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Implementation of TSI requirements in railway infrastructure modernization projects of Ukraine in the context of EU transport system integration

The article is devoted to the analysis of technical and institutional aspects of the implementation of the requirements of the Technical Specifications for Interchangeability (TSI) in projects for the modernization of the railway infrastructure of Ukraine with financial support from the European Union within the framework of the Connecting Europe Facility (CEF) program. The current regulatory and institutional framework is analyzed, barriers and risks are identified, and models of cooperation with European certification bodies are proposed. The main attention is paid to the project "Modernization of the Mostyska-Lviv railway connection" as a representative example of integration into the TEN-T network. The article substantiates the feasibility of implementing a pilot model of cooperation between Ukrainian institutions and European certification bodies to confirm the compliance of design solutions with the TSI requirements. Special attention is paid to the issues of ensuring traffic safety, risk management, environmental safety, and compliance with functional safety standards, which are critically important for the certification of infrastructure facilities and obtaining funding from the EU. The pilot model of cooperation between Ukrainian participants and European certification bodies proposed in the article can become a scalable tool for ensuring TSI compliance. Institutional support from ERA and CINEA, technical dialogue, national capacity building and a multidisciplinary approach to project evaluation are the determining conditions for Ukraine's full participation in the European railway system.

Keywords: TSI, CEF, TEN-T, railway infrastructure, safety, environmental safety, conformity assessment, certification, European integration.

Introduction. The integration of Ukraine's railway infrastructure into the European Union's transport system has become a strategic priority in the context of the country's European integration agenda and the need for post-crisis reconstruction. As a full participant in the Connecting Europe Facility (CEF) programme since 2023, Ukraine has secured EU financial support for several cross-border and domestic infrastructure projects aimed at increasing interoperability and capacity [1].

A key requirement for these modernization projects is compliance with the Technical Specifications for Interoperability (TSI) [2], which establish harmonized standards across EU Member States for railway subsystems, including infrastructure, energy, control-command and signalling, and rolling stock. Meeting TSI requirements ensures seamless operation across national borders and promotes safe, reliable, and efficient rail transport throughout the trans-European transport network (TEN-T).

The TEN-T policy [3] plays a central role in the EU's long-term strategy for sustainable and interconnected transport across the continent. The extension of the core TEN-T corridors into the territory of Ukraine [4] highlights the strategic importance of integrating key routes such as Poland–Lviv, Romania–Chernivtsi–Lviv, Chop–Uzhhorod–Lviv, among others. These corridors not only strengthen physical connectivity but also facilitate Ukraine's economic and political alignment with the European Union.

The Connecting Europe Facility (CEF) [5] serves as the primary financial instrument supporting the implementation of cross-border and high-impact transport infrastructure projects within the TEN-T framework. In the case of Ukraine, CEF co-funding allows for accelerated modernization of infrastructure sections that are critical for interoperability with EU railway systems, including the introduction of 1435 mm standard-gauge lines, electrification, and implementation of signalling and safety systems in line with TSI.

In addition to its role in enhancing connectivity, CEF also contributes to the European Green Deal objectives [6] and works in alignment with the policies of the Directorate-General for Climate Action (DG CLIMA). CEF-funded railway projects prioritize sustainable mobility by supporting modal shift from road to rail, which significantly reduces greenhouse gas emissions and air pollution. In the Ukrainian context, infrastructure modernization with a focus on electrification and TSI-compliant systems is not only a step toward technical interoperability, but also an essential contribution to climate resilience and environmental sustainability. The integration of environmental standards and climate mitigation goals into CEF projects reflects a broader EU commitment to developing a transport network that is both efficient and ecologically responsible.

However, the process of adapting infrastructure projects to meet TSI requirements in Ukraine faces institutional and technical challenges. The absence of notified bodies (NoBos) within the country limits the ability to conduct independent conformity assessments, requiring cooperation with European certification institutions.

This paper explores the technical and procedural aspects of implementing TSI requirements within Ukrainian infrastructure projects supported by CEF. It analyses the current legal and institutional framework, identifies barriers and risks, and proposes models for cooperation with European certification bodies. The study also outlines the broader benefits of TSI alignment, including enhanced safety, operational interoperability, and access to EU markets and transport corridors.

