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THE MAJOR CHALLENGES FACING SLOVAK ROAD AND RAILWAYS INFRASTRUCTURE: CURRENT CONDITIONS, ADMINISTRATION AND PRIORITIES

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ABSTRACT: The aim of the paper is to assess the current condition of bridges in Slovakia with an emphasis on two key determinants: the ownership and administration of structures and their structural health condition. The study combines official data from the Road Database of the Slovak Road Administration (SSC), available information from the Slovak Railways (ŽSR), findings of the Supreme Audit Office of the Slovak Republic (NKÚ SR), and analytical outputs of the Value for Money Division (UHP). The paper presents an analysis of data related to ownership, administration, categories of current health condition, and accompanying documentation, providing a transparent overview of where the highest risks are concentrated. These infrastructures were identified for the purposes of the REMAKE 3D project. As part of this project, several activities were undertaken to collect information and data; however, such information is often inaccessible or does not exist. The paper includes details about bridge ownership based on a comparison of owner databases, a BIM model of bridge M7441, and an example of image processing for defect detection. The conclusion and discussion section outlines proposals for future research.

KEYWORDS: *Bridges, Road Infrastructure, Railway Infrastructure, Model.*

INTRODUCTION

The health condition of Slovakia bridges in the first quarter of the twenty-first century is alarming. In recent years, Slovakia has joined the group of European countries that have recorded bridge collapses. As illustrated in Figure 1, this group also includes neighbouring Czechia, as well as Germany and Italy. In Slovakia various type of prestressed girders are used for many years and after the years in services the numbers of defects on precast prestressed girder are presented as removed concrete cover, corroded tendons with some ruptured wires, corroded anchors, water leakage through the carriageway and insulation, overloading of construction, hollow space or voids within concrete caused during casting of the girder, absence of shear reinforcement in prestressed girders, minimal reinforcement ratio was not fulfilled, absence of bonded post-tensioned prestressing, inadequate grouting of tendons and incorrect position of girders on the bearings as reported in Bujnakova (2017) and Bujnakova (2020). In other cases, collapses were triggered by hydraulic and geotechnical hazards such as scouring at foundations followed by slope instability, or by acute external actions attributable to the human factor, exemplified by the road bridge in Baltimore (USA) where a large, uncontrolled vessel impacted the structure. Slovakia's challenges are further compounded by ageing infrastructure, exposure to increasingly volatile hydrological events, and fragmented ownership and management responsibilities. These systemic factors shape inspection regimes, maintenance planning, and the timeliness of interventions, and they strongly influence the distribution of bridges across the poorest condition categories. The result is a widening gap between identified needs and executed work, with mounting operational restrictions and growing lifecycle costs.

In Germany, a bridge collapsed in September 2024 in the city of Dresden. The investigation found that the bridge, completed in 1971, had suffered corrosion damage during its construction through a combination of manufacturing methods employed 50 years ago and the influence of the weather on the steel during construction. This corrosion, combined with material fatigue caused by traffic stress, led to the bridge's failure. Over 68% of the tendons in the carriageway on the collapsed section were found to be severely damaged to the point of failure (Gerrard, 2024).

Figure 1 Map of countries that have experienced recent bridge collapses (Moravcik 2025)

In Italy, the Morandi Bridge in Genoa collapsed on 14 August 2018 primarily due to long-term corrosion damage to the prestressing tendons within the reinforced-concrete stays at Pier 9, which precipitated a sudden failure of the load-bearing system and a subsequent progressive collapse of the span; 43 people were killed. Corrosion was accelerated by increased moisture and chloride exposure in the marine and industrial environment, while the low-redundancy design (few load-carrying elements per pylon) and inadequate maintenance or monitoring progressively eroded the structure's reliability margins (Ponte Morandi 2025). Unfortunately, this is not an isolated case in Italy (Figuli 2021).

In Slovakia, the number of collapsed bridges has been steadily increasing. A pedestrian bridge collapsed in Spišská Nová Ves in 2020, followed by further incidents in Trstená over the Oravica River in 2021. In the past, a pedestrian bridge over the Turiec River collapsed in 2006, despite an inspection performed just one year earlier. Other reported cases include failures in Brodské and Chorvátsky Grob. The primary causes of these failures in Slovakia include ageing infrastructure, delayed allocation of financial resources, and untimely preventive measures. All these factors highlight the resilience—or lack thereof—of bridge structures and their structural health condition, which is the focus of this paper. The condition assessment is presented in Figure 2, accompanied by Table 1, which lists the exact numbers of bridges in each condition category according to the Slovak Road Administration Annual Report from 2023 (published in 2024).

