REPORT
of the joint World Heritage Centre/ICOMOS
Advisory mission
to the World Heritage property ‘Historic Centre of Prague’ (Czechia)
11-12 December 2024

unesco
World Heritage Convention

ICOMOS
international council on monuments and sites

Contents

ACKNOWLEDGEMENTS 4
EXECUTIVE SUMMARY 5
I. INTRODUCTION 9
The World Heritage Property 9
The issue 10
Background to the 2024 advisory mission 11
Terms of reference of the mission 12
II. THE VYŠEHRAD BRIDGE: HISTORY, SIGNIFICANCE AND CONTRIBUTION TO OUTSTANDING UNIVERSAL VALUE 13
Origin and evolution 13
Significance of the Vyšehrad bridge as an historic monument 14
Contribution of the Vyšehrad bridge to Outstanding Universal Value 15
Conclusions 17
III. THE STRUCTURE OF THE BRIDGE 18
Introduction 18
Current state of the bridge structure 20
Verification calculations and different projects 21
Separation of the tracks 23
The Výtoň viaduct and Rašínovo Embankment 23
Environmental considerations 25
Construction and cost issues 26
Conclusions and recommendation 26
IV. TRANSPORT CAPACITY AND THE THIRD TRACK 29
The capacity of the Vyšehrad rail crossing 29
Providing a third track 29
Conclusions and recommendation 30
V. THE VÝTOŇ APPROACH STRUCTURES, URBANISTIC PROPOSALS, PEDESTRIAN AND CYCLE CROSSINGS 31
Introduction 31
Urban revival and the new station 31
Pedestrian and cycle crossing 32
Conclusions and recommendations 32
VI. ANNEXES 34
Annex I: Terms of Reference of the mission 34
Annex II: Statement of Outstanding Universal Value 36
Annex III: Programme of the mission 39
Annex IV: List of participants 41

Annex V: Glossary of technical terms 43
Annex VI: Figures 45

ACKNOWLEDGEMENTS

The mission team would like to express its gratitude to the Ministry of Culture of the Czech Republic, the Prague City authorities and the Czech Railway Administration for their kind hospitality and for the excellent arrangements put in place to ensure the smooth running of the mission. The programme of the mission, combining presentations from various stakeholders on the main topic – the Vyšehrad Railway Bridge across the Vltava River – with on-site visits, allowed the mission team to appreciate the setting in which the historic bridge is located within the World Heritage property ‘Historic Centre of Prague’, and to assess its state of conservation and the need for its upgrading.

The mission team would like to convey its special thanks to Ms Dita Limová, Head of UNESCO Affairs Unit, International Relations and EU Department at the Ministry of Culture, for the overall coordination of the mission. The mission team was able to engage with the representatives of the Ministry of Culture and the National Heritage Institute, the Ministry of Transport (including the Minister), Prague City authorities (including Deputy Mayor for Urban Development), numerous representatives of the Railway Administration (including its Director General) and other specialists, particularly engineers and architects.

Meetings with these representatives and other stakeholders, including NGO representatives, helped the mission team to obtain comprehensive information on the issues to be assessed. Our thanks go to all stakeholders for their inputs and efforts to make the mission as informative and fruitful as possible.

EXECUTIVE SUMMARY

The March 2023 ICOMOS Technical Review of the proposal by the Czech Railway Administration to replace the historic Vyšehrad Railway Bridge within the boundaries of the World Heritage property 'Historic Centre of Prague' with a modern one, concluded that there should be a presumption in favour of the conservation of the bridge due to its contribution to the overall river panorama of Prague, its role in supporting the Outstanding Universal Value (OUV) of the property and its status as a cultural monument of national importance. In its Decision 45 COM 7B.183 (Riyadh, 2023), the World Heritage Committee requested the State Party to revise and amend the proposal for the bridge in accordance with the above-mentioned Technical Review. Information received by the World Heritage Centre from various stakeholders regarding the proposal to replace the historic bridge with a new structure, both prior and following the above-mentioned Decision, indicated the need for a broad consultative approach and a careful consideration of different options.

Consequently, the Terms of Reference of the joint World Heritage Centre/ICOMOS Advisory mission (Annex I), which took place on 11 and 12 December 2024, focused on receiving and reviewing information on the overall transport requirements in Prague that support the need to upgrade the Vyšehrad Railway Bridge across the Vltava River, any other spatial options that have been considered, the justifications for the preservation of the bridge in its current location, and engineering opinions on whether the existing bridge can be strengthened to accommodate new generation trains or whether it should be retained for pedestrian use only. On the basis of the above, the mandate of the Mission was to assess the options and conditions for the conservation of the Bridge, taking into account the extent of its contribution to the OUV of the World Heritage property, and to consider alternatives for its replacement, with a view to making recommendations to the State Party on the optimal solution in terms of preserving the attributes that underpin the OUV of the property.

The main conclusions and recommendations of the mission are as follows:

History and significance of the Vyšehrad bridge and its contribution to Outstanding Universal Value

1. The steel Vyšehrad bridge, built in 1901 to cross the Vltava river in three spans using semi-parabolic steel truss girders, makes a notable contribution to the OUV of the World Heritage property 'Historic Centre of Prague'. The riverine landscape is one of the main visual axes of the historic centre, and the sequence of bridges over it is a key element in shaping the image of the city and a key attribute of the OUV of the property. The Vyšehrad Bridge and its adjacent areas are visible from far and near, both outwards from the property and inwards from Vyšehrad towards its centre. It is part of the 'ensemble of outstanding quality' of the city, as reflected in the Statement of OUV.

2. The Vyšehrad Bridge is also of significant public interest, which is reflected in its listing as a cultural monument. This derives from its rarity as a surviving large, authentic example of a once common type, which by its form and technology illustrates a notable and influential phase in the continuous urban development of Prague.

3. The steel truss bridge therefore warrants a strong presumption in favour of its repair and retention in use in its current location. The Výtoň approach structures to the eastern end of the river bridge make a much more modest contribution to OUV.

The Vyšehrad river bridge

4. On the basis of technical and scientific data, the Vyšehrad Bridge can be renovated so that it can operate for 100 years without any fatigue problems.
5. Irrespective of any economic or operational considerations, both in the short term (renovation or new construction) and in the long term (maintenance), renovating the existing bridge can be seen as the optimal choice for the following reasons:
   - It best complies with sustaining the OUV of the World Heritage property. The most significant section of the listed bridge, Section 5 crossing the Vltava, would be repaired with minimal alterations compared to its total replacement under the 2T Engineering project.
   - It is technically feasible, probably with minimal steel replacement, and the renovation of the bridge will enable it to achieve a lifespan of 100 years (subject to regular inspection and maintenance).
   - It appears to be the most sustainable solution in terms of CO2e emissions.
   - By optimising the bridge deck on the eastern approach over the Rašínovo embankment, the clearance for trams could be significantly improved, to the same height as the next construction over its route to the south, the listed Vyšehrad tunnel.
6. However, due to the inherent weaknesses of the material (brittle nature), the structure of the bridge (very little redundancy) and the water-holding design of some connections, it is strongly recommended that:
   - devices, such as guard rails, be provided to contain the effects of accidental loading through a train derailment; and that, in renovation, opportunities be taken to limit the potential to trap water;
   - periodic plan be followed for detailed visual inspection of the bridge and renovation of its anti-corrosion protection;
   - and, in general, it be maintained to the high standard appropriate to cultural monuments in the Historic Centre of Prague.
7. The option of relocating the bridge to carry cycle and pedestrian traffic 6.4 km to the south was suggested, but the river there is neither wide nor majestic. While this option would result in the bridge's survival as an artefact, its contribution to the panorama of Prague and the OUV of the property would be erased by its removal from the city and the cessation of its intended purpose.

Recommendation

R1 ***The steel bridge over the river Vltava should be retained and repaired in accordance with a conservation philosophy informed by the technical and scientific data provided to the mission, incorporating safety devices to contain accidental damage, and ensuring its sustained contribution to OUV, while also implementing a programme of regular inspection and planned maintenance suitable for both a functioning engineering structure and cultural monument.***

Transport capacity and the third track

8. The development of a sustainable suburban railway system, both in terms of extent and capacity, rather than seeking to accommodate increasing car commuting, is a laudable objective that benefits the environment and the sustainability of the historic centre. In that context, the capacity of the Vyšehrad Bridge must as a minimum be rapidly restored to at least to its normal operating capacity.

9. The strategic case for adding a third track to the crossing and a station on the Vyšehrad side is clear. There is general agreement that any major intervention must maintain and improve the pedestrian and cycle capacity associated with the bridge; in particular, the mission recognises the requirement set out by the Institute of Planning and Development (IPR) for a comfortable and barrier-free connection for cyclists and the linking of the main cycling routes.

10. There would inevitably be some negative impact on the setting of the historic bridge, but a flat deck bridge with clean horizontal lines, positioned to the south, would minimise this impact while meeting the transport needs of the city. Should systems or requirements change in the future, it could of course be removed; its impact on the setting of the historic bridge is reversible.

Recommendation

R2 ***Given the operational case for a third track, it should be carried on a new flat deck bridge sited to the south of the historic bridge, with its horizontal beams not rising above the balustrade level of the footway attached to the existing bridge, with a console on the south side to improve capacity for pedestrian and cycle traffic.***

The Výtoň approach structures, urbanistic proposals, pedestrian and cycle crossings

11. In the context of a repaired bridge, an interchange station at Vyšehrad or Výtoň should revitalise and animate the immediate area. The Výtoň approach structures, which make a modest contribution to the OUV, have the capacity to contribute to this through sensitive change and adaptation, respecting the historic masonry of the piers and spans.

12. According to the information available to the mission, the reuse of the existing Vyšehrad station building would have a greater direct heritage benefit, but may be sub-optimal as an interchange point. And if, as the mission was informed, a viable, fundable scheme for the repair and reuse of the old station is finally imminent, it should not be undermined by creating uncertainty for the investors by insisting on linking it to the railway works. While the Vyšehrad option proposed by the Endowment Fund NGO would greatly benefit from the reuse of the historic station entrance, it is not dependent on it. To function as an effective interchange station, the default western entrance to the station, only about 200 m from the embankment, would be desirable, whether or not access through the historic station building is also possible.

13. The Výtoň proposal, using the viaduct, may be optimal in terms of location and, with the railway at its existing level, straightforward to deliver. But it would still have disadvantages, particularly in occupying or blighting more space at ground level than the viaduct, and the intrusion of the station and its inevitable platform shelters into views from and across the river.

14. A detailed study of the advantages and disadvantages of each option, particularly for users of the interchange/station, should inform a final decision, along with design studies that start from a decision to repair the bridge. There is a strong case for the immediate area of the station supporting commercial uses, for Vyšehrad as proposed in Vnislavova Street and for Výtoň within the viaduct arches. However, if Vyšehrad is chosen, it would be prudent to assess the viability of the rehabilitation and beneficial use of the Výtoň arches.

15. Both options would involve significant modification of the listed bridge sections (1) to (4) before the bridge (5) across the Vltava River, not least the replacement of the deck of section 4. These sections are, in terms of their contribution to OUV, subsidiary to the river bridge. The arches need to be utilised, the area needs to be revitalised, and the public transport benefits are clear. While great care will be needed in developing the design, with the tracks retained at their existing level on the masonry viaducts, either of these options could probably be assimilated into the townscape without material harm to OUV.

16. The interconnected issues of the design of a bridge carrying a third track, the improvement and updating of pedestrian and cycle links across both bridges, and the siting and design of a new station in the context of the revitalisation of the Výtoň area, will all require clear terms of reference for their design that set out constraints relating to OUV. The process of Heritage Impact Assessment can be used to inform and guide the evolution of project elements, utilising the wide-ranging scoping study presented to the mission.

Recommendations

R3 ***The location and design of a new station on the east bank, between Vyšehrad and Výtoň, should be the subject of further study to determine which location, in the context of tracks retained at their current level, optimises the balance between operational and townscape/ heritage considerations.***

R4 ***Building on the work already undertaken in the scoping study, detailed Terms of Reference are required that include clear constraints relating to OUV, for the revised proposals for a third track bridge, pedestrian and cycle movement and urban revitalisation in the context of conservation of the historic bridge across the Vltava. The Heritage Impact Assessment of preferred proposals should be carried out in accordance with the methodology of the*** **Guidance and Toolkit for Impact Assessments in a World Heritage context*****, together with detailed project information. This should be shared with the World Heritage Centre for review by ICOMOS at the earliest possible opportunity, prior to making any decisions.***

I. INTRODUCTION

The World Heritage property

The Historic Centre of Prague was inscribed on the World Heritage List in 1992. The inscribed site is a serial property comprising the Historic Centre of Prague situated on the territory of the self-governing administrative unit of the City of Prague, and of the Průhonice Park, located southeast of the city on the territory of the Central Bohemia.

Prague is one of the most beautiful cities in Europe in terms of its setting on both banks of the Vltava River, its townscape of burgher houses and palaces punctuated by towers, and its individual buildings. The historic centre represents a supreme manifestation of Medieval urbanism (the New Town of Emperor Charles IV built as the New Jerusalem). It has been saved from any large-scale urban renewal or massive demolitions and thus preserves its overall configuration, pattern and spatial composition. The Prague architectural works of the Gothic Period (14th and 15th centuries), of the High Baroque of the 1st half of the 18th century and of the rising modernism after the year 1900, influenced the development of Central European, perhaps even all European, architecture. The historic centre also represents one of the most prominent world centres of creative life in the field of urbanism and architecture across generations, human mentality and beliefs.

In the course of the 1100 years of its existence, Prague’s development can be documented in the architectural expression of many historical periods and their styles. The city is rich in outstanding monuments from all periods of its history. Of particular importance are Prague Castle, the Cathedral of St Vitus, Hradčany Square in front of the Castle, the Valdštejn Palace on the left bank of the river, the Gothic Charles Bridge, the Romanesque Rotunda of the Holy Rood, the Gothic arcaded houses with Romanesque cores around the Old Town Square, the Church of Our Lady in front of Týn, the High Gothic Minorite Church of St James in the Old Town (Staré Město), the Early Gothic so-called Old-New Synagogue in the Jewish Quarter (Josefov), the late 19th century buildings and the medieval town plan of the New Town (Nové Město).

As early as the Middle Ages, Prague became one of the leading cultural centres of Christian Europe. The Prague University, founded in 1348, is one of the earliest in Europe. The milieu of the University in the last quarter of the 14th century and the first years of the 15th century contributed among other things to the formation of ideas of the Hussite Movement which represented in fact the first steps of the European Reformation. As a metropolis of culture, Prague is connected with prominent names in art, science and politics, such as Charles IV, Petr Parléř, Jan Hus, Johannes Kepler, Wolfgang Amadeus Mozart, Franz Kafka, Antonín Dvořák, Albert Einstein, Edvard Beneš (co-founder of the League of Nations) and Václav Havel.

The Průhonice Park (the area of 211.42 ha) was founded in the year 1885 by the Count Arnošt Emanuel Silva-Tarouca. The result of his lifelong work is an original masterpiece of garden landscape architecture of worldwide importance. The park uses advantage of the miscellaneous valley of the Botič Stream and the unique combination of native and introduced exotic tree species. The Průhonice Park became in the time of its foundation the entrance gate to Bohemia (as well as to the whole Europe) for newly introduced plants. An integral part of the park is also a Neo-Renaissance country house. In the area there is also a small medieval church of the Nativity of the Virgin Mary.

Criterion (ii): The Historic Centre of Prague admirably illustrates the process of continuous urban growth from the Middle Ages to the present day. Its important role in the political, economic, social, and cultural evolution of Central Europe from the 14th century onwards and the richness of its architectural and artistic traditions meant that it served as a major model for urban development of much of Central and Eastern Europe.

Criterion (iv): Prague is an urban architectural ensemble of outstanding quality, in terms of both its individual monuments and its townscape, and one that is deservedly world-famous.

Criterion (vi): The role of Prague in the medieval development of Christianity in Central Europe was an outstanding one, as was its formative influence in the evolution of towns. By virtue of its political significance in the later Middle Ages and later, it attracted architects and artists from all over Europe, who contributed to its wealth of architectural and artistic treasures. The 14th century founding of the Charles University made it a renowned seat of learning, a reputation that it has preserved up to the present day. Since the reign of Charles IV, Prague has been intellectual and cultural centre of its region, and is indelibly associated with such world-famous names as Wolfgang Amadeus Mozart and Franz Kafka.

The World Heritage Committee at its 40th session (Istanbul, 2016) adopted the Retrospective Statement of Outstanding Universal Value for the property (Annex II).

The issue

This report is concerned with the future of the three-span steel truss bridge, built in 1900-01, carrying the twin railway tracks of the Prague Connection Line across the Vltava River, from Smichov to the foot of Vyšehrad Hill, within the southern boundary of the Historic Centre of Prague. The bridge was listed as a Cultural Monument in 2004 (no. 101315) and is widely acknowledged to make a positive contribution to the OUV of the property.