Analysis of recent research and problem statement. The modernization and interoperability of railway infrastructure have become strategic priorities of the European Union's transport policy, particularly within the framework of the TEN-T. The Technical Specifications for Interoperability (TSIs) represent a cornerstone of this policy, establishing harmonized standards for infrastructure, energy, control-command and signaling, and rolling stock subsystems. Their consistent implementation enables the creation of a unified, safe, and efficient railway system across the EU.

Recent publications [6-14] provide valuable insights into the technical, legal, and interoperability-related challenges of Ukraine's railway system. Their work contributes significantly to shaping a modern, EU-integrated railway infrastructure in Ukraine.

Recent research [15] and technical documentation [16-20] - developed by the European Union Agency for Railways (ERA), infrastructure managers, and international projects such as Rail Baltica [21] and ERTMS deployment [22, 23] — highlight the importance of TSI conformity for achieving seamless cross-border operations. These studies largely focus on EU Member States or accession countries with established regulatory frameworks and operational Notified Bodies (NoBos). They provide insights into conformity assessment methodologies, the roles of Designated Bodies, and the processes of authorization for placing railway subsystems into service.

However, there is a noticeable gap in the literature regarding the implementation of TSI requirements in third countries undergoing systemic transformation—particularly Ukraine. Despite Ukraine's recent accession to the Connecting Europe Facility (CEF) programme in 2023 and the launch of several modernization projects with EU co-financing, the country currently lacks accredited NoBos capable of conducting independent conformity assessments. This institutional deficit complicates the application of the European regulatory framework and creates dependency on cross-border cooperation mechanisms with EU certification institutions.

Given Ukraine's active integration into the European transport system and the launch of infrastructure projects under the Connecting Europe Facility (CEF), there is a growing need to examine the conformity assessment procedures for railway infrastructure modernization projects in the Ukrainian context. Key issues include the adaptation of national regulatory frameworks, cooperation with European certification bodies (NoBos, AsBos), technical support during project implementation, and the methodology for verifying compliance during the design, construction, and commissioning stages.

The absence of Notified Bodies in Ukraine capable of conducting full TSI conformity assessments further emphasizes the need for the development of effective international cooperation mechanisms and the strengthening of national institutional capacity. Therefore, there is a clear demand for academic analysis of both the legal and practical dimensions of TSI implementation in Ukrainian modernization projects—a gap this study seeks to address.

The purpose and tasks of the study. The purpose of this study is to investigate the implementation of the Technical Specifications for Interoperability (TSI) in Ukraine's railway infrastructure modernization projects supported by the Connecting Europe Facility (CEF), with a focus on the role of these requirements in Ukraine's integration into the EU transport system.

To achieve this purpose, the study addresses the following tasks:

- to examine the legal and institutional framework for the application of TSI in Ukraine's railway sector.
- to analyze the content and technical objectives of a representative infrastructure project financed by CEF.
- to explore the methodological aspects of conformity assessment procedures in the EU railway domain.
- to identify challenges and barriers arising from the absence of notified bodies (NoBo) in Ukraine.
- to assess cooperation models between Ukrainian stakeholders and European certification bodies for the evaluation of TSI compliance.
- to evaluate the benefits of TSI implementation, including enhanced safety, interoperability, and access to EU transport corridors.

Materials and methods of research.

1. The legal and institutional framework for the application of TSI in Ukraine's railway sector.

The implementation of the Technical Specifications for Interoperability (TSI) in Ukraine is governed by a hybrid legal framework shaped by both national legislation and Ukraine's international commitments under the EU–Ukraine Association Agreement.

At the national level, the Law of Ukraine *"On Technical Regulations and Conformity Assessment"* [24] establishes the general legal foundation for the harmonization of national technical regulations with European standards, including the procedures for conformity assessment. This law is complemented by specific technical regulations, such as the *"Technical Regulation on the Safety of Railway Infrastructure"* [25], which partially transposes the provisions of Directive (EU) 2016/797 [16] and the related TSIs into Ukrainian law.