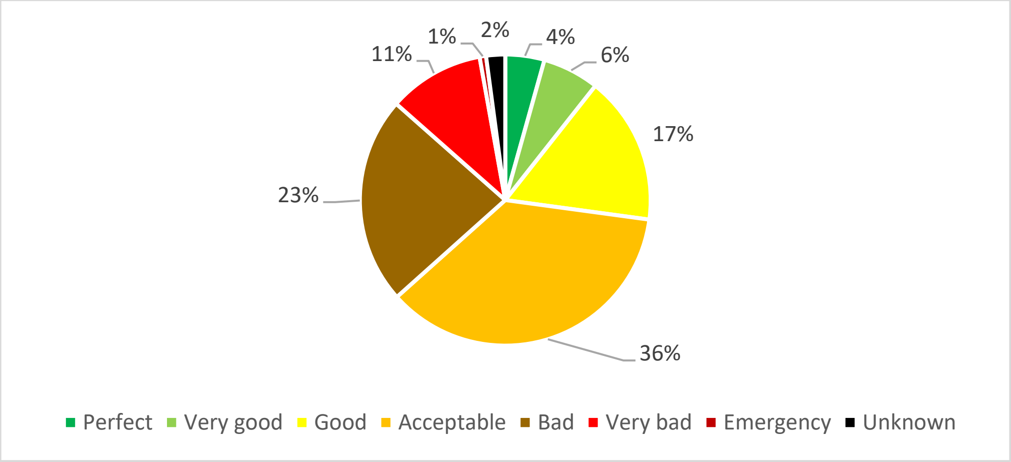


Figure 2 Classification of bridges according to structural condition

An initial examination of Table 1 does not reveal any fundamental problems; nevertheless, in terms of the evolution of the structural condition of bridges in Slovakia, it is important to reiterate the negative trend.

Table 1 Number of Bridges in each structural condition (Slovak Road Administration, 2024)

Structural conditions	Number of Bridges
Perfect	361
Very good	522
Good	1370
Acceptable	3008
Bad	1918
Very bad	885
Emergency	59
Unknown	176

Looking retrospectively, Slovakia's bridges were in better condition ten years ago, in 2015. For comparison, there were 522 bridges in perfect condition, 707 in very good condition, and 3,012 in good structural condition. In 2015, only 25 bridges in Slovakia were classified as being in emergency condition. Ten years later, this number has more than doubled. This trend is driven by several factors, which are analysed in detail in the second chapter of this article.

1. INFRASTRUCTURE PROJECT APVV REMAKE 3D

For the purposes of this paper, the challenges and proposed solutions focus on bridges identified within the APVV REMAKE 3D project (Figuli, 2025). These structures were selected following an initial screening of the area in the vicinity of the district town of Púchov. Table 2 lists 20 items of transport infrastructure; in addition to bridges, the project scope also includes the dam of the Nosice Reservoir, the Diel Tunnel carrying the new high-speed railway corridor between Bratislava and Žilina (ŽSR, 2024), as well as a pedestrian underpass and a pedestrian footbridge (Doprastav, 2025).

Table 2 Type of infrastructure of Púchov district (Figuli, 2025)