Operationally, Vyšehrad bridge, often referred to simply as 'Railway Bridge', forms part of the core trans-European network, as well as being important to national and regional transport. It also provides a pedestrian and cycle crossing, via walkways attached to each side.

The condition of the bridge has deteriorated to the point where the frequency and speed of trains crossing it are significantly constrained. Moreover, the *Prague Metropolitan Railway Development Strategy* identified the short to medium term need for a third track to increase capacity. For these reasons the State Railway Administration (Správa železnic) advocates replacement of the bridge with a new three-track steel structure carried on the (modified) existing piers, while the National Heritage Institute and civil society organisations argue for the retention and authentic repair of the historic bridge, potentially with a new single-track bridge alongside.

Background to the 2024 advisory mission

The 2019 Reactive Monitoring mission report[1] expressed concern (first raised in the 2010 mission report) about the poor condition of the long redundant Vyšehrad Station building on the Prague Connection Line. It also noted, in relation to 'Railway Bridge' carrying the line across the Vltava, that '*thanks to the lightness and elegance of its design, there appears to be general agreement that it makes a positive contribution to the urban architectural ensemble of Prague, despite not having been painted for many years'.* The mission concluded that *'the State Party should submit details of the options for the future of Railway Bridge to the World Heritage Centre for review by the Advisory Bodies*.'[2]

The State Party submitted further information to the World Heritage Centre in December 2022, including details of the Railway Administration's long preferred approach, to replace the bridge with a new steel structure on the existing piers, to a design selected following a 'Competitive Dialogue' with invited participants in 2021. By this point the Railway Administration (*Správa železnic)* had made two unsuccessful applications for the de-listing of the bridge as a cultural monument, in 2010 and 2018.

The successful proposal which emerged from the competitive dialogue was subject to a Technical Review by ICOMOS, dated March 2023, which concluded that: '*From the documentation provided, ICOMOS considers that there should be a presumption in favour of the conservation of the bridge for its contribution to the river panorama of Prague and the Outstanding Universal Value of the property. That contribution derives primarily from its iron superstructure. Its status as a cultural monument underlines its national importance'*.

The National Heritage Institute maintained its objection to demolition of the historic bridge. A civil society organisation, 'Vyšehrad Bridge Salvation Endowment Fund' was established to challenge the need for replacement. It raised funds to commission an expert team to examine if, and how, the historic bridge was reasonably capable of repair, and to prepare an urban design scheme for its Výtoň (eastern) approach.

Decision 45 COM 7B.183 of the World Heritage Committee (September 2023) requested the State Party to *'revise and amend the proposals for the Vyšehrad Railway Bridge … in accordance with the technical review provided by ICOMOS, and to continue to inform the World Heritage Centre of the specific proposals for these projects … in accordance with Paragraph 172 of the Operational Guidelines'.*

'*On 19 March 2024, talks took place between representatives of Správa železnic and the City of Prague and representatives of the UNESCO World Heritage Centre in Paris, at which the current state of the project was clarified, and information was provided on the proposed drafting of an HIA for this project. Following up on this meeting, a letter was sent to the director of the UNESCO World Heritage Centre in May 2024, in which the City of Prague along with Správa železnic invited representatives of the UNESCO WHC and ICOMOS International to Prague, where these talks could continue along with invited experts and the authors of the peer reviews.*'[3]

[1] 2019 Mission Report, 5.1.10.2, pp. 39-40.
[2] Recommendation R 09, p. 41.
[3] 2024 State Party State of Conservation Report.

The State Party subsequently invited a joint World Heritage Centre/ICOMOS Advisory mission to consider and advise on the issue, which took place on 11-12 December 2024. Meanwhile, in July 2024, the Michael Kloos planning and heritage consultancy, instructed by *Správa železnic*, began work on a scoping report, with the aim of *'establishing the common ground by involving various stakeholders as a base for the Heritage Impact Assessment report'*.[4] The Scoping Report includes a detailed account of the evolution of the project to replace the Vyšehrad bridge.[5]

The City of Prague on 8 December 2024 resolved that if preservation of the existing bridge is impractical and it must be replaced, it should be relocated as a pedestrian and cycling connection across the Vltava River at Vltavanů – Chuchle, 6.5 km south of its existing location.[6]

Terms of reference of the mission

The mission's terms of reference were as follows:

1. Receive and consider details of the overall transport requirements that indicate the need to upgrade the Vyšehrad Railway Bridge across the Vltava River; and details of any other spatial options that have been considered in addition to upgrading the existing bridge.

2. Receive and consider the justifications for the preservation of the Vyšehrad Railway Bridge across the Vltava River in its current location from various stakeholders (relevant Ministries, city authorities, heritage specialists and representatives of civil society).

3. Receive and consider engineering opinions on whether the existing bridge could be strengthened to accommodate new generation trains; or whether it could be retained for pedestrian use only.

4. Assess the possibilities and conditions for the preservation of the bridge in the light of the extent of its contribution to the Outstanding Universal Value (OUV) of the World Heritage property 'Historic Centre of Prague'.

5. Assess alternatives for the replacement of the bridge and the potential impact of the proposed new structure on the OUV of the property.

6. Provide recommendations to the State Party on the optimal solution in view of preserving the attributes that underpin the OUV of the property.

[4] Michael Kloos planning and heritage consultancy*, Heritage Impact Assessment (HIA) Vyšehrad Railway Bridge in Prague, Phase 1 Scoping Report, Prague,* 12 December 2024, Hereafter 'Kloos 2024'.
[5] In slides 56-66.
[6] Resolution 1593.

II. THE VYŠEHRAD BRIDGE: HISTORY, SIGNIFICANCE AND CONTRIBUTION TO OUTSTANDING UNIVERSAL VALUE

Origin and evolution

The line connecting Smichov Station with Prague Central Station was built in 1872, initially crossing the Vltava on a single-track bridge of five spans of iron truss girders with parallel chords. The piers (but not the abutments) had been built wide enough to accommodate two tracks, but in 1901 the first bridge was replaced by the extant three span double track bridge using semi-parabolic steel truss girders, each spanning 72 m (Fig. 1-3 – see Annex VI).

The eastern abutment of the new bridge now coincided with a masonry embankment wall constructed after a flood in 1891, including culverting the Botič Stream just to the south of the bridge.[7] The new river bridge was connected to the masonry viaduct (Fig. 1, Sections 4 & 6) which had formed the abutment of the 1872 bridge by a four span beam bridge (Fig. 1, Sections 2 & 3). The second track was laid in 1907-8, following the widening of the viaduct on the east bank and the rebuilding of the bridge over Vyšehradská Street (Fig. 1, Section 5).[8] The masonry viaducts are therefore composite structures, the 1872 viaduct built of sandstone visible on the north side, and the 1907 widening built in granite visible on the south side. Copies of the original construction drawings for all phases survive in the Prague City Archives.

The new bridge was part of a major investment in the Prague Connection Line. The main railway station was rebuilt at the same time, 1901-09, in the Art Nouveau style to the designs of Josef Fanta.[9] Between it and the new bridge, a rather grand station, also in the Art Nouveau style, was built at Vyšehrad in 1905. It was designed by Antonin Balšanák, who was also involved in the design of the Legions Bridge over the Vltava.[10]

The structure of the existing, 1901, steel bridge is considered in detail in the expert report of Friedmar Voormann,[11] commissioned to inform the HIA Scoping Study, and so need only be summarised here. The girders, posts and struts of the bridge are formed of flat bars and angles rivetted together, graded according to the calculated forces and so not of constant section, primarily to minimise (optimise) the amount of steel required, the major factor in the cost of European steel structures at the time.

The river bridge was designed and built by the engineering firm Bratří Prášilové (Prášil Brothers Bridge Works), in conjunction with Prager Maschinenbau Actien-Gesellschaft (Ruston & Co.). Prášil Brothers were leaders in steel construction in Prague and throughout Bohemia and Moravia. They designed the steelwork of other notable surviving constructions, such as the Petřín Observation Tower and the Industrial Palace (built for the 1891 Prague Industrial

---

[7] The bridge carrying the riverside boulevard (Rašínovo Embankment) over the Stream was part of the primary works; in 1904 the culvert to the east was also covered over (Presentation 2, Slides 12-13).
[8] National Heritage Institute presentation, slide 5; letter, Railway Administration to WHC, 20 June 2023, pp.1-2. The bridge over Vyšehradská Street was rebuilt again in 1994 with a modern welded steel chamber structure.
[9] *Industrial Prague, 2006, p.* 123, a cultural monument recently restored to its historic splendour by *Správa železnic.*
[10] *Industrial Prague,* 2006*,* pp. 48, 20. The station is also listed as a cultural monument. The contemporaneity of the stations and new bridge is noted in the inscription of the bridge as a cultural monument.
[11] Prof. Dr-Ing Friedmar Voormann*, Expert Report on the Aspects of the Construction History of the Railway Bridge on Prague's Vyšehrad* Wiesbaden, October 2024; hereafter 'Voormann 2024'.

Exhibition) and provided the steel structure of the Čechův Most (Svatopluka Čecha Bridge), 1907, over the Vltava.

The footbridges attached to cantilevers on either side of the 1901 bridge, reached by stairs from street level, although integral to the design were completed slightly later than the main structure, one opening in 1902.[12] They were funded by the municipalities and so are now in the ownership of the City of Prague rather than the state railway service.

Modern works to the 1901 bridge structure are recorded as follows:

- In 1969-70, during the electrification of the line,' *the articulated truss cross stiffening of the perpendiculars was completely removed. The catenary brackets were attached directly to the perpendicular sections of the main beam'*. This is described by *Správa železnic* as *'a very insensitive intervention in the appearance of the original bridge structure'.*[13]
- In 1987, *'extensive structural modifications were made … concentrated on the bridge deck section, where the longitudinal trusses were strengthened, sub-bridge stiffening and brake stiffening at the edges and in the centre were added'*.
- In 1994, the bridge over Vyšehradská Street (Fig. 1, Section 5) was replaced with a modern welded steel chamber structure.
- In 1997-8, '*the steel structures of the Výtoň foreground were comprehensively reconstructed. As part of the reconstruction, the longitudinal trusses and the lower chords of the full-wall main beam were reinforced'*.
- In 2018-19, the footbridges attached to the railway bridge were comprehensively repaired by the City of Prague, during which much of their steelwork was renewed, but to the original design.[14]

The steel bridge across the river now presents in distant views as being reddish brown in colour, a combination of rust and the remaining areas of multiple coats of dark red paint, probably rich in red lead oxide. Subject to technical investigation, this appears to have been the original finish. Painting was neglected after World War II, although there are superficial traces of a grey anti-corrosion finish applied over the dark red layers (Fig. 4).[15]

Significance of the Vyšehrad bridge as an historic monument

As Friedmar Voormann explains,[16] the first large railway bridge using semi-parabolic truss girders was built in 1865-8 in the Netherlands, of twice the span (154 m) of those of the Vyšehrad bridge. The 'double intersection Pratt-truss with counter diagonals in the middle of the field', as in the Vyšehrad railway bridge, appeared soon afterwards. Between about 1870 and 1900, the design was widespread for bridges in continental Europe, particularly Germany and Austria, and notably on the expanding railway network. By the 1890s the design of many had been further refined, with rigid diagonals eliminating the need for counter-diagonals. From around 1900, steel arch designs became increasingly widely used in Europe for major bridges,

[12] Prague 5 presentation, slide 4.
[13] Letter, Railway Administration to WHC, 20 June 2023, p. 3.
[14] *Scoping Study*, slide 59; letter, Deputy Mayor of Prague for Transport and Heritage Care, Adam Scheinherr, to Director WHC, 14 February 2023.
[15] Probably from the last comprehensive repair in 1957.
[16] Voormann 2024, *op. cit*.

primarily the result of changing aesthetic preference, although they had some technical advantages.

It is clear, therefore, that the significance of the Vyšehrad bridge does not lie in technical innovation. Its technology had been fully developed thirty years earlier, and more refined forms were being used in the decade of its conception. Nor were its 72 m spans exceptional in a European context. While it was one of the largest bridges built in the Austro-Hungarian Empire at the time, especially in the regions of Bohemia and Moravia, bridges of this type with spans of 100 m or more were being built elsewhere.

That is not to say that the bridge lacks inherent significance as a structure, but rather that its significance stems both from its integrity of material, technology, design and function, being relatively little changed over time, and from its survival. It is a large-scale exemplar of a once common but now rare type, in a very prominent location in a World Heritage property. Most of its load-bearing members survive from its original construction. Intervention to facilitate electrification in 1969-70 was insensitive but localised; strengthening of the deck was mostly by addition and in the least visible part of the structure. Overall, these changes have had a minimal impact on its structure or its appearance in the Prague townscape. While its design was typical of railway bridges and widespread in Europe in the late 19th century, only three remain in the Czech Republic, and Vyšehrad is the only one of large scale, carrying two tracks over multiple spans.[17] Furthermore, Voormann's report demonstrates the extreme rarity of surviving steel semi-parabolic truss girder bridges of more than 60 m span anywhere in the European context.[18]

Contribution of the Vyšehrad bridge to Outstanding Universal Value

The contribution of Vyšehrad Bridge to the OUV of the property must begin with the most relevant of the reasons for its inscription on the World Heritage List, namely Criterion (ii): "*The historic centre of Prague admirably illustrates the process of continuous urban growth from the Middle Ages to the present day",* and Criterion (iv): *"Prague is an urban architectural ensemble of outstanding quality, in terms of both its individual monuments and its townscape, and one that is deservedly world-famous"*.

Vyšehrad Bridge illustrates a notable phase in the *continuous urban growth* of Prague, the development of the railway network which reached its historic peak around the end of the 19th century, in the form of a large, unadorned, but visually complex expression of structural engineering, typically associated with railway works (Fig. 5). Rivetted steel structures exemplified by the bridge played an essential part in architectural developments in Prague in the late 19th and early 20th century. The Prášilové Brothers were not only involved in building bridges; they and other firms fabricated the steelwork essential to the structures of the domed roofs which characterise buildings like the National Museum.[19] These are mostly hidden skeletons, albeit less so in the Petřín Observation Tower and the Hall of Industry, but neither express the structural use of rivetted steel as clearly, powerfully and publicly as the Vyšehrad Bridge.

[17] Another bridge of this type survives in Prague, built by the Prášil Brothers in 1912-14. Most Bohdalec, with a single span of 78m carrying a road over a railway, was renovated 'with replacement of many elements' in 2005 (Voormann 2024, *op. cit.,* 17; Rotter, T. *et al.*, *Ocelové Nýtované Mosty v Praze* (2023), 129-51).
[18] Voormann 2024, 14-17.
[19] A contemporary cutaway model of the dome displayed in the National Technical Museum, with preserved fragments of other structures demonstrate the technology.

The Vltava is one of the main visual axes of the historic centre of Prague and the sequence of bridges over it is one of the key elements shaping the image of the city and a key attribute of the OUV of the property. The Vyšehrad Bridge and the adjacent areas are visible from far and near, both looking outwards from the property and inwards towards its centre. The bridge appears in the fore or middle ground of views from Vyšehrad Hill towards the Castle (Fig. 6) and terminates the sequence of bridges visible on a clear day in views up the river from the vicinity of Kramářova villa, the residence of the Prime Minister of the Czech Republic (Fig. 7) and from the nearby Letna Park. The bridge forms part of the '*outstanding urban ensemble'* of the city.

Unlike the Art Nouveau Čechův Bridge, built in 1907 north of the historic centre, whose steel arched structure is mediated, as was usual for urban road bridges, by architecture and sculpture, Vyšehrad Bridge is an unadorned engineering structure, 'designed purely from a technical, practical and economic point of view'. It may seem particularly appropriate that such a design should have connected the industrial suburb of Smichov with the historic centre. But the preference for such unadorned structures carrying railway tracks was almost universal, even, when, as here, it formed part of a major urban project which included the Art Nouveau grandeur of the Central and Vyšehrad stations.