While the current Law of Ukraine *"On Railway Transport"* [26] outlines the overall legal and organizational framework for the sector, it was adopted prior to Ukraine's commitment to European integration and does not yet fully reflect the principles of market liberalization, interoperability, and safety management as stipulated by EU railway legislation. In this regard, the adoption of a new, modernized law on railway transport—harmonized with the provisions of Directive (EU) 2016/797 [16],

Directive (EU) 2016/798 [17], and Directive 2012/34/EU [27] — is a critical step toward enabling the full implementation of the TSI framework in Ukraine and ensuring legal compatibility with the EU railway acquis.

Institutionally, The Ministry for Development of Communities and Territories of Ukraine is responsible for policy coordination in the railway sector and for aligning sectoral legislation with the EU acquis. The State Service for Transport Safety of Ukraine (Ukrtransbezpeka) acts as the national supervisory authority. However, Ukraine currently lacks a Notified Body (NoBo) for railway subsystems assessment, which prevents full implementation of TSI conformity procedures domestically. This institutional gap necessitates cooperation with European NoBos, especially in CEF-funded projects.

The legal framework also includes references to relevant EU delegated and implementing acts, including:

- Commission Delegated Regulation (EU) 2019/777 on common specifications for the register of infrastructure [28];
- Commission Implementing Regulation (EU) 2023/1694 on the TSI for the infrastructure subsystem [18];
- And others regulating subsystems of rolling stock, energy, and control-command and signaling.

Furthermore, under the ongoing approximation process, Ukraine is aligning with Commission Delegated Regulation (EU) 2018/762 [19], which sets common safety methods and requirements for Safety Management Systems (SMS) used by railway undertakings and infrastructure managers.

This hybrid and transitional legal-institutional structure are a key consideration in the methodology of this research, particularly in evaluating the challenges and constraints in applying TSI conformity assessment in practice. Case study data from current CEF-supported modernization projects will be analyzed in this legal context, with emphasis on how gaps in domestic capability (e.g., absence of NoBos) are addressed through international cooperation mechanisms.

2. Analysis of the content and technical objectives of a representative infrastructure project financed by CEF

The Connecting Europe Facility (CEF) [29] supports the development of railway infrastructure projects located on the Comprehensive and Core Networks of the Trans-European Transport Network (TEN-T). In line with the Work Programme priorities, eligible actions include both studies and works related to the construction and upgrading of cross-border sections, elimination of missing links, and capacity enhancement of existing lines to accommodate international rail traffic.

Particular emphasis is placed on:

- upgrading infrastructure to allow for 740-meter freight trains;
- removal of level crossings;
- increasing capacity at key network nodes;
- improving multimodal connections between rail and inland waterways, maritime ports, or airports;
- ensuring efficient integration of freight terminals with the TEN-T railway network;
- electrification and modernization of railway lines and traction systems.

Support is strictly limited to railway infrastructure components. Passenger station buildings and rolling stock are not eligible. Furthermore, activities related to national Class B signalling systems are excluded from funding. Deployment of interoperable components such as ERTMS [30], GSM-R, and interlockings is supported separately under the “Smart and Interoperable Mobility” section of the CEF Work Programme.

In order to receive CEF funding, all supported actions must comply with Directive (EU) 2016/797 on the interoperability of the rail system and the applicable Technical Specifications for Interoperability (TSIs). Where applicable, projects must ensure procedural alignment across borders to maximize the efficiency of the infrastructure and enhance operational compatibility.

In line with EU principles, facilities developed under CEF must remain accessible to all railway operators on a non-discriminatory basis.

This requirement is of particular relevance to Ukraine, which became eligible for CEF Transport funding in 2023. The project *Modernisation of the railway connection from Mostyska to Lviv*, implemented by JSC “Ukrainian Railways” [1] and co-financed by the CEF, must adhere to the TSI framework and interoperability rules to ensure integration with the EU rail system.

According to the official decision of the European Commission on the selection of CEF Transport projects in 2023, Ukraine has been formally included among the eligible countries for EU transport infrastructure funding. In particular, the Mostyska–Lviv railway reconstruction project was approved under the Connecting Europe Facility framework, with the requirement to comply with relevant TSIs for interoperability [1]. The priority railway corridors of Ukraine covered by CEF projects are shown in Figure 1.