No.	Type of infrastructure	Title	Owner	Structural Conditions	Documentation
1	Dam wall	Nosice Dam	Slovak Water Management Company	???	Confidential
2	Footbridge	Footbridge for passengers and general public	Púchov City	Perfect (1)	Bridge record, overview drawing, technical inspection
3	Road bridge	???	???	???	???
4	Road bridge	???	???	???	???
5	Road bridge	???	Agricultural Cooperative Mestečko	???	???
6	Railway bridge	Viaduct	Slovak Railways	Perfect (1)	Scan
7	Railway bridge	Viaduct	Slovak Railways	Perfect (1)	Scan
8	Railway bridge	Viaduct	Slovak Railways	Perfect (1)	Scan
9	Railway bridge	Viaduct	Slovak Railways	Perfect (1)	Scan
10	Railway bridge	New railway bridge over Nosický canal	Slovak Railways	Perfect (1)	FEM model, drawings
11	Underpass	Underpass for passengers of Railway Station Nosice	Slovak Railways	Perfect (1)	???
12	Railway bridge	New railway bridge over Váh	Slovak Railways	Perfect (1)	???
13	Road bridge	New road bridge in 159,506	SC of Trenčín district	Perfect (1)	Technical inspection, drawing, FEM model
14	Road bridge	Road bridge over railway in 158.120	Slovak Road Administration	Good (3)	Bridge notebook, drawings, technical report
15	Road bridge	Road bridge Prístovec in Púchov	Slovak Road Administration	Good (3)	Bridge notebook
16	Road bridge	49_061 Road bridge over Váh in Púchov	Slovak Road Administration – IVaSC Žilina	Bad (5)	Complet project documentation, scan
17	Road bridge	Road bridge near Nimnica on the road 507	SC of Trenčín district	Bad (5)	BIM model, Concrete hardness test
18	Bicycle bridge	Cycling bridge near road 507	Out of Púchov territory	???	???
19	Road bridge	Road bridge over the Nimnický Brook	???	???	???
20	Railway tunel	Tunnel Diel	Slovak Railways	Perfect (1)	???

In Table 2, several information gaps are evident and clearly visible, along with an excessive number of different owners and administrators within the relatively small area of the town of Púchov. The table also identifies bridges in poor condition, for which preventive measures to enhance their resilience should be adopted.

2. THE CHALLENGES IN ACHIEVING BETTER STRUCTURAL HEALTH OF TRANSPORT INFRASTRUCTURE

The first and most obvious factor is structural conditions and negative trend of bridges in Slovakia observed over recent years. For example, Figuli (2021) reports poor bridge conditions not only in Slovakia but also in Italy. Bujňáková (2020) describes this phenomenon as a growing risk for prefabricated bridges, of which there is an extremely large number in Slovakia. In another publication, Miške (2025) presents results on how strongly the structural condition depends on the year of construction. But the dependence is found to be very weak, suggesting that older bridges do not necessarily tend to be in worse condition in comparison to new bridges (Figuli 2023). Which determinants can be considered most influential in explaining the adverse progression of the bridge conditions? From the perspective of road and deck quality, the most problematic seasons are summer and winter. Overloaded heavy goods vehicles constitute the most immediate risk. Field enforcement is challenging static weigh stations have limited capacity, mobile weighing is costly and coordination intensive. A practical response combines several measures (Slomka-Slupik 2021):

- Weigh-In-Motion (WIM) gates on major corridors and ahead of sensitive bridges, with automated screening and notification for targeted pullovers,
- Geofencing and permitting regimes for oversize or overweight transports (mandated routes, time windows, escorts),
- Control of axle loads and load distribution,
- Dynamic restrictions (temporary speed reductions, one-way operation over the bridge) where diagnostics indicate reduced residual capacity.

At the sub-national level, it is advisable to install local WIM lines on approach roads to industrial zones and link them to a maintenance prioritisation model: bridges exposed to a high share of heavy goods traffic should have shorter inspection cycles, earlier prescribed diagnostic tests, and timely strengthening of critical details like waterproofing, drainage, deck surfacing, reinforcement protection. This approach minimises the risk of sudden operational restrictions and extends the bridge’s lifecycle at acceptable cost.

Secondly, another fundamental problem is the fragmentation of the bridges in terms of ownership and management. In practice, this results in non-standardised assessment procedures, differing levels of maintenance, divergent priorities in the allocation of financial resources, and variable decision quality often determined by the internal rules of a given owner. Within the set of 20 transport objects included in the REMAKE 3D project, as many as eight different owners were identified, illustrating the degree of fragmentation. In addition to municipalities and self-governing regions, other administrators include the National Highway Company (NDS), the remaining regional road authorities, and private owners. This diversity translates into disparities in capacities (staffing, technical, and process), in the periodicity and quality of inspections, in the methodologies used (e.g., the scope of diagnostics and the use of non-destructive testing). The consequence is that the same types of defects may be evaluated differently, and identical risks may receive different intervention priorities across administrators (Alonso 2023).