In the vicinity of the river crossing, the Vltava River, Vyšehrad Basilica, Vyšehrad Hill, the Cubist buildings below the Vyšehrad Hill, the railway bridges and the (much older) former Podskalská Customs House 'form a unique and harmonious ensemble that captures the dynamism of the era at the turn of the 20th century' (Fig. 5).[20] The siting of the Cubist houses close to a large pure engineering structure seems almost perverse, but '*the railways were seen as modern not only in the nineteenth century, but throughout the inter-war years. Rather than being appreciated for their function as such, they were now appreciated for their functional aesthetic'.*[21] The modernist literary critic and poet František Xaver Šalda (1867-1937) had insisted that a direction for modern architecture '*would not be found in any new ornamental vocabulary, but rather in the strict logic of industrial structures. He wrote of the power of the impression made "by a huge railway bridge, bare, desolate, without ornament, the sheer embodiment of constructive thought," and concluded that "the new beauty is above all the beauty of purpose, inner law, logic and structure".'* [22]

While the bridge was not necessarily Šalda's specific inspiration, it perfectly illustrates his point, made around the time of its construction. While the bridge also attracted negative criticism at the time of its construction, the aesthetic it expressed was to be influential in the evolution of architectural style in Prague through the early 20th century, as Art Nouveau gave way to Cubism, Rondo-cubism and Functionalism. Respect for the bridge rooted in such appreciation of its values has ensured its continuing appreciation as one of the defining elements of the urban panorama of the city. That is reflected in its frequent and ongoing appearance in artistic images through 20th century,[23] including a postage stamp of 1971 (Fig. 8).

[20] National Heritage Institute presentation, Slide 20.
[21] Jeschke, F K, *2016 Iron Landscapes, Nation-Building and the Railways in Czechoslovakia, 1918–1938* Doctoral thesis, University College London 2016, p168, available at https://discovery.ucl.ac.uk/id/eprint/1476693/1/Jeschke_Thesis%20Final.pdf. The quotation from Šalda is from *Nová krása—jejĺ genese a charakter* (*The new beauty—its genesis and character*),1898-1904; his thoughts were drawn to our attention by Nebourat, Slide 10.
[22] Jeschke, *op. cit*.
[23] National Heritage Institute presentation, Slide 24.

The approach structures on the Výtoň side, particularly the masonry elements, have evidential value in demonstrating the evolution of the railway crossing over the Vltava, although some of the simple steel spans between the masonry elements have been modified or replaced.[24] Spatially the structures have been a determining element in the evolution of the townscape in their vicinity, but are not visible in the panoramic views of Prague. They make a more modest, contribution to the OUV, as an extension of the steel truss bridge.

Conclusions

The steel Vyšehrad bridge, built in 1901 to cross the Vltava river in three spans using semi-parabolic steel truss girders, makes a notable contribution to the OUV of the World Heritage property 'Historic Centre of Prague'. The riverine landscape is one of the main visual axes of the historic centre and the sequence of bridges over it is a key element in shaping the image of the city and a key attribute of the OUV of the property. The Vyšehrad Bridge and its adjacent areas are visible from far and near, both outwards from the property and inwards from Vyšehrad towards its centre. It is part of the 'ensemble of outstanding quality' of the city, as reflected in the Statement of OUV.

The Vyšehrad Bridge is also 'of significant public interest', which is reflected in its listing as a cultural monument.[25] This derives from its rarity as a surviving large, authentic example of a once common type, which by its form and technology illustrates a notable and influential phase in the continuous urban development of Prague.

The steel truss bridge therefore warrants a strong presumption in favour of its repair and retention in use in its current location. The Výtoň approach structures to the eastern end of the river bridge make a much more modest contribution to OUV.

[24] See p.13 above.
[25] Kloos 2024, Slide 74.

III. THE STRUCTURE OF THE BRIDGE

A glossary of technical terms is provided at Annex V.

Introduction

The railway bridge over the Vltava River consists of three identical spans of 72 m each (Fig. 2, 1). As noted above, the truss girders are of a type well known (and already old) at the time of construction in 1901. They are highly optimized in terms of steel use: the shape (variable height) and the cross-sections of the elements are adapted to the magnitude of the forces to be transmitted. This gives the bridge a lightweight appearance: the total mass of the bridge is just 1,710 t of steel.[26]

This optimization is the result of the dimensioning method adopted at the time, the premises of which are no longer valid today. The methods available in 1900[27] for determining the forces in the various truss elements assumed that all the truss elements were hinged together at their intersections, and that the forces could be determined by expressing equilibrium equations alone. This is called an isostatic, or statically determined, structure (see glossary). The immediate consequence from a safety point of view is that if a single element in such a structure were to fail, it would collapse like a mechanism: there is no redundancy, or reserve of load-bearing capacity in the event of localized failure, in an isostatic structure.

The dimensioning method used in 1900 therefore makes simplifying assumptions.

The first is the assumption that elements are articulated at the nodes: this is not verified in practice, since connections are made more or less rigidly using gusset plates assembled by riveting (Fig. 9). Without going into detail, this means that elements such as diagonals or vertical members are subjected not only to normal tensile forces, but also to bending moments. The latter induce bending stresses in the elements,[28] often termed as “secondary” (or even parasitic) to the “primary” stresses resulting from the normal force. Even then, it was well known that the magnitude of these bending stresses was by no means negligible compared to that of the “primary” stresses associated with normal forces. But in 1900, it was almost impossible to take these “secondary” stresses into account in design calculations. So, they were deliberately ignored, relying (1) on a generous safety coefficient between the strength (elastic limit) of the material and the work rate allowed for the stresses and (2) on the possibility of adaptation of the structure to the results of the calculation, thanks to local plasticization and the de facto limitation of stresses by the yield plateau (see glossary) of the material. In fact, all truss structures – first in iron, then in steel – built since they became “calculable” until the advent of computer calculation (in the 1970s) have been dimensioned using these simplifying assumptions, without this seeming to have been a major concern.[29] Having said that, it is certain that throughout its life, this bridge was physically subjected to stress levels higher than those determined by the (elastic) calculation and therefore higher than those accepted as the maximum permissible stress; there is no doubt about this, and the bridge did not collapse as a result.

---

[26] E-Mail from Ing. Jiří Krouský (*Správa železnic*) dated 14 January 2025.
[27] These are graphical methods: the - typical - force determination drawings can be found in the bridge documentation.
[28] Stress: a force applied to a unit area of material.
[29] Apart from problems of instability (buckling), which do not concern us here.

The second simplifying assumption is that of isostaticity. Voormann's report states that this type of truss is sometimes referred to in the literature as "double Pratt". And indeed, the graphical statics sketches (Fig. 10) indicate that the calculations have assumed that each main girder consists of two independent (isostatic) Pratt trusses. However, while they are independent in terms of triangulation (diagonals and vertical members), they are not independent in terms of chords (top, semi-parabolic, and bottom, rectilinear): the chords are common to both Pratt trusses. So, in reality, the overall truss structure is statically indeterminate (or hyperstatic). This constructive reality probably has little influence on the distribution of normal forces in the truss elements, compared with the fact that statical indeterminancy is not taken into account in the calculations. But from a safety point of view, the fact that the structure is materially statically indeterminate rather than statically determinate introduces redundancy: this means, for example, that the disappearance of a diagonal (not just any diagonal, however) will not necessarily lead to the collapse of the bridge.

Nowadays, the determination of forces and stresses in so-called "truss" structures no longer makes this kind of assumption: computerized calculation methods take into account the stiffness of the connections (and therefore "parasitic" bending stresses) and the "hyperstatic" character of the structure is automatically taken into account. This is not to say, however, that the stresses resulting from a "modern" calculation perfectly represent the reality of what is happening in the structure: any model, even the most sophisticated, introduces assumptions and ignores certain things. In particular, the actual state of stress under dead weight is inaccessible to (experimental) investigation.

That said, the "format" and conception of safety also changed significantly between 1900 and 2000.

In 1900, safety consisted in checking that, at no point in the structure, the stresses calculated using the simplifying (and reductive) assumptions just mentioned did not exceed an admissible stress, a fraction of the yield strength of the material. The notion of fatigue failure had only been discovered 25 years earlier and was not yet part of the design criteria. Fatigue was not taken into account in the design of railway bridges until after the Second World War, mainly because of its impact on welded structures. Today, following the format of the Eurocodes standards, the conception of safety is very different from that of 1900, and taking fatigue into account is an essential element in the dimensioning of rail bridges.

But it is not easy. Fatigue is material damage resulting from the repetition of a very large number of loading-unloading cycles. For rail bridges, these cycles correspond to the passage of trains, which introduces stress variations at every point of the construction between the loaded and unloaded states. These cycles introduce progressive damage into the material, which can lead to local failure in the form of a crack at a maximum stress level that is lower (or even much lower) than the material's resistance. This depends on many factors, not least the number of cycles and the amplitude of the stress variation (max-min). However, it is considered that there is a maximum stress level, known as the endurance limit, which is such that failure will never occur as long as the maximum stress does not exceed this endurance limit, regardless of the (large) number of cycles to which the structure is subjected.

When we apply Eurocodes standards, which are primarily intended for the design of new structures, to old or even very old structures, it is not uncommon to deduce that their safety is not assured. However, these structures, if properly maintained, have stood the test of time. The application of Eurocodes to old structures, such as the railway bridge over the Vltava River, must therefore be carried out with discernment, evaluating at each stage whether certain formulas and provisions are applicable. Of course, changes in load conditions (typical convoys) and damage resulting from lack of maintenance must also be taken into account.

Current state of the bridge structure

The bridge was last completely repainted in 1957. Periodic repainting of metal bridges is the main protection against steel corrosion. It is well known that some large, renowned metal structures, such as the Eiffel Tower or the Firth of Forth Bridge, are periodically – not to say constantly – repainted.

It is not the purpose of this report to determine why the maintenance of this bridge has been neglected to the extent that it suffers from metal corrosion in many places. In 2017, the railroad administration commissioned the engineering firm SUDOP PRAHA to assess the condition of the bridge and the possibility of renovating it. This was followed by a very thorough visual inspection of the bridge, with detailed mapping of all traces of corrosion and the presence of any cracks.

At this stage, only two cracks, which seem to be fatigue cracks, were found in one of the stringers, and more specifically in the 1987-reinforced part of this stringer: this implies that, even at the time, it was felt that the stringers needed to be reinforced (Fig. 11) to stand up to fatigue. It should be noted that the stringers carry the rails directly via the timber sleepers. The failure of a stringer would be catastrophic.

Steel corrosion affects the diagonals, vertical members and their connections with the lower chord elements of the main girders (Fig. 12). This corrosion is certainly the result of a lack of regular maintenance, but it is also favoured by the original poor design of the construction details, which favours water retention and the development of rust. Corrosion leads to the loss of material and therefore of stress-resistant cross-sectional area. In some places, this cross-section has even locally disappeared. The SUDOP report[30] estimates that 63% of the components would have to be renewed, i.e. around 1,130 t of steel (Fig. 13). In other words, the authenticity of the bridge's materiality would be greatly affected.

In 2023, two further cracks were identified, this time in an area affected by corrosion in the region of a diagonal connection to the lower chord.

Sampling and laboratory testing revealed that the constituent steel is S235 JR. As might be expected at the time, this is a mild steel with an elongation at rupture in the static tensile test of at least 30%, i.e. good ductility under normal loading conditions. Nevertheless, the Charpy test (see glossary) indicates that it is a brittle steel, even at ambient temperature, under impact conditions.

One of the manifestations of brittle fracture is that the fractured surface shows no striction, extension or plastic elongation. Brittle behaviour is the opposite of ductile behaviour. From the reports presented to the mission, it seems to the mission team that the consequences of this brittle character of steel in the Charpy test have not been properly or fully assessed.

[30] Martin Vlasák *et al*, Reconstruction of Pod Vyšehradem Railway Bridges, Technical Report, SUDOP PRAHA, May 2018.

First, it should be pointed out that this characteristic (brittleness) is in no way exceptional for a steel intended for structural steelwork, not only at that time (1900), but even decades later. Admittedly, this type of steel is no longer acceptable for the construction of new steel bridges, but the fact remains that on all European road and rail networks, there are many old steel bridges (pre-1950) whose steel is no better than that of this bridge in terms of resilience (resilience measured by the Charpy test).

Furthermore, there is no direct correspondence between Charpy strength and fatigue. While it is conceivable that the speed of crack propagation will be enhanced by the material's brittleness (as measured by the Charpy test), it is not necessarily the case that brittleness is a measure of susceptibility to fatigue damage. In other words, brittleness and fatigue should not be confused. However, a brittle crack may easily be confused with fatigue crack and *vice-versa.*

In fact, under "normal" loading conditions, even with heavy convoys and taking into account the dynamic effect of loading, the brittleness of steel poses no particular problem: brittleness does not affect the material's strength value. The material's brittleness only becomes a problem at very high loading speeds, but these are of the kind only encountered in the event of accidental loading, such as the effect of an explosion. In this case, a brittle fracture could be observed: thus, an explosive charge placed on a specific diagonal or member could, if triggered, induce a brittle fracture of an element essential to equilibrium and precipitate the span into the river. This is where there is a need to think in terms of the structure's robustness; as pointed out above, robustness, which is a concept distinct from strength or load-bearing capacity, is intimately linked to the hyperstaticity and redundancy of the structure. And in this case, because of its design or typology, this structure is not very redundant and not very robust.

Verification calculations and different projects

Any calculation for sizing a new structure, or for recalculating the load-bearing capacity of an existing one, is highly dependent on the calculation assumptions. And the choice of these assumptions is not neutral: it will depend on the engineer's experience, familiarity with the object of the study, habits, the modelling tools at his/her disposal and apprehension of the risks. In this case, it is not surprising that two engineers, using the same framework of Eurocode standards, should come to different, even opposing, conclusions, both equally correct.

Engineer Martin Vlasák[31] of SUDOP PRAHA not only estimates that 63% of the metal elements would have to be replaced, but also deduces from the fatigue limit state calculations that the service life of the renovated bridge would be 30 years at most. The survey of SUDOP PRAHA's corrosion defects was validated by a mission entrusted to the Klokner Institute,[32] which also examined the bridge under static and dynamic loading. The structural and fatigue calculations carried out by SUDOP PRAHA were analyzed by a team from the University of Žilina (Slovakia) who, with a few observations, validated the choice – described as "correct" – of the numerical model.[33]

[31] Martin Vlasák, 2018, *op.cit*.
[32] Milan Holý *et al,* Evaluation of the Diagnostic Survey of the bridge structures at km 3.706 - Pod Vyšehradem, Expert Report 1800 J 239, Klokner Institute, 14 November 2018.
[33] Josef Vičan *et al.*, Expert Assessment of the Static Recalculation of the Bridge "SO-20-20-OR Railway Bridge at km 3.706 - Pod Vyšehradem", Žilina, August 2018.

At the request of the Klokner Institute, Eugen Brühwiler of EPFL, a world-renowned expert in the maintenance of engineering structures and a specialist in the fatigue of riveted structures, was invited to intervene. He visited the bridge in February 2019 and had one of his Master's students, whom he supervised, recalculate the bridge's load-bearing capacity. The conclusions of the Brühwiler study[34] are fundamentally opposed to the conclusions of the SUDOP PRAHA study: technically, the bridge can be renovated; it will have the necessary load-bearing capacity, and fatigue is not a limiting consideration; a service life of 100 years after renovation is entirely possible.

A joint report by Brühwiler and the Klokner Institute[35] clearly explains the differences in approach between SUDOP PRAHA and the Brühwiler study. The main ones are as follows: the SUDOP PRAHA study uses corrosion-reduced element cross-sections, performs Class 3 cross-section strength calculations and assesses fatigue with a Palmgren Miller-type cumulative damage model; the Brühwiller study assumes restored element cross-sections, performs Class 2 cross-section strength calculations[36] and assesses fatigue by ensuring that maximum stresses do not exceed the endurance limit.

In fact, the two approaches have different starting assumptions and do not assess the same thing: the SUDOP PRAHA analysis is concerned with the residual load-bearing capacity of the bridge in its non-renovated state; the Brühwiler study is concerned with the load-bearing capacity and service life of the bridge assumed to be renovated or even reinforced.

In 2021, the railroad administration organized a competition[37] called "competitive dialogue", which attracted 12 entries. The project ranked first replaces the existing two-lane bridge with a 72 m-long three-spans bridge, using the existing piers, but with three tracks. The spans are of the "bowstring" type, i.e. a completely different structural principle. The total mass of the new bridge would be around 4,950 t.[38]

To compare the use of steel in the original 1901 bridge and in the winning project resulting from the "competitive dialogue", we can compare, as a first approximation, the masses per track and per running meter. This gives around 4 t/(m.track) in the original bridge and 7.64 t/(m.track) for the winning bridge. The latter is unquestionably more material-consuming, albeit with approximately the same structural height. Clearly, the bowstring arches will appear less slender than the top chords of the current trussed spans: that this bridge is more massive than the original can be seen in the architectural sketches (Fig. 25). These figures (4 vs. 7.64) confirm the impression that the original deck is highly optimized. Conversely, we can deduce that a modern bridge will have a more comfortable safety margin and is more robust. This more robust character also stems from the bowstring structural typology, which is currently quite standard for rail bridges of this span.

---

[34] Eugen Brühwiler, Vyšehradem Railway Bridge in Prague - Preservation of the existing bridge. Assessment and feasability study for the restoration, Report E19-02/01, I July 2019.