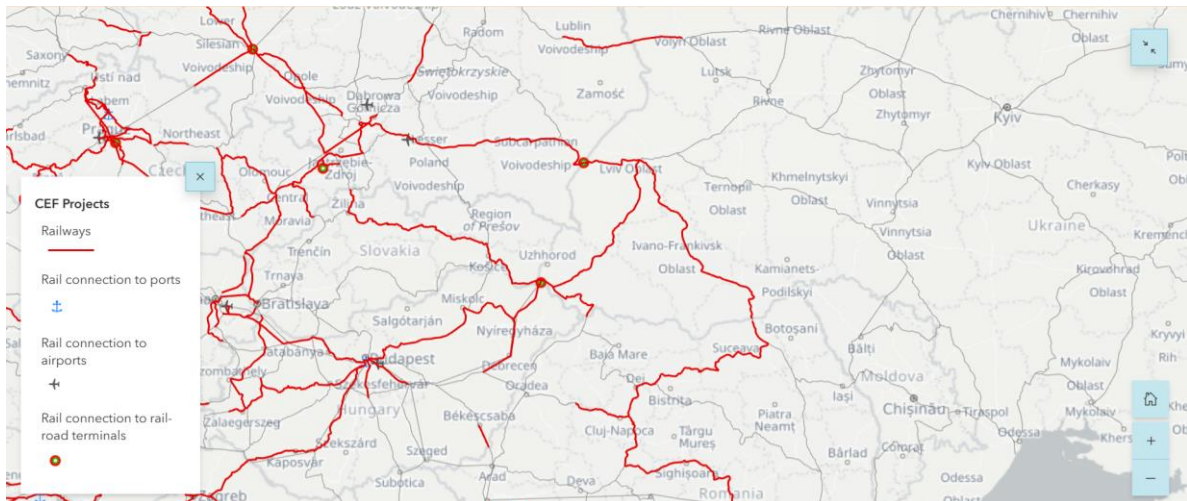


Fig 1. Priority railway corridors of Ukraine covered by CEF projects

Since Ukraine’s accession to the Connecting Europe Facility (CEF) programme in 2023, JSC Ukrainian Railways (Ukrzaliznytsia) has gained access to EU co-financing for infrastructure projects aimed at integrating the Ukrainian railway network into the Trans-European Transport Network (TEN-T). Several projects have already been selected for funding and are being implemented in coordination with the European Climate, Infrastructure and Environment Executive Agency (CINEA).

Notable examples include:

- Modernisation of the Mostyska II – Medyka border crossing, enhancing cross-border capacity with Poland;
- Construction of a standard-gauge (1435 mm) railway link between Chop and Uzhhorod, co-financed 50% by CEF;
- The large-scale project "Modernisation of the Railway Connection from Mostyska to Lviv", officially included in the list of selected actions under CEF Transport Call 2023 [1].

All of these initiatives are subject to compliance with the provisions of Directive (EU) 2016/797 on the interoperability of the rail system and the related TSIs [31].

According to official EU publications and a 2024 report by the International Union for Road-Rail Combined Transport (UIRR) [32], part of the funding allocated to Ukraine is specifically intended for conformity assessment with TSI requirements—particularly for the Kovel–Yahodyn and Mostyska II–Lviv (Sknyliv) sections.

Ensuring compliance with TSI is not only a legal prerequisite for receiving CEF grants, but also serves as a strategic institutional indicator of Ukraine’s readiness for integration into the European transport system. Without proper conformity assessment validated by authorised EU institutions, further funding and long-term infrastructure integration would be impossible.

3. *The methodological aspects of conformity assessment procedures in the EU railway domain.*

The conformity assessment process within the European Union's railway sector is a legally regulated mechanism designed to ensure that infrastructure projects, subsystems, and components comply with the Technical Specifications for Interoperability (TSIs), as required by Directive (EU) 2016/797 [6]. This process is particularly critical in modernization projects, where updated or reconstructed infrastructure must align with harmonized European norms to facilitate interoperability, safety, and environmental performance across the Trans-European rail Network (TEN-T).

The assessment of conformity is guided by the European Union Railway Interoperability Directive 2016/797 [6], which mandates that railway subsystems—such as infrastructure, energy, control-command and signaling, and rolling stock—must meet specific TSI requirements before being placed into service or upgraded. Each subsystem must undergo verification procedures that include both documentation and physical inspections, depending on the scope and complexity of the modernization.

