application of TBM technology in this section is subject to significant conceptual constraints. Deployment of a TBM requires adherence to minimum horizontal and vertical alignment requirements, which the current geometry of the Hostivice Tunnel does not satisfy. TBMs are suitable for long, relatively homogeneous sections with sufficient overburden, where stable geological conditions can be ensured without significant variations. In the assessed section, the environment exhibits pronounced vertical heterogeneity, with stronger rock layers at the tunnel invert compared to the crown. This condition creates the risk of frequent machine realignment and reduced control over vertical alignment during excavation.

While the use of a slurry-shield TBM could help limit surface deformations, in combination with the very shallow overburden, it introduces the risk of overburden breakthrough or slurry escape toward the surface. Such a scenario is unacceptable in an active airport environment due to safety and operational concerns and would require extensive preventive and monitoring measures.

Another critical risk is the need to alter the tunnel structural concept. TBM technology is typically associated with a circular tunnel profile and prefabricated segmental lining, which directly conflicts with the frame structure of the cut-and-cover sections of the Hostivice Tunnel and its protective measures. Transitions between these structural systems represent highly atypical and high-risk locations, requiring complex advanced stabilization measures and bespoke technical solutions. In addition, the circular profile does not efficiently accommodate the spatial arrangement of the central turning track, which would require a distinct excavation technology.

Economic and organizational risks are also significant. Given the short length of the section under consideration (approximately 700 m), TBM deployment entails high mobilization and demobilization costs that cannot be effectively amortized over the excavation length. These costs affect the economic feasibility of this alternative and increase the project's sensitivity to delays or technical complications. Thus, while the TBM option offers minimal impact on airport operations, it comes at the cost of fundamental changes to the design concept, increased coordination requirements, and substantial financial risks.

2.4 MILAN TUNNELING METHOD

In addition to purely technological alternatives, combined solutions were analyzed within the Hostivice Tunnel project, integrating cut-and-cover construction with mined sections executed using the temporary roof excavation method. The objective of this approach was to identify a compromise between construction duration, airport operational constraints, and the level of technical and coordination risks.

The principle of this variant involves a temporary closure of runway 12/30, construction of a load-bearing roof structure beneath it, subsequent reopening of the runway, and then excavation of the tunnel under the protective roof. This procedure allows significant reduction of surface interventions in later stages, thereby decreasing the risk of operational disruptions.

The main risk of this approach remains runway deformation, both during the construction of the roof structure and during the subsequent tunneling beneath it. Roof construction requires the installation of vertical load-bearing elements, typically in the form of diaphragm walls or secant pile walls, which must safely transfer loads from the airport pavements. These techniques necessitate the use of heavy machinery, such as drilling rigs, grabs, or hydro-cutters, whose operation near active airport roadways poses significant safety and logistical challenges.

Another substantial risk is the time demand for constructing the load-bearing elements and roof. Given the strict operational limitations of the airport and the need for staged work, these technologies cannot be executed at high productivity. Resulting estimates indicate that the overall construction duration within the airport perimeter for this variant would be longer than that of the purely cut-and-cover solution, partially negating one of the primary anticipated benefits of the combined method.

Excavation under a temporary roof therefore represents a technically feasible but organizationally and temporally demanding solution. While it offers some reduction of risk during the excavation phase itself, it comes at the cost of increased coordination requirements, heavy mechanization, and extended construction time in the most sensitive part of the project.

3. CONCLUSION

The analysis of construction alternatives for the Hostivice Tunnel underpass beneath runway 12/30 has demonstrated that none of the evaluated technologies represents an unequivocally optimal solution without significant technical, operational, or coordination risks. The cut-and-cover option is structurally feasible and based on well-established construction methods, yet it is heavily constrained by airport operational requirements and the exceptionally strict limits on surface deformation. Bored alternatives, whether based on the New Austrian Tunneling Method (NATM) or employing a Tunnel Boring Machine (TBM), potentially reduce surface interventions but introduce increased technical uncertainty, high demands for monitoring and risk management, and, in some cases, substantial economic and conceptual constraints.

Therefore, the decisive criterion for selecting the final construction method is not merely the technical feasibility of individual alternatives, but primarily the ability to identify, manage, minimize, and coordinate the associated risks within the broader context of concurrent airport infrastructure modernization and related construction activities. The results of this analysis confirm the necessity of a comprehensive and integrated design approach, a strong coordinating role for the client, and the early incorporation of risk management measures during the project planning stages. These factors will be critical for achieving a technically safe, operationally acceptable, and constructible solution for the Hostivice Tunnel underpass beneath RWY 12/30.

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