[35] Jiří Kolísko *et al.*, Eugen Brühwiler *et al.*, Evaluation of the work and assessment carried out to date to the railway bridge at km 3.706 Pod Vyšehradem with the participation of a foreign expert, Expert Report 1900 J 059, Klokner Institute, 23 October 2019.

[36] A Class 3 cross-section calculation assumes that a cross-section operates entirely in the elastic regime; a Class 2 calculation admits yielding of the cross-section, leading to a higher bending strength than in Class 3.

[37] The team cannot comment on the reasons why the railroad administration decided to organize this competition, nor on the terms defining the conditions of the call for projects, nor on the ranking of the projects.

[38] E-Mail from Ing. Jiří Krouský (Správa železnic) dated 14 January 2025.

The final project worth mentioning is the one presented by the Endowment Fund (NGO), prepared by Ian Firth (COWI-UK), Andreas Galmarini (WG, Zürich), Petr Tej and Marek Kopeć. It should be emphasized from the outset that the presentation of this project is very recent (October 2024) and that it could not be technically evaluated independently of the authors and the referees they chose. This project is drawn up with a view to preserving the existing bridge and, if necessary, suggesting the addition of a minimalist modern bridge to carry a third track. Like Eugen Brühwiler in 2019, Ian Firth – probably one of the world's best-known bridge designers – is confident that the bridge can be preserved and restored for at least 100 years without concern for fatigue. He estimates (Fig. 14) that it will only be necessary to replace around 15% of the metal (compared with 63% in the SUDOP PRAHA study: Fig. 13). The feasibility of this project in terms of maintaining the original bridge, and the compliance of the calculations with the standards in force in the Czech Republic, is attested to in the document presented by Czech experts and by Andreas Taras of ETHZ, a specialist in the fatigue of steel structures (the expert reports were not provided). With regard to the bridge that would eventually support the third track, which has not been studied in this project, the team suggests organising a competition. It is interesting to note that the authors have taken into account the question of noise reduction (certified by expert attestation), which a priori is not self-evident for old truss bridges. The feasibility of renovating the bridge by working span by span is also studied. In this project, the level of the tracks remains unchanged.

This report is not intended to provide an opinion on the amount of steel or components to be replaced in the maintenance project. There is a significant discrepancy between estimates of 63% and 15%. Nor can this report give an opinion either on the cost estimates (which is the most economical solution?) or on the duration of the work.

Separation of the tracks

With regard to the positioning of the tracks, the comparison between the 2T Engineering project and the project presented by the NGO Endowment Fund calls for comment.

In 2T Engineering's project, the distance between the centre lines of the tracks is 4 m, as required in § 2.5.2 of the competitive dialogue specifications. Is this (modern code optimum) minimum distance really necessary for this part of the line, where train speeds will remain limited to 70 km/h? In the project presented by the NGO Endowment Fund, the distance between tracks remains the same as at present (3.8 m); the difference is 20 cm. To achieve a distance of 4 m between the centre lines of the tracks with the renovated bridge, the distance between the main girders would have to be increased, which would mean completely changing the deck structure.

The Výtoň viaduct and Rašínovo Embankment

The three-span steel truss bridge over the river is not the only one to be considered, despite its strong symbolic character and visual identity. In fact, the decree listing this bridge in 2004 simultaneously classified as heritage a set of five bridges:

1. the railway bridge with five openings located at km 3.390[39] with a total bridge span of 38.60 m (Fig. 1.6);

[39] Km from the Prague main station in the direction of Smíchov.

2. the railway bridge with one opening located at km 3.415 across Vyšehradská Street (Fig. 1.5);

3. the railway bridge with eight openings located at km 3.470 line with a total bridge span of 69.0 m (Fig. 1.4);

4. the railway bridge with four openings located at km 3.545 with a total bridge span of 77.5 m (Fig. 1.3 and 1.2);

5. the railway bridge with three openings located at km 3.706 with a total bridge span of 261.05 m (Fig. 1.1).

The bridges (1) to (4) will be referred to here as the viaduct.

So far, the analysis has concentrated on bridge (5), but the project also affects the other four bridges, in particular through the desire expressed to have a new station on the east bank of the Vltava River on the Výtoň-Vyšehrad side. The station is considered in section V below, but particular mention should be made here of the problem posed by the insufficient clearance for the free passage of trams and buses under the last span of the bridge (4) (Fig. 1.2) just before the river crossing (5) (Fig. 1.1). The current clearance is 3.1 m.[40] The competitive dialogue specified in § 2.7.2 that the project should provide a clearance height of 4.5 m at this point.[41] This 'optimal' clearance is a strong request from the City of Prague.

2T Engineering's project, which won the competitive dialogue, involves raising the current level of the railway tracks by 1.15 m to elevation 198.4[42] in order to achieve the optimal headroom required in the brief of 4.5 m. It should be noted that the difference between 1.4 m (=4.5-3.1) and 1.15 m, i.e. 25 cm, can be explained by a reduction in the structural depth of the deck in the new project for bridge (4) compared with the existing deck.

The NGO Endowment Fund's Walt Gamini+COWI project does not involve raising the level of the rails, but it does allow an increase in headroom from 3.1 m to 3.5 m (i.e. a gain of 40 cm)[43] by optimising the structural deck height in the new project for the bridge (4). This is the same clearance as the Vyšehrad Tunnel, also a listed cultural monument, about 400 m to the south on the same tram line along the embankment.[44] It would be a significant improvement on the current situation.

It seems almost unthinkable to envisage gaining much height by lowering the level of the roadway and tramway tracks because of the presence, just to the south of the viaduct, of the culvert that allows the Botič Stream to flow into the Vltava River: the full section of this gallery (Fig. 16) is necessary to evacuate the torrential floods of the Botič Stream. But if essential, and subject to investigation, a further marginal increase in clearance might be achieved by optimising the street deck over the Botic Stream culvert without compromising its existing cross-section and so facilitating localised lowering of the street surface (Fig. 16). The height of

[40] Marek Zděradička, City Requirements For The Bridge And The Výtoň Area, IPR Praha, Presentation 09 on 12 December 2024, Slide 6.
[41] 'Railway Bridges under Vyšehrad', Annex P01 - Task Specification for the architectural and structural design of railway bridges under Vyšehrad, Správa železnic, 2021.
[42] Pod Vyšehradem Railway Bridge, 2T Engineering, 05.2023, Slide 4. Also, document titled Att7c.
[43] Marek Zděradička, *op. cit*, Slide 15.
[44] Presentation 17, Slide 94.

the embankment wall, important as part of the city's flood defences, would not be affected, only the road and footway behind it.

Be that as it may, the two projects significantly modify the viaduct comprising bridges 1 to 4, which affects their heritage value, if only in terms of the replacement of the metal decks of these bridges. However, as the Endowment Fund's presentation[45] points out, the modification of bridges 1 to 4 in 2T Engineering's (competing) project would have a much greater impact on the heritage value of this viaduct, not only because of the raising of the track level (by 1.15 m), but also because of the construction of the new station at Výtoň. What is more, the architectural views of this project (for example, Fig. 25) do not show any protective canopies for passengers on the platforms of the new station. The NGO Endowment Fund's project prefers to locate the new station at Vyšehrad, which would have much less impact on the existing viaduct structure. The proposals for the Výtoň approach are considered further below.

Environmental considerations

There are two environmental issues that are specifically addressed in the design report[46] documenting the design proposed by WG+COWI for the refurbishment and conservation of the bridge.

Noise

The first of these considerations relates to noise caused by passing trains, a source of nuisance frequently mentioned during the presentations made on 11 and 12 December 2024. In § 4.6.7 of this report, various technical solutions for reducing noise are mentioned. The report[47] presented to the mission on 12 December states that the results of the acoustic study have been certified by a Czech expert as guaranteeing that the noise generated by the passage of trains over the renovated bridge will be at a hygienically acceptable level.

No comparable attention to detail was found in the documents submitted to the mission relating to the 2T Engineering's project (the winning project in the competitive dialogue). A question put on this subject to the representative of 2T Engineering after the presentation[48] of this project was not answered. Presumably the authors of the project are assuming that adopting the most modern rail technologies will be sufficient to obtain a satisfactory level of acoustic comfort. It should be noted that the issue of noise pollution was explicitly addressed in one of the specifications[49] of the competitive dialogue.

The issue of noise and acoustic comfort is very complex and difficult to model. Furthermore, running trains in the open air in an urban area will always generate a certain amount of noise pollution. If further consideration is given to both projects under discussion, they should be assessed according to the same criteria at the final detailed stage.

[45] Ian Firth *et al., op. cit*, Slides 107-110.
[46] Andreas Galmarini *et al.,* August 2024, *op. cit*, § 4.6.7.
[47] Ian Firth et al., Presentation on 12 December 2024, *op. cit*, slide 118.
[48] Presentation 13 on 12 December 2024.
[49] Annex P01, 2021, *op.cit*, § 2.6.7.

Sustainability and embodied carbon

The second original – but essential – consideration taken into account in the WG+COWI proposal is the calculation of the CO_2 equivalent emissions associated with the project [5]. Using a methodology developed by the consultancy COWI and calibrated on data from more than 150 bridges, the renovation of the bridge over the Vltava River would consume only 2,000 to 2,200 tonnes of carbon dioxide equivalent (tCO_2e), whereas at least three times as much (6,000 to 7,500 tCO_2e) would be emitted if a replacement 2-track bridge were built. It is obviously the re-use of existing steel that represents the main saving in terms of tCO_2e.

There are no embodied carbon calculations in the documents drawn up by 2T Engineering and submitted to the mission team. However, it should be remembered that the weight per running metre and per track of the existing truss bridge is 4 t/m, compared with 7.64 t/m for the 2T Engineering's project.

Taking into account the construction of a third track would probably slightly reduce the difference in CO_2e emissions between the two approaches (renovation of the existing bridge + construction of a minimalist modern bridge for the second track or construction of a completely new 3-track bridge), but it is highly likely that the solution of keeping the existing bridge is the most favourable from the point of view of circularity and sustainability.

Construction and cost issues

The documents made available to the mission do not make it possible to assess how the new bridge would be erected and the old bridge dismantled in the case of 2T Engineering's project, nor to have any idea of how long traffic would be interrupted: span-by-span construction is unimaginable if one chooses to raise the level of the tracks.

However, by renovating the existing structure (NGO project) and keeping the tracks at the same level, it is easy to renovate the bridge span by span, replacing the span being renovated (removed from the bridge) with a temporary span,[50] which means that traffic is interrupted as little as possible. And traffic may not even be interrupted at all if a bridge supporting a third track (considered below) is built first, before renovation of the existing structure begins. In this case, traffic could be diverted to the new bridge while the old bridge is being renovated.

The official estimated cost of the SŽ (Railway Administration) project was stated in the NGO project presentation to be 3.4 bln CZK (Czech crowns).[51] Employing the 'standard methodology used by SŽ' the costs for the NGO project were stated to be 2.548 bln CZK for the Vyšehrad station option, and 2.822 bln CZK for the Výtoň station option. The Railway Administration did not comment on or challenge those figures.

Conclusions and recommendation

World-renowned engineering experts such as Eugen Brühwiler and Ian Firth assert that the Vyšehrad bridge can be renovated to remain in service for 100 years without fatigue issues, making it challenging to dispute their conclusion on technical and scientific grounds. While

[50] Andreas Galmarini, Ian Firth, Cameron Archer-Jones, WG+COWI Design Report, August 2024; Ian Firth, Andreas Galmarini, Petr Tej, Marek Kopeć, Vyšehrad Bridge refurbishment and urban solution of relevant area, Presentation 17 on 12 December 2024.
[51] Presentation 17*, ibid*, slides 122-123.

their opinion may be questioned based on economic or practical considerations, it is supported by scientific evidence.

Irrespective of any economic or operational considerations, both in the short term (renovation or new construction) and in the long term (maintenance), renovating the existing bridge can be seen as the optimal choice for the following reasons:

- It best complies with sustaining the OUV of the World Heritage property. The most significant section of the listed bridge, Section 5 (Fig. 1.1) crossing the Vltava, would be repaired with minimal alterations compared to its total replacement under the 2T Engineering project.

- It is technically feasible, probably with minimal steel replacement of steel, and the renovation of the bridge will enable it to achieve a lifespan of 100 years (subject to regular inspection and maintenance).

- It appears to be the most sustainable solution in terms of CO_2e emissions.

- By optimising the bridge deck on the eastern approach over the Rašínovo embankment, the clearance for trams could be significantly improved, to the same height as the next construction over its route to the south, the listed Vyšehrad tunnel.

However, due to the inherent weaknesses of the material (brittle nature), the structure of the bridge (very little redundancy) and the water-holding design of some connections, it is strongly recommended that:

- devices, such as guard rails, be provided to contain the effects of accidental loading through a train derailment; and that, in renovation, opportunities be taken to limit the potential to trap water; [52]

- a periodic plan be followed for detailed visual inspection of the bridge and renovation of its anti-corrosion protection;

- and, in general, it be maintained to the high standard appropriate to cultural monuments in the Historic Centre of Prague.

The option of relocating the bridge to carry cycle and pedestrian traffic 6.4 km south was suggested,[53] but the river there is neither wide nor majestic. While this option would result in the bridge's survival as an artefact, its contribution to the panorama of Prague and the OUV of the property would be erased by its removal from the city and the cessation of its intended purpose.

[52] See Presentation 17, *op. cit.,* slide 40.
[53] See above, 'Background to the mission', p.12.

Recommendation

R1 The steel bridge over the river Vltava should be retained and repaired in accordance with a conservation philosophy informed by the technical and scientific data provided to the mission, incorporating safety devices to contain accidental damage, and ensuring its sustained contribution to OUV, while also implementing a programme of regular inspection and planned maintenance suitable for both a functioning engineering structure and cultural monument.

IV. TRANSPORT CAPACITY AND THE THIRD TRACK

The capacity of the Vyšehrad rail crossing

The established city policy is to encourage and facilitate the use of public transport 'above all', and cars – only when there is no other way. The volume of car traffic in the inner city has been falling steadily from a peak in 1997/8 and continues to decline, albeit slowly. However, the population of the Prague metropolitan region is growing rapidly, mainly through increasing suburbanisation. The number of people travelling regularly to the city therefore continues to grow, and while more people are using public transport (train and bus) to do so, the increase is far outstripped by the growth of commuting by car. The amount of traffic in the city border therefore continues to grow, both absolutely and as a proportion of commuter trips. This is unsustainable, leading to growing congestion, which delays buses and makes them an even less attractive alternative. The number of passengers travelling to the city by train has grown from 37 million in 2016 to 54 million in 2023, but the barrier to further expansion of the suburban railway service is the lack of capacity within the existing railway corridors, unless at the expense of long-distance services.[54]

The Vyšehrad railway bridge is part of the of the pan-European Rhine – Danube transport corridor and has carried occasional freight trains on diversion from a route which normally takes them around the city centre. The route serves both long distance and local passenger trains to the centre of Prague, connecting it to the western part of Bohemia, one of the busiest commuting lines from Prague's Metropolitan Region into the city centre. Vyšehrad is one of the busiest railway bridges in the Czech Republic; over 300 trains cross daily, expected to rise to 500 by 2035.[55] The short- and medium-term solution to developing passenger traffic is seen by the city to lie in upgrading existing lines, the long term – in the expansion of the infrastructure, including building high speed lines for long distance traffic, in line with the *Prague Metropolitan Railway Development Strategy* (2018).

The existing section of line between Smichov and Prague Central station, even if capable of operating at full capacity (without the present restrictions due to the condition of the bridge) forms a significant constriction, since two lines on either side unite to cross the bridge. The 2024 *Feasibility Study for the Reconstruction of the Prague Railway Node* has confirmed the need to increase its capacity in the short term through the addition of a third track. The S*trategy* envisages further medium to long-term capacity increases on key radial lines, linking them to cross in tunnels under the city centre, which would add two more tracks to the route (Fig. 17). A new station utilising the viaduct is proposed at Výtoň, on the east bank, sited to provide an interchange with the tram routes which run along and Svobodova Street.

The bridge also provides an important, although currently inadequate, link in the pedestrian and cycle network of Prague, but its use by cycles is impeded both by the capacity of the attached decks and the access to them, which on the Výtoň side is by (1901-2) stairs (Fig. 16).

Providing a third track

If the existing bridge is to be preserved and renovated, the construction of an additional bridge alongside it carrying a third track is the only practical way of increasing capacity of the rail crossing. Since the perspective of views of Prague's bridges over the Vltava River, which is

---

[54] The background to all this is set out at length in Kloos 2024, slides 40-48.
[55] Kloos 2024, slide 47.

important to sustaining OUV, runs from north to south, it seems logical to recommend that such a bridge be located on the south side of the existing bridge, its piers or supporting columns aligned with the historic ones, so that in the perspective, the view of the truss bridge is disturbed as little as possible.