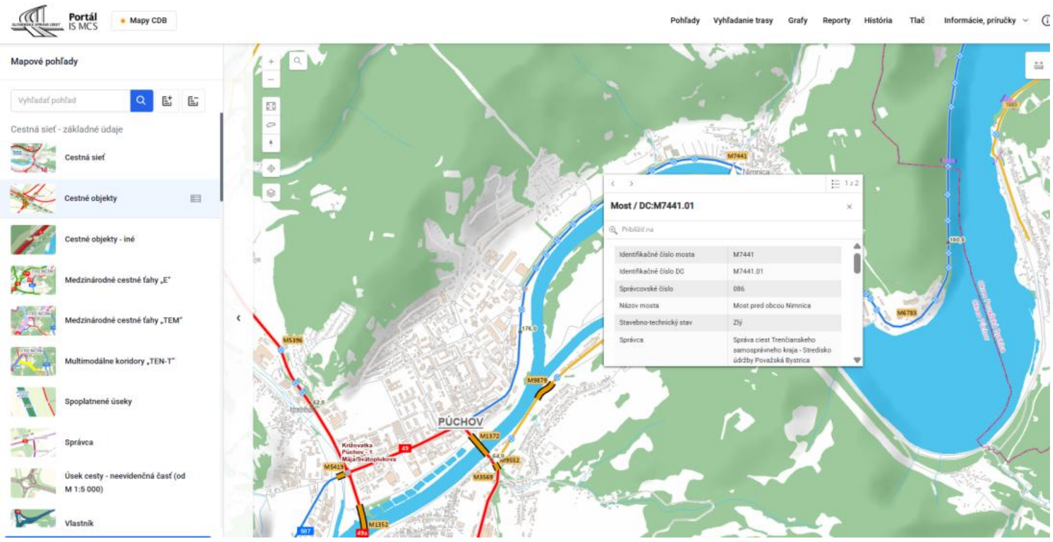
Figure 3 Defects on bridge M7441 (Figuli 2025)

NDS typically exhibits a more favourable condition profile, largely due to a higher share of newly built sections (e.g., the Višňové tunnel and bypass links around Bratislava) and relatively more stable financing from the state budget and European funds. By contrast, sub-national administrators of class II/III roads often operate with constrained budgets and less accessible project preparation, which leads to deferred rehabilitation and faster degradation of bridges with higher age and traffic loading.
The key system-level response is to unify the rules across owners by:

- Harmonising inspection methodologies and condition classification,
- implementing risk-based prioritisation (combining condition, network criticality, and detourability),
- introducing multi-year rehabilitation programmes with transparent funding allocation,
- setting minimum standards for diagnostics and record-keeping (including open data),
- and strengthening the capacities of smaller administrators through methodological and technical support.

According to Table 2, another major issue concerns technical documentation. Each bridge owner is responsible for maintaining a complete record set; in practice, however, files are frequently incomplete, outdated, or missing altogether. In the REMAKE 3D sample, for nearly half of the twenty identified objects it was impossible to retrieve the documents needed to streamline the project workflow. For some bridges, e. g. bridge M7441 in Nimnica, the entire dossier had to be reconstructed: the concrete strength class was unknown, technical drawings were obsolete, and the bridge record card contained insufficient data. One of the few available documents was an inspection report, which confirms that the bridge is in poor structural condition and recommends preventive measures to improve resilience and extend service life. Without such measures, temporary replacement and full rehabilitation are likely.

By comparing the individual information systems of the owners referenced in the APVV REMAKE 3D project, we can also illustrate their ability to maintain bridges, keep information up to date, and, consequently, manage documentation. In terms of clarity and the ability to retrieve data, the best information system is operated by the Slovak Road Administration (SSC), where it is possible to view the necessary bridge information under the sections “Road Structures” and “Other Road Structures.” An example from the Slovak Road Administration database is shown in Figure 4. In the illustration, bridge M7441 is selected; the filter provides key details such as the bridge ID, year of construction, structural/technical condition, owner, and the estimated load-carrying capacity.



Most / DC:M7441.01

Identifikačné číslo mosta	M7441
Identifikačné číslo DC	M7441.01
Správcovské číslo	086
Názov mosta	Most pred obcou Nimnica
Stavebno-technický stav	Zlý
Správca	Správa ciest Trenčianskeho samosprávneho kraja - Stredisko údržby Považská Bystrica

Figure 4 Road databank of the Slovak Road Administration

Another owner of bridges within the Púchov area is the Trenčín Self-Governing Region. However, its information system for road structures, in Figure 5, provides only a map of the so-called Road Maintenance Districts and the classification of the respective roads. It is not possible to retrieve more detailed information or inspection results for specific road bridges. Most information can ultimately be found in the national Road Database. This may explain why the Trenčín Region does not offer the same information-system capabilities as the Slovak Road Administration.