There would inevitably be some negative impact on the historic river bridge's visual contribution to OUV, through the proximity of a new structure. To minimise visual intrusion, such a structure should not rise above the top of the walkway balustrade, and should do so in a horizontal form, so that, filtered through the structure of the historic bridge in long-distance high-level views from the north, it would not be a distraction. From the south, a new bridge would of course be visible, but would be subservient in scale to the historic bridge. Assuming that a footway/ cycleway is attached on this side, it should present a minimal depth of solid structure at its leading edge. The concept put forward in Presentation 17, slide 77 (Fig. 18 here) would meet these criteria. Some doubt was cast on the adequacy of the parapet beam depth over a span of 72 m; but its depth below the deck is less critical than limiting its projection above it, because in views from the south the edge beam of the 3 m pedestrian console would be perceived as the edge of the bridge, with the structure below in shadow.

Conclusions and recommendation

The development of a sustainable suburban railway system, both in terms of extent and capacity, rather than seeking to accommodate increasing car commuting , is a laudable objective that benefits the environment and the sustainability of the historic centre. In that context, the capacity of the Vyšehrad Bridge must as a minimum be rapidly restored to at least its normal operational capacity.

The strategic case for adding a third track to the crossing and a station on the Vyšehrad side is clear. There is general agreement that any major intervention must maintain and improve the pedestrian and cycle capacity associated with the bridge; in particular, the mission recognises the requirement set out by the Institute of Planning and Development (IPR) for a comfortable and barrier-free connection for cyclists and the linking of the main cycling routes.[56]

There would inevitably be some negative impact on the setting of the historic bridge, but a flat deck bridge with clean horizontal lines, positioned to the south, would minimise this impact, while meeting the transport needs of the city. Should systems or requirements change in the future, it could of course be removed; its impact on the setting of the historic bridge is reversible.

Recommendation

R2 Given the operational case for a third track, it should be carried on a new flat deck bridge sited to the south of the historic bridge, with its horizontal beams not rising above the balustrade level of the footway attached to the existing bridge, with a console on the south side to improve capacity for pedestrian and cycle traffic.

[56] IPR Prague Presentation 'City Requirements', Slide 2.

V. THE VÝTOŇ APPROACH STRUCTURES, URBANISTIC PROPOSALS, PEDESTRIAN AND CYCLE CROSSINGS

Introduction

This discussion proceeds from the previous conclusions made in this report, that the 1901 steel bridge over the Vltava should be repaired and retained in its historic form, that a third track should be provided on a new bridge flanking it on the south, and the new bridge provides an opportunity to improve provision for pedestrian and cycle traffic. Keeping the bridge means keeping the rail tracks at their historic level. That avoids the need for the superstructure over the viaduct envisaged in the 2T scheme, which would lift them about 1.15 m higher, visually dominating the stone viaducts, and significantly increasing the scale of the railway structure in the Výtoň townscape (Fig. 19 and 25). Importantly, keeping the tracks at or near the existing level obviates the need for drastic interventions in the masonry piers carrying the bridge and the viaduct arches. Only repair would be needed (particularly to the piers in the river below water level), since the loading on these structures would not materially change.

Urban revival and the new station

The Výtoň approach to the steel bridge is a complex structure, the result of the construction of the Rašínovo Embankment after the first bridge was in place, and the widening of the approach after 1901 to accommodate the additional track provided on the extant bridge. The viaduct is flanked by streets, with public parking under Section 3 on Fig. 1. The vaults under the masonry viaducts are mostly unused and the openings closed with stone walls, while the structure is defaced with graffiti. Further east, the abandoned former Vyšehrad Station building is now in very poor condition, while its setting is compromised by hoardings.

The overall impression of the viaduct and its immediate vicinity is one of neglect and decay, creating a hostile pedestrian environment not only because of dereliction but also through the lack of any active frontages. In any scheme for the revitalisation of the area, the mission is of the view that repairing these structures and where appropriate, bringing them back into active beneficial use is crucial. There appears to be general agreement on this, since the concepts of both 2T (in the context of a new bridge) and the Endowment Fund NGO (in the context of repair) propose to open the arches and bring some of them into active commercial use.

There is also general agreement that the growth of public transport usage in Prague again justifies a railway station on the Connecting Line in the vicinity of Výtoň / Vyšehrad. Multiple tram routes using the lines line along Svobodova Street, and particularly the lines along Rašínovo Embankment make Výtoň a potentially significant interchange node. A new or reinstated station in this vicinity would benefit the public transport network and would revitalise and animate this currently neglected area. However, there are differences of opinion as to whether it should be located on the viaduct at Výtoň or, in the preferred solution of the NGO, on the original site at Vyšehrad. Although the derelict station building is in private ownership, the track and platform area remains in state ownership, with access from Svobodova Street (Fig. 20-24).

Restoring the old Vyšehrad station, presumably with residential or commercial use on the upper floors, would have the major benefit of bringing a derelict monument back to the use for which it was designed, and the shape of the site reflects a former island platform layout, essential to serve three tracks. By contrast, siting the station at Výtoň would require significant horizontal expansion of the railway zone, beyond that necessary for the third track, to accommodate an island platform layout, to the detriment of other uses, and the townscape, as in the 2T concept. Fig. 25 shows the scale of both their proposed new bridge and the scale of the station compared to the current situation. However, Vyšehrad has the disadvantage of being somewhat distant from the transport intersection on the embankment. A new station based on the currently unused viaduct arches would probably be a better functional location and directly revitalise the Výtoň area by bringing them into particularly active use.

Pedestrian and cycle crossing

The 2T concept includes major improvement to pedestrian and cycle crossings, with both 'long options' descending by ramps to street level some distance east of the new bridge, supplemented by stairs and escalators, and 'short options' via ramps attached to the sides of the outer spans of the new bridge. In the 'alternative proposals' of the NGO, improved provision particularly for cyclists would be made on a console attached to the south side of the third track bridge, and a widened console on the north (Fig. 18), both of which could descend to street level without barriers east of the Rašínovo Embankment, at Vyšehrad, supplemented by stairs and elevators on the embankment.

Conclusions and recommendations

In the context of a repaired bridge, an interchange station at Vyšehrad or Výtoň should revitalise and animate the immediate area. The Výtoň approach structures, which make a modest contribution to the OUV, have the capacity to contribute to this through sensitive change and adaptation, respecting the historic masonry of the piers and spans.

According to the information available to the mission, the reuse of the existing Vyšehrad station building would have a greater direct heritage benefit, but may be sub-optimal as an interchange point. And if, as the mission was informed, a viable, fundable scheme for the repair and reuse of the old station is finally imminent, it should not be undermined by creating uncertainty for the investors by insisting on linking it to the railway works. While the Vyšehrad option proposed by the Endowment Fund NGO would greatly benefit from the reuse of the historic station entrance, it is not dependent on it. To function as an effective interchange station, the default western entrance to the station, only about 200 m from the embankment, would be desirable, whether or not access through the historic station building is also possible.

The Výtoň proposal, using the viaduct, may be optimal in terms of location and, with the railway at its existing level, straightforward to deliver. But it would still have disadvantages, particularly in occupying or blighting more space at ground level than the viaduct, and the intrusion of the station and its inevitable platform shelters into views from and across the river.

A detailed study of the advantages and disadvantages of each option, particularly for users of the interchange/station, should inform a final decision, along with design studies that start from a decision to repair the bridge. There is a strong case for the immediate area of the station supporting commercial uses, for Vyšehrad as proposed in Vnislavova Street[57] and for Výtoň within the viaduct arches.However if Vyšehrad is chosen, it would be prudent to assess the viability of the rehabilitation and beneficial use of the Výtoň arches.

---

[57] Endowment NGO presentation, slides 87, 99.

Both options would involve significant modification of the listed bridge sections (1) to (4) before the bridge (5) across the Vltava River, not least the replacement of the deck of section 4. These sections are, in terms of their contribution to OUV, subsidiary to the river bridge. The arches need to be utilised, the area needs to be revitalised, and the public transport benefits are clear. While great care will be needed in developing the design, with the tracks retained at their existing level on the masonry viaducts, either of these options could probably be assimilated into the townscape without material harm to OUV.

The interconnected issues of the design of a bridge carrying a third track, the improvement and updating of pedestrian and cycle links across both bridges, and the siting and design of a new station in the context of the revitalisation of the Výtoň area, will all require clear terms of reference for their design that set out constraints relating to OUV. The process of Heritage Impact Assessment can be used to inform and guide the evolution of project elements, utilising the wide-ranging scoping study presented to the mission.

Recommendations

R3 The location and design of a new station on the east bank, between Vyšehrad and Výtoň, should be the subject of further study to determine which location, in the context of tracks retained at their current level, optimises the balance between operational and townscape/ heritage considerations.

R4 Building on the work already undertaken in the scoping study, detailed Terms of Reference are required that include clear constraints relating to OUV, for the revised proposals for a third track bridge, pedestrian and cycle movement and urban revitalisation in the context of conservation of the historic bridge across the Vltava. The Heritage Impact Assessment of preferred proposals should be carried out in accordance with the methodology of the **Guidance and Toolkit for Impact Assessments in a World Heritage context*****, together with detailed project information. This should be shared with the World Heritage Centre for review by ICOMOS at the earliest possible opportunity, prior to making any decisions.***

VI. ANNEXES

Annex I: Terms of Reference of the mission

Terms of Reference
Joint World Heritage Centre/ICOMOS Advisory mission
to the World Heritage property 'Historic Centre of Prague' (Czechia)
(11-12 December 2024)

I. Purpose of the Advisory mission

In its Decision 45 COM 7B.183 (Riyadh, 2023), the World Heritage Committee requested the State Party to revise and amend the proposal for the Vyšehrad Railway Bridge in accordance with Technical Review provided by ICOMOS in March 2023. Information received from various stakeholders regarding the proposal to replace the historic bridge with a new structure, both prior and following the above-mentioned Decision, indicates the need for a broad consultative approach and a careful consideration of different options.

With regard to this purpose, the mission shall:

1. Receive and consider details of the overall transport requirements that indicate the need to upgrade the Vyšehrad Railway Bridge across the Vltava River; and details of any other spatial options that have been considered in addition to upgrading the existing bridge;

2. Receive and consider the justifications for the preservation of the Vyšehrad Railway Bridge across the Vltava River in its current location from various stakeholders (relevant Ministries, city authorities, heritage specialists and representatives of civil society);

3. Receive and consider engineering opinions on whether the existing bridge could be strengthened to accommodate new generation trains; or whether it could be retained for pedestrian use only;

4. Assess the possibilities and conditions for the preservation of the bridge in the light of the extent of its contribution to the Outstanding Universal Value (OUV) of the World Heritage property 'Historic Centre of Prague';

5. Assess alternatives for the replacement of the bridge and the potential impact of the proposed new structure on the OUV of the property;

6. Provide recommendations to the State Party on the optimal solution in view of preserving the attributes that underpin the OUV of the property.

II. Organisation of the Advisory mission

The State Party undertakes to provide the mission team with all relevant documentation and information necessary for the fulfilment of its tasks, no later than two weeks before the mission. Should additional information be required, as identified during the mission, it should be provided by the State Party no later than seven days after the end of the mission.

The State Party undertakes to facilitate the necessary consultations through working meetings with stakeholders, including government authorities at the national and local levels, the property management authority and any other relevant stakeholders, as well as NGOs and the local community.

In accordance with established UNESCO and ICOMOS practice, their experts will not address the media or discuss the findings and recommendations of the mission, which should only be presented in the final report of the mission.

III. Deliverable

The joint Advisory mission shall prepare a detailed report (in electronic format), according to its Terms of Reference, which will be transmitted to the State Party for verification of possible factual errors no later than two months after the end of the mission.

Annex II: Statement of Outstanding Universal Value

Brief synthesis

The inscribed site is a serial property comprising the Historic Centre of Prague situated on the territory of the self-governing administrative unit of the City of Prague, and of the Průhonice Park, located southeast of the city on the territory of the Central Bohemia.

Prague is one of the most beautiful cities in Europe in terms of its setting on both banks of the Vltava River, its townscape of burgher houses and palaces punctuated by towers, and its individual buildings. The historic centre represents a supreme manifestation of Medieval urbanism (the New Town of Emperor Charles IV built as the New Jerusalem). It has been saved from any large-scale urban renewal or massive demolitions and thus preserves its overall configuration, pattern and spatial composition. The Prague architectural works of the Gothic Period (14th and 15th centuries), of the High Baroque of the 1st half of the 18th century and of the rising modernism after the year 1900, influenced the development of Central European, perhaps even all European, architecture. The historic centre also represents one of the most prominent world centres of creative life in the field of urbanism and architecture across generations, human mentality and beliefs.

In the course of the 1100 years of its existence, Prague's development can be documented in the architectural expression of many historical periods and their styles. The city is rich in outstanding monuments from all periods of its history. Of particular importance are Prague Castle, the Cathedral of St Vitus, Hradčany Square in front of the Castle, the Valdštejn Palace on the left bank of the river, the Gothic Charles Bridge, the Romanesque Rotunda of the Holy Rood, the Gothic arcaded houses with Romanesque cores around the Old Town Square, the Church of Our Lady in front of Týn, the High Gothic Minorite Church of St James in the Old Town (Staré Město), the Early Gothic so-called Old-New Synagogue in the Jewish Quarter (Josefov), the late 19th century buildings and the medieval town plan of the New Town (Nové Město).

As early as the Middle Ages, Prague became one of the leading cultural centres of Christian Europe. The Prague University, founded in 1348, is one of the earliest in Europe. The milieu of the University in the last quarter of the 14th century and the first years of the 15th century contributed among other things to the formation of ideas of the Hussite Movement which represented in fact the first steps of the European Reformation. As a metropolis of culture, Prague is connected with prominent names in art, science and politics, such as Charles IV, Petr Parléř, Jan Hus, Johannes Kepler, Wolfgang Amadeus Mozart, Franz Kafka, Antonín Dvořák, Albert Einstein, Edvard Beneš (co-founder of the League of Nations) and Václav Havel.

The Průhonice Park (the area of 211.42 ha) was founded in the year 1885 by the Count Arnošt Emanuel Silva-Tarouca. The result of his lifelong work is an original masterpiece of garden landscape architecture of worldwide importance. The park uses advantage of the miscellaneous valley of the Botič Stream and the unique combination of native and introduced exotic tree species. The Průhonice Park became in the time of its foundation the entrance gate to Bohemia (as well as to the whole Europe) for newly introduced plants. An integral part of the park is also a Neo-Renaissance country house. In the area there is also a small medieval church of the Nativity of the Virgin Mary.

Criterion (ii): The Historic Centre of Prague admirably illustrates the process of continuous urban growth from the Middle Ages to the present day. Its important role in the political, economic, social, and cultural evolution of Central Europe from the 14th century onwards and the richness of its architectural and artistic traditions meant that it served as a major model for urban development of much of Central and Eastern Europe.

Criterion (iv): Prague is an urban architectural ensemble of outstanding quality, in terms of both its individual monuments and its townscape, and one that is deservedly world-famous.

Criterion (vi): The role of Prague in the medieval development of Christianity in Central Europe was an outstanding one, as was its formative influence in the evolution of towns. By virtue of its political significance in the later Middle Ages and later, it attracted architects and artists from all over Europe, who contributed to its wealth of architectural and artistic treasures. The 14th century founding of the Charles University made it a renowned seat of learning, a reputation that it has preserved up to the present day. Since the reign of Charles IV, Prague has been intellectual and cultural centre of its region, and is indelibly associated with such world-famous names as Wolfgang Amadeus Mozart and Franz Kafka.

Integrity

All the key elements that convey the Outstanding Universal Value of this serial property are situated within the inscribed area. The boundaries and the areas of the two component parts of the serial property are adequate. At the national level, their buffer zones are defined in accordance with existing regulations. The two component parts have stabilized town-planning structures.

The integrity of the Historic Centre of Prague is threatened by the pressure of the developers wishing to build oversized new buildings in the historic centre and its buffer zone. For this reason, the height and volume of new buildings must be reviewed by competent authorities. The integrity of the Historic Centre of Prague is also threatened by an increasing development pressure on the roofscape and it might have a negative impact on the visual integrity of the city which has remained well-preserved so far. The integrity of the Průhonice Park is threatened by the pressure of urban development in its buffer zone. This fact is provoked by the location of Průhonice close to the capital city.

Authenticity

The Historic Centre of Prague is of high authenticity. It represents an organic urban development over more than a thousand years.

The degree of authenticity of single buildings or building complexes is also very high, especially in terms of preservation of their original plots, massing, structures, materials, decoration and architectural details, in spite of the fact that some adaptations and changes were made necessary to allow continued use. The present form and appearance of the Historic Centre of Prague reflect different stages of its centuries-long development, which also proves exceptionally valuable archaeological terrain, which is protected by law. The long tradition of conservation in Prague helps to keep the authenticity of the property. Restoration works are carried out in accordance with strict criteria and using historical materials and technological processes.

The Průhonice Park is of high authenticity concerning at its present form and appearance closely reflect an example of a uniquely preserved landscape park with its original combination of native and introduced tree species. This assertion is proved by the comparison of the present form with historical plans and other documents.

Annex III: Programme of the mission

<u>11 December 2024</u>

9:00-9:20 Tour of the Fanta building, official welcome

9:20-9:55 Presentation of the Historic Centre of Prague as a World Heritage property: the role of the Vyšehrad Railway Bridge from the point of view of heritage conservation and transportation, discussion *(Prague City authorities)*

9:55-10:30 Introductory presentation by the Railway Administration of the Vyšehrad Railway Bridge, discussion *(Railway Administration)*

10:30-11:00 Transport connections, urban planning, development of the area, presentation of transport requirements for railway connections and the general transport situation in Prague *(Deputy Mayor of Prague, Prague Institute of Planning and Development)*

11:00-13:00 Inspection of the Vyšehrad Railway Bridge with its surroundings and of the Prague panorama from two viewpoints (Letenské sady and Vyšehrad), site visit of the bridge: walk across the bridge and on the embankment

14:25-14:55 Information on the traffic requirements leading to the need to modernise the bridge – study of the Prague Railway Node, need for three tracks, suburban trains, discussion *(Railway Administration, Prague Institute of Planning and Development)*

14:55-15:40 Adjacent municipal districts, Prague 2 and Prague 5: development and needs of the area, opinion of the municipality, discussion *(authorities of Prague 2 Prague 5 districts)*

15:40-16:25 Information on other spatial options that were considered besides the modernisation of the bridge, presentation of the results of the competitive dialogue, discussion *(Railway Administration, A69 architectural studio)*

16:25-17:20 Cultural values of the Vyšehrad Railway Bridge ensemble, its contribution to the OUV of the World Heritage property 'Historic Centre of Prague', discussion *(National Heritage Institute)*

17:20-18:00 Virtual reality view of the winning bridge design, discussion

<u>12 December 2024</u>

9:00-9:30 Bridge solutions for trains, solutions for pedestrians and bicycle traffic, discussion *(Prague Institute of Planning and Development)*

9:30-10:00 Bridge condition and assessments carried out, discussion *(bridge engineers from SUDOP Prague and TOP CON Servis s.r.o.)*

10:00-10:45 Official speeches given by the Minister of Transport and the Director General of the Railway Administration

11:00-11:45 Scoping report of the Heritage Impact Assessment, discussion *(Michael Kloos)*

11:45-12:20 Winning design for the new bridge, discussion *(Iveta Torkoniaková Studio)*

12:20-13:05 Vyšehrad Railway Bridge ensemble*:* conclusion by the National Heritage Institute, discussion

14:00-16:00 Presentations by NGOs *(Výtoň 21, Nebourat, Nadační fond pro záchranu Vyšehradského železničního mostu)*

16:15-17:00 Experts' concluding remarks

Annex IV: List of participants

Ministry of Culture of the Czech Republic:

- Jiří Vajčner, Director of the Heritage Preservation Department
- Martin Zídek, Director of the Heritage Inspectorate Department
- Dita Limová, Head of UNESCO Affairs Unit, International Relations and EU Department
- Lada Pekárková, UNESCO Affairs Unit
- Renata Klímová, Cultural Heritage Section

National Heritage Institute:

- Naděžda Goryczková, Director General
- Věra Kučová, Head of the Division of Monuments with International Status
- Jan Holeček, Head of Heritage Preservation Division
- Jaroslav Podliska, Director of the Regional Office in Prague
- David Měska, Regional Office in Prague, National Heritage Institute
- Miloš Matěj, Methodological Centre for Industrial Heritage
- Michaela Ryšková, Methodological Centre for Industrial Heritage

Ministry of Transport:

- Martin Kupka, Minister of Transport

Prague City authorities:

- Petr Hlaváček, Deputy Mayor for Urban Development
- Zdeněk Völfl, Assistant of Deputy Mayor for Urban Development
- Eliška Kokinová, Cultural Heritage Section
- Jiří Skalický, Director of the Department of Heritage Protection
- Simona Vladíková Nesázalová, Head of the World Heritage Site Office
- Radka Šimková, Mayor of Prague 5 District
- Jan Recman, Deputy Mayor of Prague 2 District
- Tomáš Halva, Councillor, Prague 2 District

Railway Administration:

- Jiří Svoboda, Director General
- Pavel Paidar, Director of the Construction Preparation Department
- Vladimír Filip, Director of the Regional Directorate Prague
- Petr Hofhanzl, Director of the Construction Management West
- Mojmír Nejezchleb, Deputy Director General for Rail Infrastructure Modernisation
- Jiří Krouský, Project Manager of the Vyšehrad Railway Bridge project
- Martin Vaněk, Technical Specialist of the Construction Planning Department
- Andrea Janoudová, Communication Unit

Prague Institute of Planning and Development:

- Ondřej Boháč, Director
- Marek Zděradička, Deputy Director of the Institute, Director of Infrastructure Planning Section
- Kristýna Lhotská, Director of the Section of City Detail

<u>Czech Technical University in Prague</u>:

- Pavel Ryjáček, Head of the Department of Steel and Wooden Structures
- Jiří Kolísko, Director of Klokner Institute

<u>Other participants</u>:

- Michael Kloss, architect, urban planner (Michael Kloos Planning and Heritage Consultancy)
- Merve Demiröz-Torun, architect (Michael Kloos Planning and Heritage Consultancy)
- Iveta Torkoniaková, architect (Ing. Arch. Iveta Torkoniaková Studio 2T Engineering), author of the new proposal
- Jaroslav Wertig, architect (A69 architectural studio), consultant to the jury of the competition dialogue
- Libor Marek, bridge engineer (TOP CON servis s.r.o.), co-author of the new proposal
- Martin Vlasák, bridge engineer (SUDOP Prague), author of static calculation
- Jiří Jaroš, moderator

<u>Czech National Committee of ICOMOS</u>:

- Josef Štulc, Honorary President
- Karel Kuča, Vice-President
- Šárka Jiroušková, Specialist in industrial monuments

<u>NGOs</u>:

- *Výtoň 21*: Jiří Grund
- *Nebourat*: Ina Koldová, Pavel Štorch, Jiří Pospíšil, Petr Kutílek, Olga Peková
- *Nadační fond pro záchranu Vyšehradského železničního mostu*: Tomáš Bistřický, Ian Firth, Marek Kopec, Petr Tej, Petr Lhotan, Petra Tomášková, Petr Janda

Annex V: Glossary of technical terms

Equilibrium equation: in a planar truss – like the main girders of the bridge – the diagonals, chords and vertical intersect and are connected at “nodes”. Each member carries or transmits a (normal) force – tension or compression - to the node. The sum of the forces acting on a node should be in equilibrium (meaning zero). At each node, two equilibrium equations involving known and unknown forces can be written.

Statically determined (or isostatic): solving the system of equilibrium equations for all nodes is sufficient to determine the forces in all members. This analytical approach can be replaced by an equivalent graphical method for the determination of the forces acting in the members and on the nodes.

Statically undetermined (or hyperstatic): solving the system of equilibrium equations for all nodes is not sufficient to determine the stresses in each member. Other physical and mechanical considerations are needed in addition.

Yielding: a material like steel submitted to increasing stress first behaves in elastic state, with strain (deformation) proportional to stress; the coefficient of proportionality is called the elastic or Young’s modulus. This is the normal domain of service behaviour. Elastic behaviour is reversible (no permanent deformation at unloading) and the strains are quite small. This elastic behaviour is valid up to reaching a nominal stress level in the material called the yield strength; this is reached at a strain of about 0.12 % for mild steel. From then on, the stress is not able to increase whereas the strain can increase significantly: one speaks of a yield plateau. This is the domain of plasticity. At the end of the yield plateau (typically at 1% strain), another phase begins: hardening, with the stress being again – but very slowly – able to increase again until reaching a maximum stress called “tensile” strength at a deformation which is typically 30% for a mild steel. At that stage, the materials breaks (fails). The ability of the material to reach large deformation at failure is called “ductility”.

Bending moment: in whole generality, a member is submitted to an axial force and couples at its extremities (at the nodes). These end-couples induce a bending (or curvature) of the element and associated “bending stresses”. If the distribution of the bending moment varies along the element (usually the case), there will be in addition a shear force acting on the element perpendicular to its axis. The magnitude of the shear stresses is small and neglected in the computations.

Charpy test: after the tensile test, the Charpy test is the second most common test used to characterize metals. The tensile test and the Charpy test measure different properties. The tensile test will provide the yield strength and the tensile strength (both used in the calculations) and the extent of ductility. This is a test performed at room temperature and slow speed of loading or deformation. The Charpy test is an impact test (high rate of loading), often performed at different temperatures to detect the so-called transition temperature between the brittle and ductile behaviour. The Charpy test is performed in a laboratory with a pendulum where a hammer impacts a notched specimen. The notch induces a stress concentration and predefines the place where failure will initiate under the impact loading. If the energy necessary to break the specimen is small, this will be characteristic of a brittle behaviour, always unwelcome. Contrarily, if high energy is required to break the specimen, the material will be called ductile, or resilient. The Charpy test value is expressed in energy units, but the values are not used in the computations. The Charpy test is a technological test, used to compare steels with a standardized procedure. The Charpy value depends on the composition of the steel and the processes of its elaboration.

Annex VI: Figures

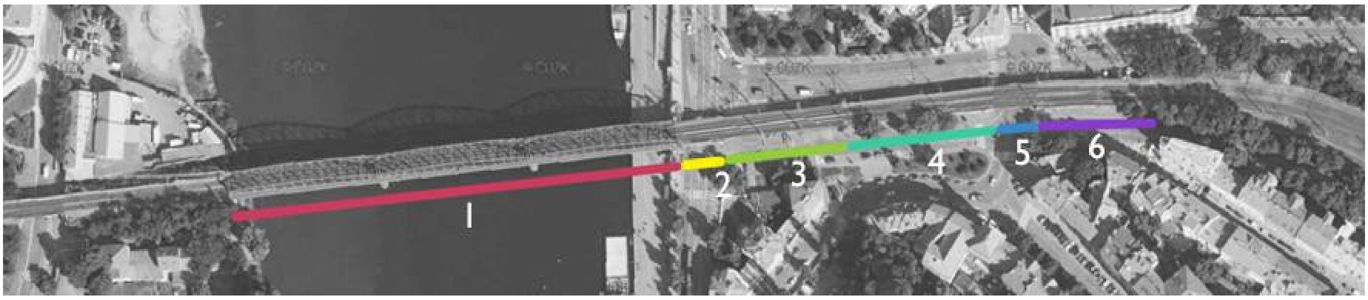


Fig. 1 The listed ensemble of Vyšehrad Railway Bridge (after NHI, slide 4, with additions).

1. Three span steel semi-parabolic truss bridge
2. Single span steel bridge
3. Three span steel bridge
4. Stone viaduct 8 arches – south part granite, north part sandstone
5. Single span steel bridge
6. Stone viaduct (5 arches – south part granite, north part sandstone)

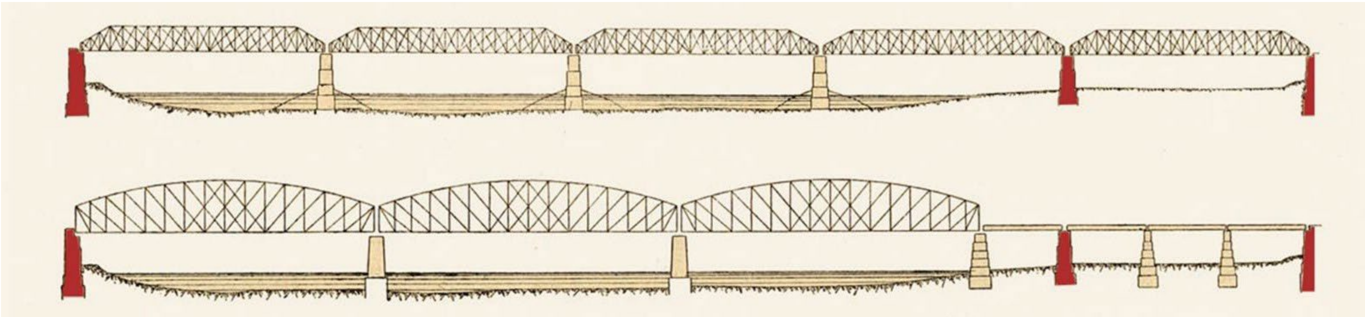


Fig. 2 The relationship between the 1872 and 1901 bridges (HNI, slide 15, reversed to align with Fig. 1.

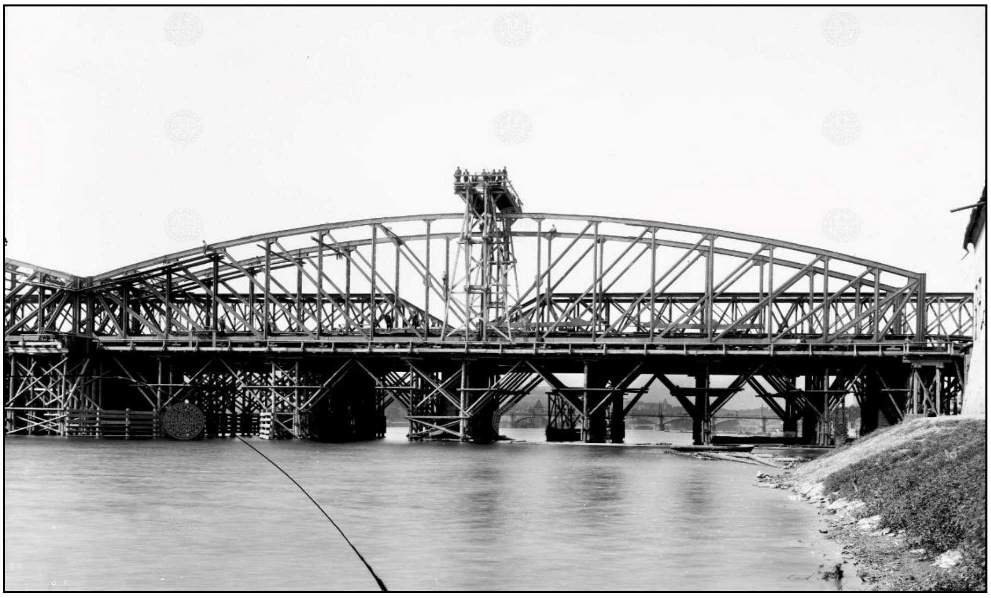


Fig. 3 The 1901 bridge in course of construction, with the 1872 bridge beyond (NHI, slide 10).

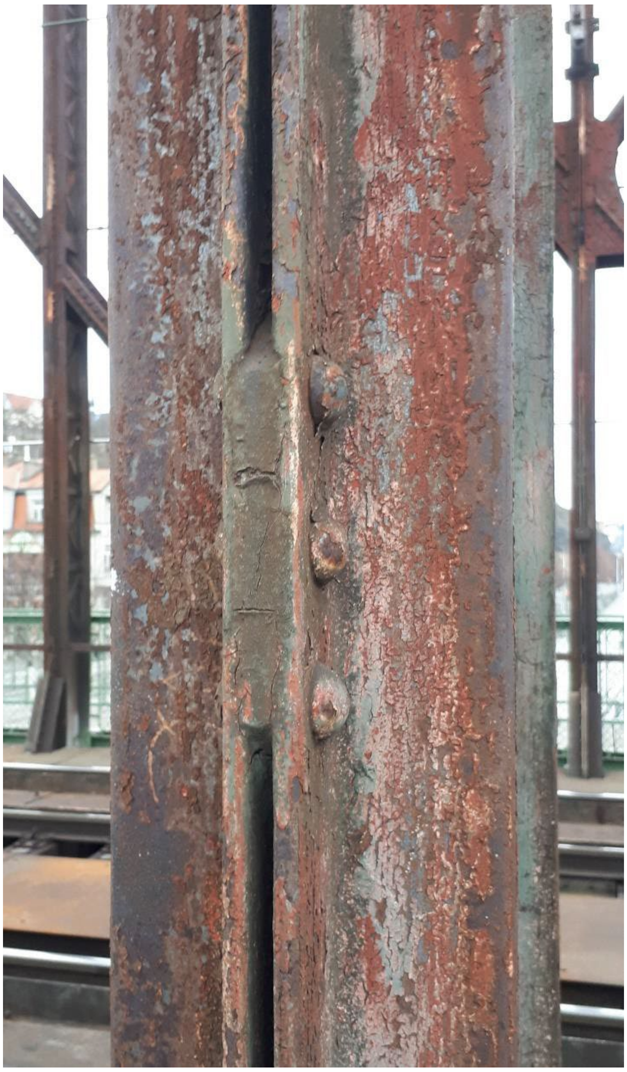


Fig. 4 Decaying paint layers on the steelwork of the bridge (Paul Drury, 11 December 2024).