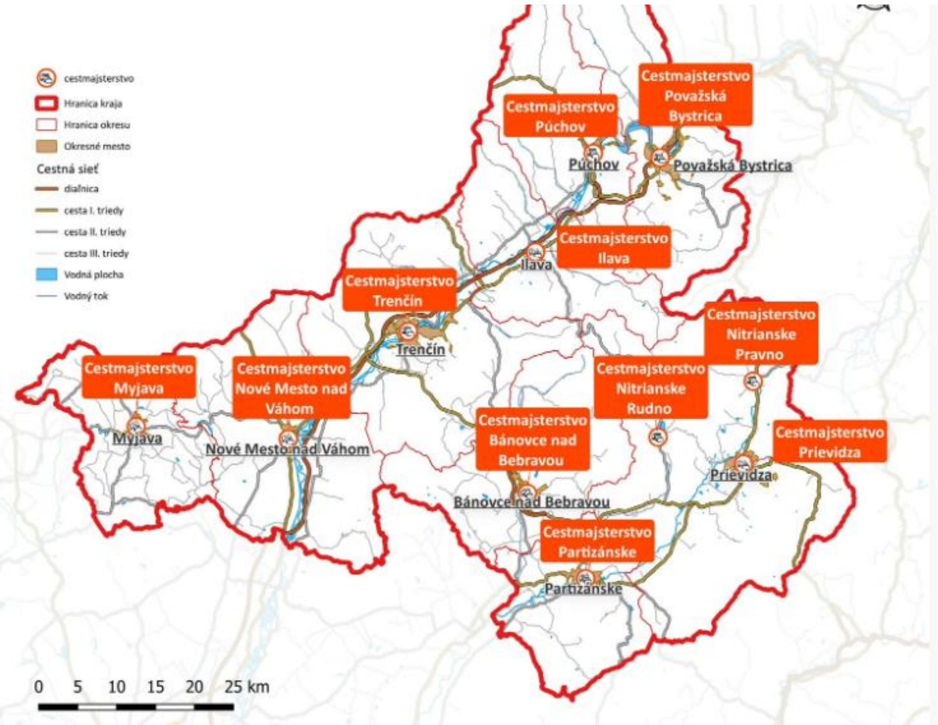
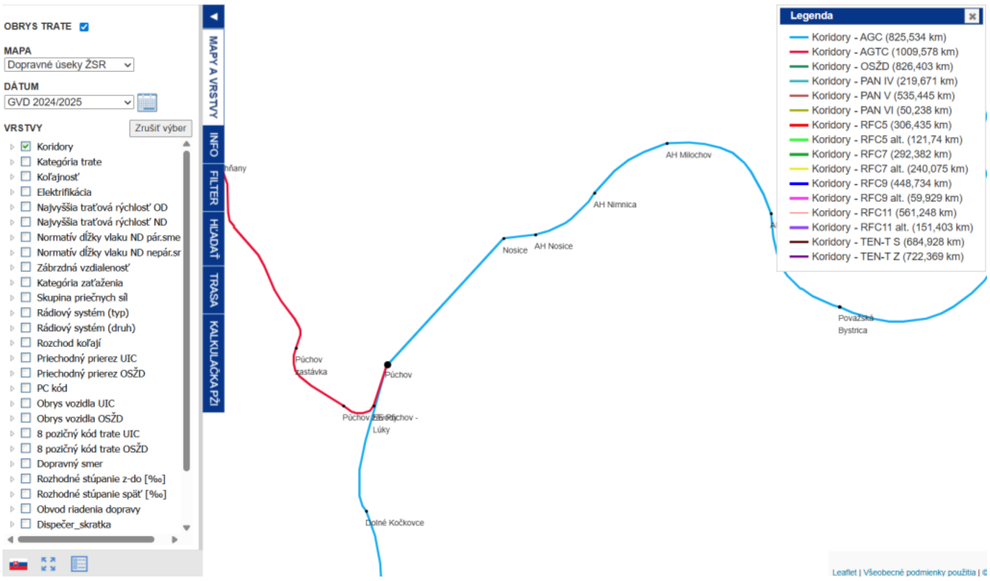


Figure 5 Road administration of the Trenčín Region

The last information system is the Information System of the Railways of the Slovak Republic (Figure 6). However, this system is highly non-intuitive. It does not provide options to display different layers; only the routes i.e., railway corridors that are highlighted on a plain white map background. As with the Trenčín Region's information system, it does not offer details on railway infrastructure such as bridges or tunnels. Information on railways is tightly guarded and generally inaccessible to the public, primarily for security reasons.