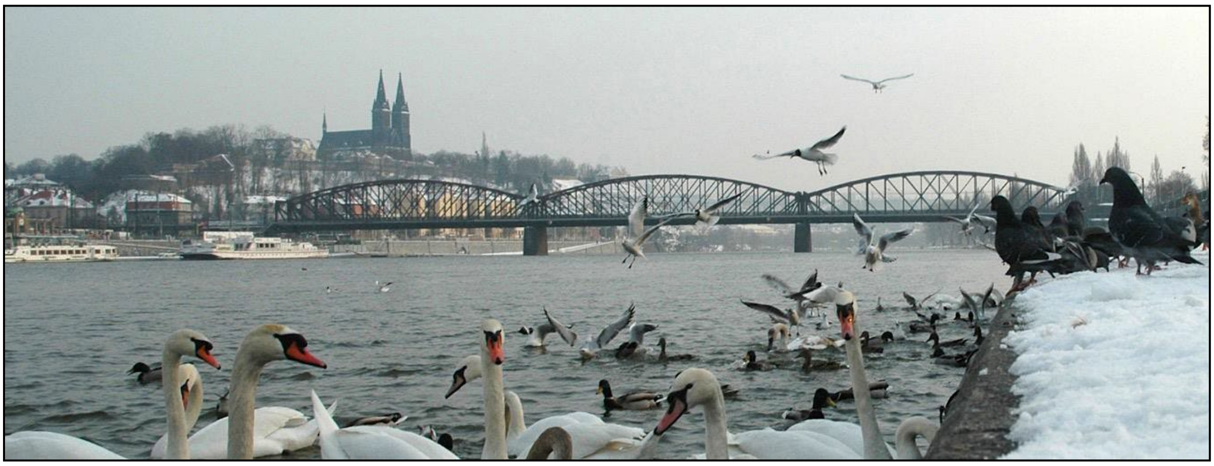


Fig. 5 The bridge, with Vyšehrad fortress and basilica in the background. Note how the appearance of the trusses varies according to the angle of view (NHI, slide 20).

Fig. 6 View from the Vyšehrad Fortress towards Prague Castle (Kloss slide 3, 20).

Fig. 7 The river bridge ensemble seen from the terrace of Kramářova villa (Kloos slide 23).

Fig. 8 Postage stamp from the 1970s (NHI, slide 24).


Fig. 9 Typical connection between diagonal, bottom chord and vertical, with angles and gusset plates connected with rivets. (B. Espion, 11 December 2024).

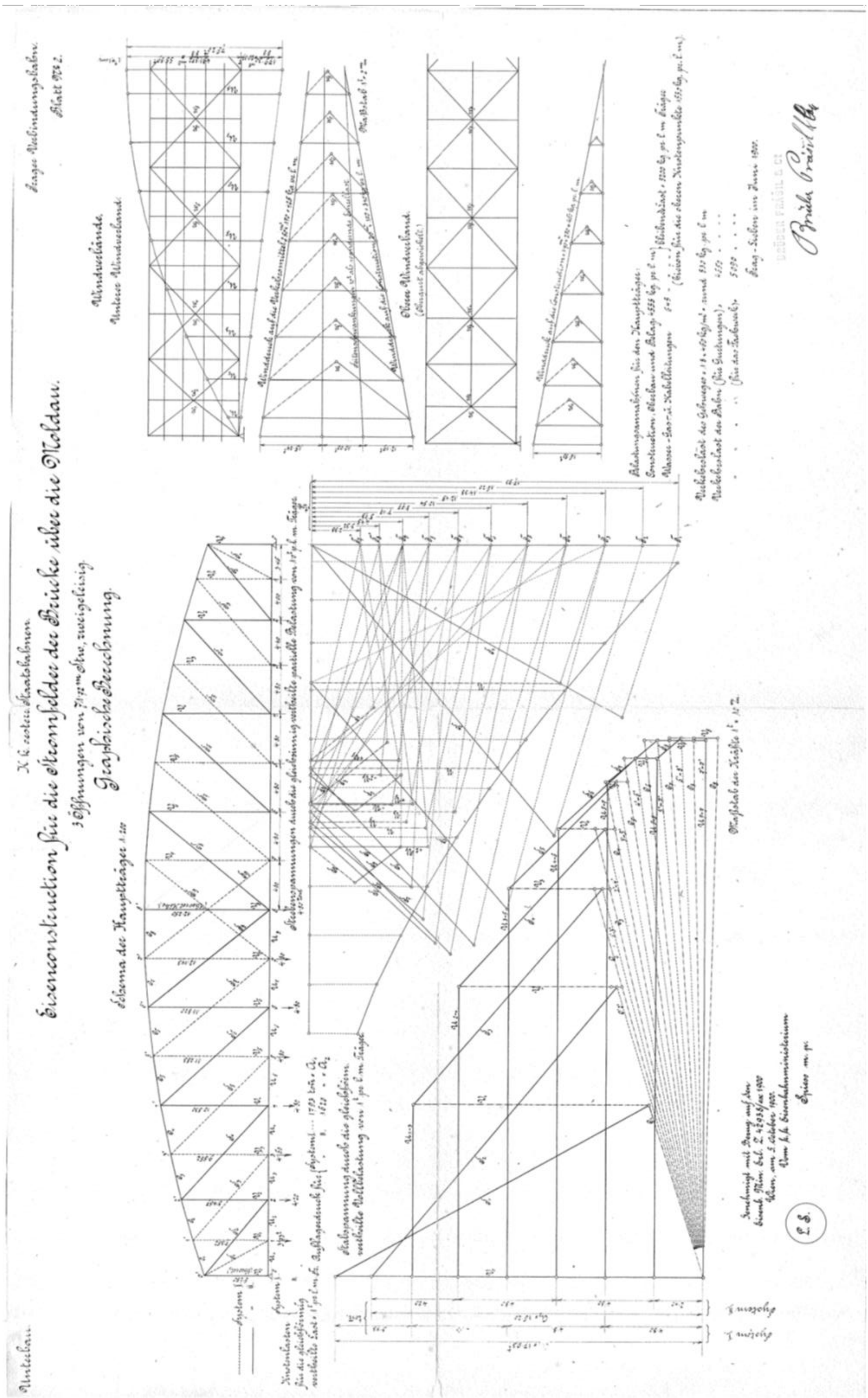


Fig.10 Typical graphical statics drawing (‘Graphische Berechnung’) from 1900 (Document with reference OK 002 A – (Osové schéma hlavního nosníku) from Správa železnic.

Fig. 11 Fatigue crack in stringer (B. Espion, 11 December 2024 (also in various documents).

Fig. 12 Example (worst case) of corrosion damage in a vertical (Slide 6 of the presentation by Martin Vlasák from SUDOP PRAHA a.s. on 12 December 2024; similar picture in Slide 25 of the presentation by Ian Firth on 12 December 2024.

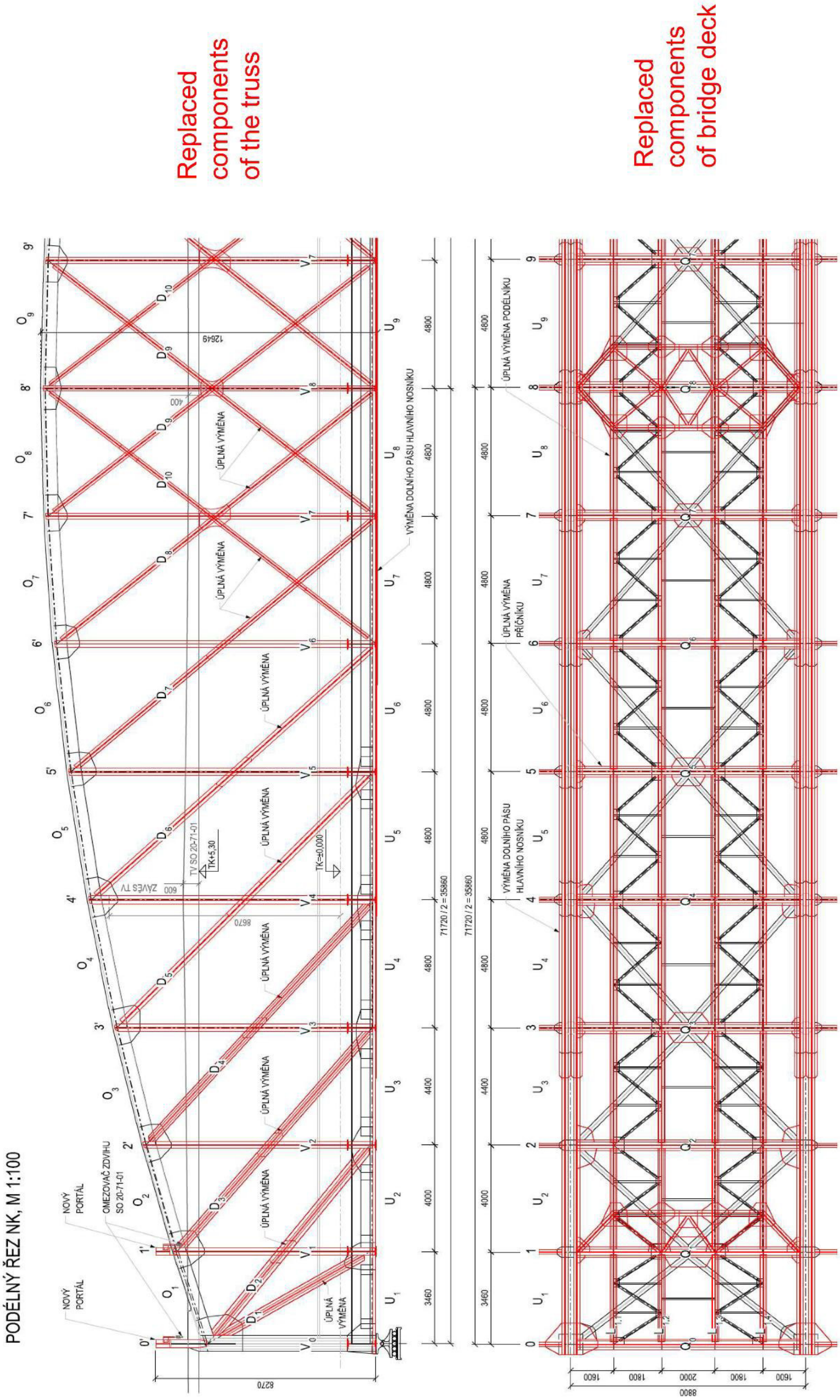


Fig. 13 Estimation of element replacement (63%) by SUDOP PRAHA a. s. (slide 23 of the presentation by Martin Vlasák on 12 December 2024).

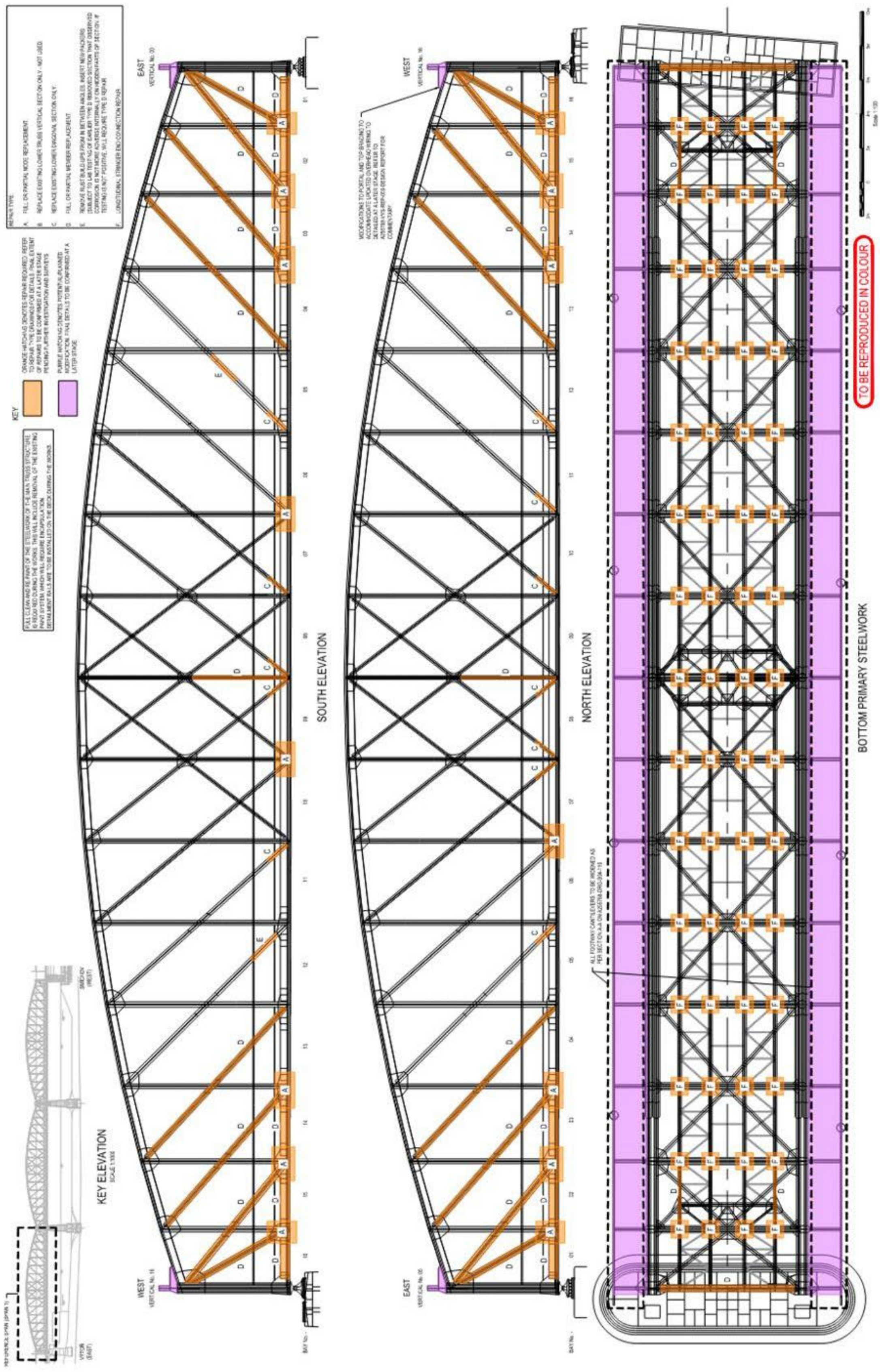


Fig. 14 Estimation of element replacement (15%) by I. Firth et al. (Slide 37 of the presentation by Ian Firth, 12 December 2024).

Fig. 15 Limited clearance (presently 3.1 m) under the last span of the viaduct Fig. 1, 2 before the trussed bridge 1 (P Drury, 11 December 2024).

Fig. 16 Mouth of the culvert allowing the Botič Stream to flow into the Vltava (P Drury, 11 December 2024, annotated).

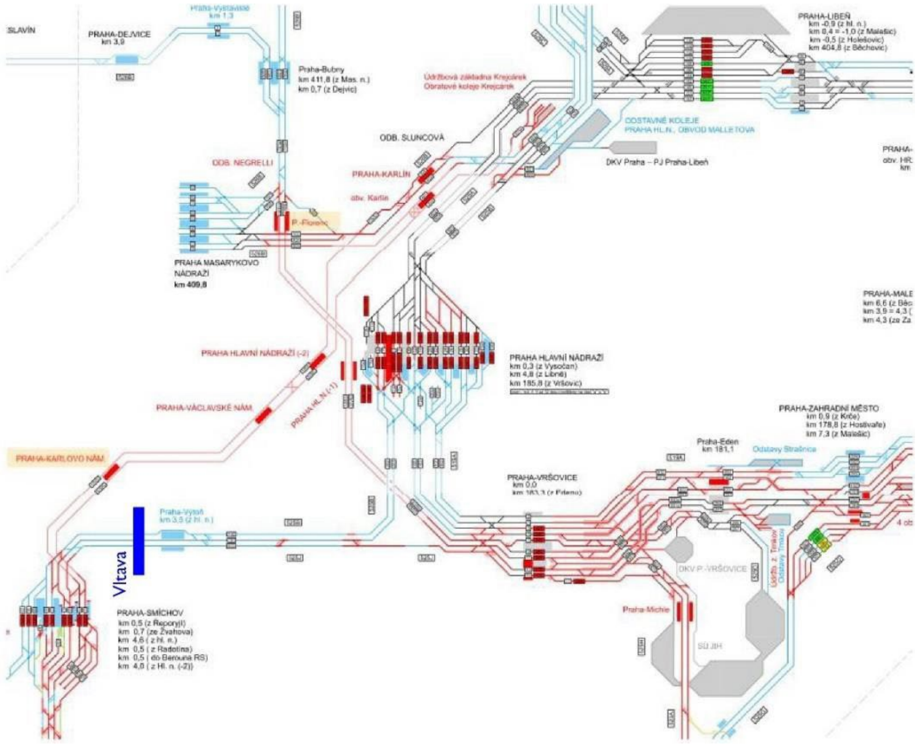


Fig. 17 Diagram of proposed development of the Prague railway hub (*The Feasibility Study for the Reconstruction of the Prague Railway Node, 2024* (from Kloos 2024, slide 47; Vltava added to locate bridge).