OBRYS TRATE ☑

MAPA
Dopravné úseky ŽSR

DÁTUM
GVD 2024/2025

VRSTVY
- ☑ Koridory
- ☐ Kategória trate
- ☐ Koľajnosť
- ☐ Elektrifikácia
- ☐ Najvyššia traťová rýchlosť OD
- ☐ Najvyššia traťová rýchlosť ND
- ☐ Normatív dĺžky vlaku ND pár.sme
- ☐ Normatív dĺžky vlaku ND nepár.sr
- ☐ Zábrzdná vzdialenosť
- ☐ Kategória zaťaženia
- ☐ Skupina priečnych síl
- ☐ Rádiový systém (typ)
- ☐ Rádiový systém (druh)
- ☐ Rozchod koľají
- ☐ Priechodný prierez UIC
- ☐ Priechodný prierez OSŽD
- ☐ PC kód
- ☐ Obrys vozidla UIC
- ☐ Obrys vozidla OSŽD
- ☐ 8 pozičný kód trate UIC
- ☐ 8 pozičný kód trate OSŽD
- ☐ Dopravný smer
- ☐ Rozhodné stúpanie z-do [‰]
- ☐ Rozhodné stúpanie späť [‰]
- ☐ Obvod riadenia dopravy
- ☐ Dispečer_skratka

Legenda
- Koridory - AGC (825,534 km)
- Koridory - AGTC (1009,578 km)
- Koridory - OSŽD (826,403 km)
- Koridory - PAN IV (219,671 km)
- Koridory - PAN V (535,445 km)
- Koridory - PAN VI (50,238 km)
- Koridory - RFC5 (306,435 km)
- Koridory - RFC5 alt. (121,74 km)
- Koridory - RFC7 (292,382 km)
- Koridory - RFC7 alt. (240,075 km)
- Koridory - RFC9 (448,734 km)
- Koridory - RFC9 alt. (59,929 km)
- Koridory - RFC11 (561,248 km)
- Koridory - RFC11 alt. (151,403 km)
- Koridory - TEN-T S (684,928 km)
- Koridory - TEN-T Z (722,369 km)

Figure 6 Information system of Slovak Railways

Unfortunately, none of the other owners of bridges in the APVV REMAKE 3D project have any information system or database. The unavailability of key information can lead to incorrect managerial decisions, which in turn may negatively affect the structural condition of the road or railway infrastructure.

The value of documentation is not merely archival, it directly affects diagnostic accuracy, load-rating reliability, the choice of intervention, and cost. Absent or inconsistent records demand conservative assumptions, additional testing, and redesign effort delaying decisions and inflating budgets. Conversely, a current, standardised dossier enables risk-based prioritisation and reduces the probability of over or under design.

To address these gaps, we propose a minimum “Bridge Documentation Set” and a process for its upkeep:

- Core records: as-built drawings, material specifications (including concrete strength class and reinforcement details), design load model, expansion joints/bearings data, and waterproofing details,
- condition history: full inspection lineage, defect logs with geolocation, photographs, and repair records,
- capacity evidence: calculations or load ratings, results of non-destructive tests (rebound hammer, UPV, GPR), cores where applicable, and any finite-element models.
- administrative data: ownership and manager of record, traffic class, detour availability, and criticality ranking,
- digital management: a common data environment (CDE) with version control, mandatory metadata, and open exchange formats, e. g. IFC/BIM, PDF/A, scheduled reviews tied to inspection periodicity.

For bridge M7441 specifically, priority actions include targeted material identification (cores with chloride profiling and carbonation depth), verification of reinforcement from GPR, bearing and joint assessment, and an updated load rating. Preventive measures should favour incremental, cost-effective interventions localized concrete repair and re-alkalisation where feasible, cathodic protection or corrosion inhibitors on high-risk zones, waterproofing and drainage upgrades, and deck surfacing improvements before committing to major capital works. This staged approach preserves safety, extends service life, and optimises limited budgets (Alonso 2023). A BIM model was also created for bridge M7441, as the available documentation was outdated and lacked sufficient technical detail. BIM is widely used today and offers numerous applications throughout the project lifecycle.

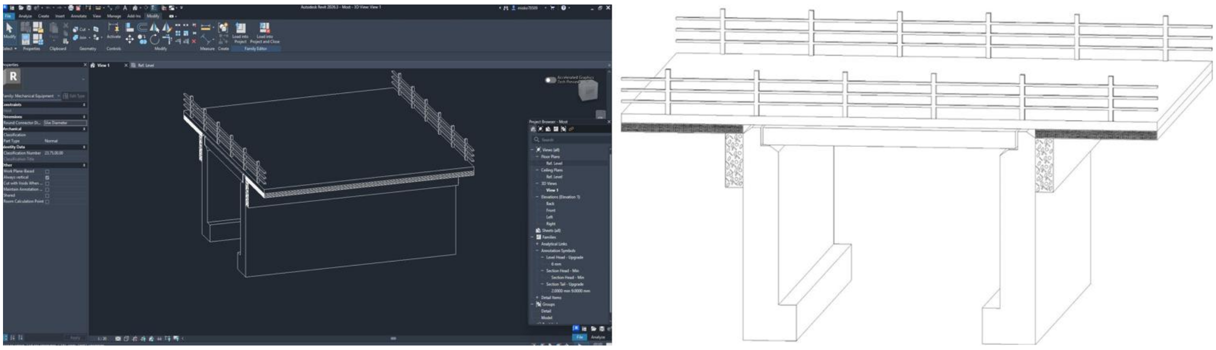


Figure 7 BIM model of M7441 bridge

DISCUSSION AND CONCLUSION

The analysis shows that the condition of bridges in Slovakia results from a confluence of technical, organizational, and process factors. The negative trend in structural condition is not driven by age alone, but primarily by environmental exposure (chlorides, hydrological extremes, thermal cycles), heavy-traffic loading, and uneven quality of asset management. Ownership fragmentation and divergent inspection methodologies lead to inconsistent diagnostics, differing priorities, and delayed implementation of interventions. A critical risk accelerator is incomplete or missing documentation, which increases uncertainty in load-rating, inflates preparation costs, and slows decision-making.

In general, the risk landscape is broader than discussed here. Nevertheless, from a practical bridge-management perspective, these three risks are foundational and tightly interlinked with others that are either seasonal such as floods, scour, freeze–thaw damage, or landslides, or as extraordinary, including accidental impacts (ships, vehicles), fires, or rare geotechnical failures. Climate variability amplifies several of these hazards by increasing hydrological extremes and thermal gradients, which in turn accelerate deterioration mechanisms already highlighted. Crucially, the three core risks act as multipliers: poor condition and fragmented ownership reduce preparedness and slow interventions, while documentation gaps hinder rapid diagnostics during emergencies. Addressing the core set through harmonized inspections, risk-based prioritisation, and robust documentation, therefore delivers co-benefits: it improves resilience to seasonal stresses, shortens recovery after extraordinary events, and reduces the likelihood that a local defect cascades into a network-level disruption.

Practice points to core recommendations are:

- harmonise inspection methodologies and condition classification across owners and link them to shorter inspection cycles for bridges with high heavy-goods traffic shares,
- implement risk-based prioritisation and multi-year rehabilitation programmes tied to risk, network criticality, and detour ability, with transparent funding allocation,
- establish a minimum Bridge Documentation Set and manage it within a common data environment, including systematic collection of diagnostic data and updated load-capacity calculations.

The deployment of WIM systems, geofencing for oversize or overweight transport, and operational restrictions where residual capacity is reduced lowers fatigue effects and the risk of sudden operational limitations. Overall, shifting from reactive to proactive, data-driven bridge management is key to improving safety, resilience, and the efficiency of public expenditures. Of course, there are also some strategies such as implementation of advanced technologies (UAV for defect detection, image processing, vibration sensors, humidity sensors, digital twins) to have relevant information in real time. Nevertheless, the implementation of these technologies is costly, and the high number of bridges in Slovakia makes widespread deployment unrealistic at present.

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