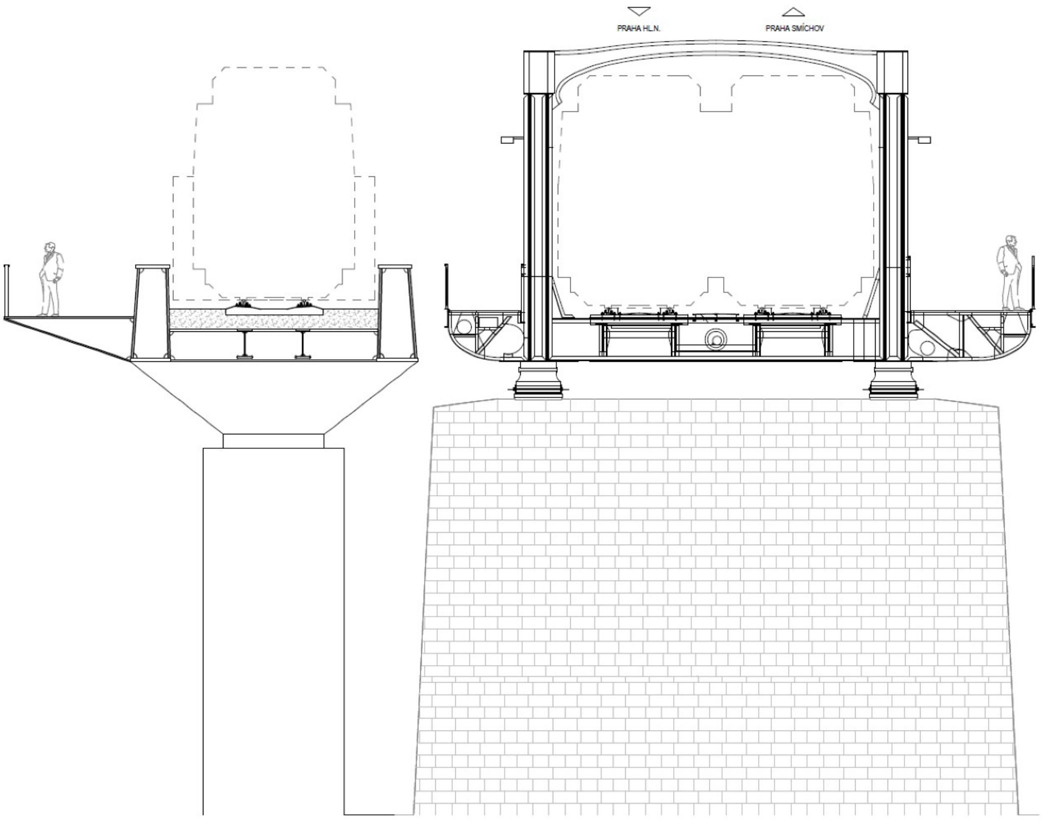


Fig. 18 Concept for third track and 3m wide pedestrian/ cycle path carried on a separate structure (Presentation 17, slide 77).

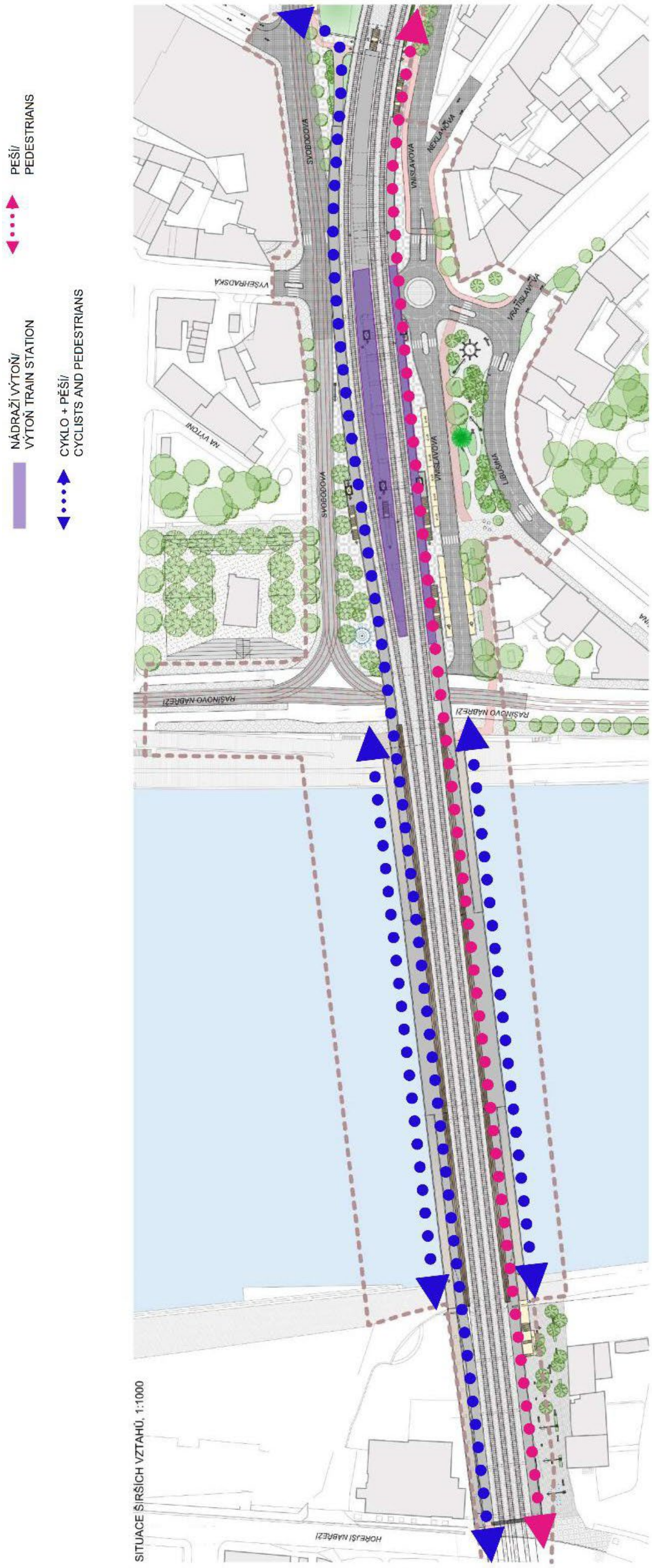


Fig. 19 Pedestrian and cycle traffic flows across a proposed replacement bridge (Správa železnic / 2T presentation, slide 14).

Fig. 20 Site plan: Alternative three-track scheme, track level (left), street level (right).

Fig 21: Detail: Alternative three-track scheme, track level, Výtoň.

Fig. 22 Detail: Alternative three-track scheme, street level, Výtoň.

Fig. 23 Detail: Alternative three-track scheme, track level, Vyšehrad.

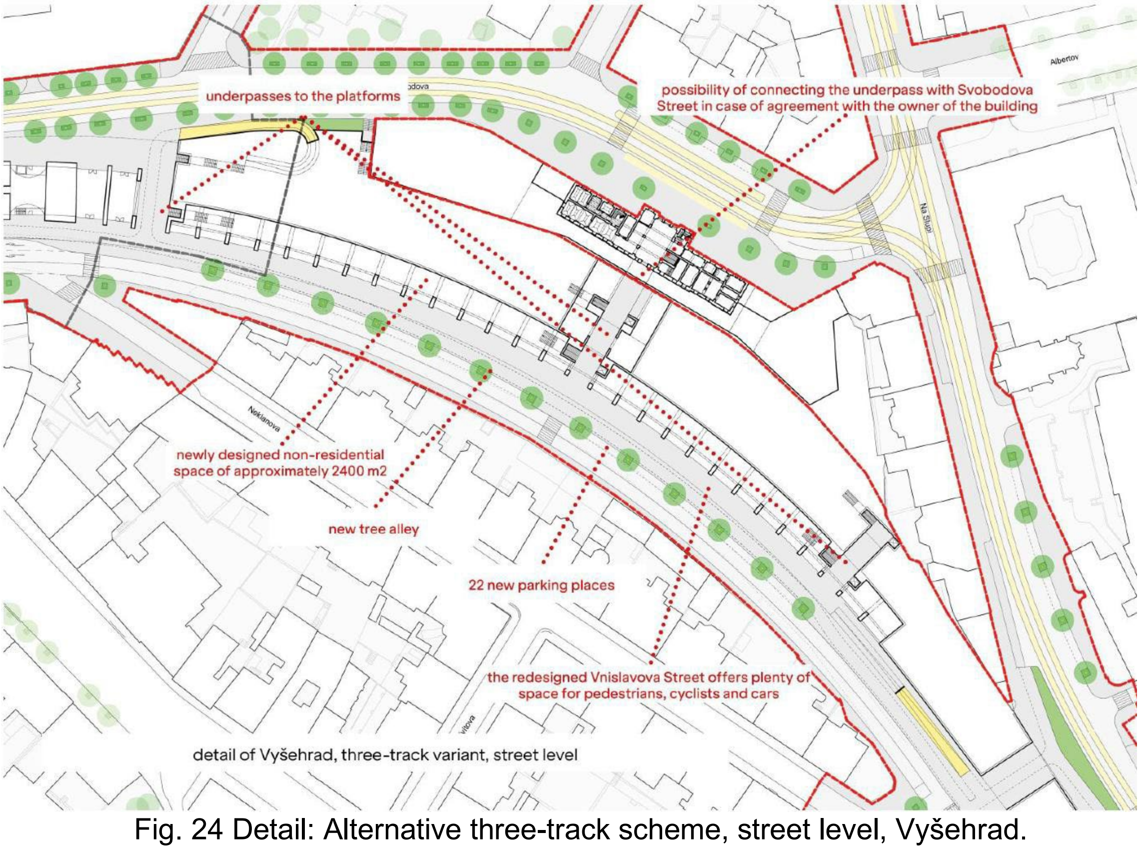
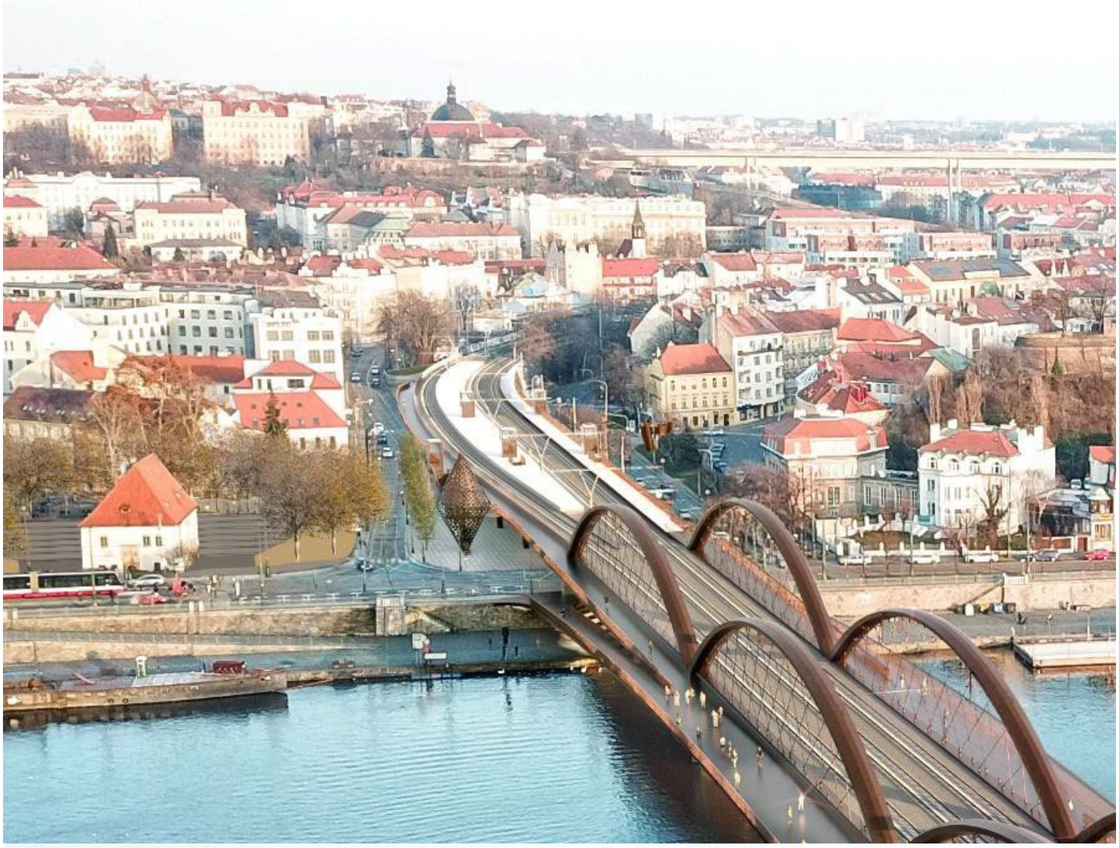


Fig. 24 Detail: Alternative three-track scheme, street level, Vyšehrad.



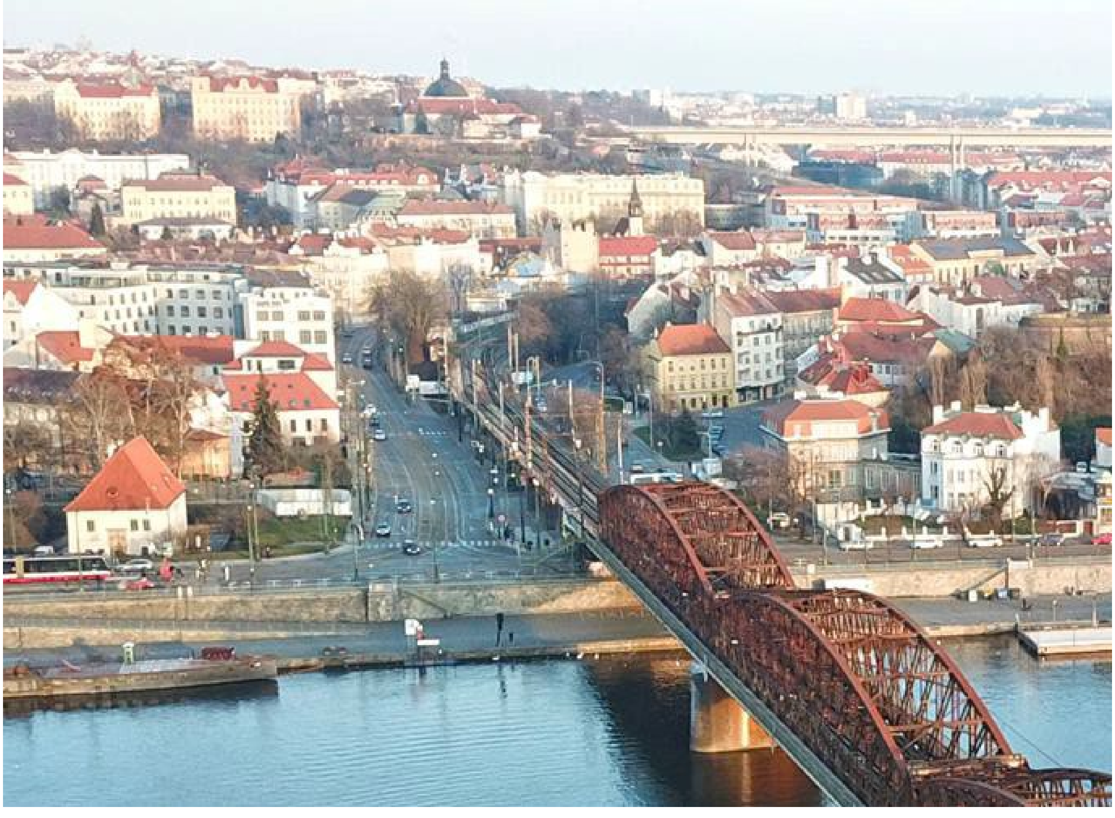


Fig. 25 Views as existing and with the proposed new Vyton Station (2T Engineering presentation, Slides 16-17), showing the space requirements of the station, horizontal and vertical (the latter presumably with canopies added to the platforms).