Key actors involved in the conformity assessment process include:

- Notified Bodies (NoBos) - independent third-party organizations designated by EU Member States to perform assessments under TSI regulations.
- Designated Bodies (DeBos) - institutions that verify compliance with national technical rules (NNTRs) where TSI applicability is not yet fully harmonized.
- Assessment Bodies (AsBos) - entities responsible for checking the application of risk management processes, especially in the case of significant changes.

The TSI conformity assessment follows a modular approach as defined in Regulation (EU) No 2010/713 [20]. Typical modules relevant for infrastructure modernization projects include:

- EC type examination - evaluation of technical design documentation.
- Production quality assurance - assurance that the implementation during modernization aligns with approved design.
- Full quality assurance - applied to the entire lifecycle, including planning, execution, and verification stages.

In infrastructure modernization projects, a combination of modules is typically used, particularly to ensure comprehensive verification of both the design and implementation stages.

Conformity assessment in modernization projects typically follows a structured and phased approach to ensure that all technical and regulatory requirements of the applicable TSIs [31] are fully met. These phases are coordinated in collaboration with a Notified Body (NoBo) and relevant stakeholders such as project designers, construction contractors, and infrastructure managers.

1. Pre-assessment phase.

The pre-assessment phase serves as a critical preparatory stage. It includes:

- Gap analysis to determine which TSI requirements are applicable to the project, depending on the subsystem and scope;
- Mapping of existing conditions of the infrastructure section, including legacy systems, deviations from TSI norms, and interfaces with other subsystems;
- Development of a Conformity Assessment Strategy outlining which modules will be used, required documentation, and a timeline for NoBo involvement.

This phase helps minimize costly redesigns and ensures that TSI compliance is integrated into the project from the outset.

2. Design phase evaluation.

During the design phase, the Notified Body (NoBo) conducts a comprehensive assessment of the following technical and regulatory components to verify conformity with applicable Technical Specifications for Interoperability (TSIs) [31]:

A. Technical documentation:

- general arrangement drawings (GADs) of infrastructure and civil works;
- longitudinal and cross-sectional profiles of track alignments;
- site layout and zoning plans for stations, depots, and intermodal terminals;
- platform design, including height, length, and access features;
- bridge and tunnel engineering designs (if applicable).

- B. Track design parameters:
 - Track gauge (e.g., 1435 mm or dual gauge);
 - Axle load and structural capacity (static and dynamic);
 - Gradient (longitudinal slope) and minimum curvature radius;
 - Super-elevation and cant deficiency values;
 - Track center distance and clearances (kinematic envelope compliance);
 - Ballast and substructure design;
 - Turnouts and crossing systems, including compatibility with EU standards.
- C. Electrification system design:
 - Type of electrification system (AC 25 kV / DC 3 kV or other);
 - Positioning and height of overhead contact lines (OCL);
 - Catenary system type (simple, stitched, auto-tensioned, etc.);
 - Mast foundations and structural calculations;
 - Interface with traction power substations and feeder systems;
 - Grounding and bonding schemes for safety and EMC compliance;
 - Earthing, lightning protection, and surge arrestors.
- D. Signalling and train control systems:
 - Interlocking systems and compatibility with existing infrastructure;
 - Block sections, balise placement, and detection systems;
 - Interface with European Train Control System (ETCS), if applicable;
 - Traffic control center architecture and remote supervision;
 - Fail-safe design features and redundancy levels.
- E. Environmental and climate resilience measures:
 - Noise and vibration mitigation measures (e.g., noise barriers);
 - Drainage and water management systems;
 - Biodiversity impact assessments;
 - Climate adaptation features (resilience to extreme weather, temperature ranges);
 - Landscape integration and vegetation management.
- F. Passenger and accessibility features:
 - Compliance with PRM TSI (Persons with Reduced Mobility);
 - Wayfinding systems, tactile surfaces, and signage;
 - Lighting and emergency systems in passenger areas.
- G. Risk and safety management documentation:
 - Preliminary Safety Plan and Safety Case (if required);
 - Risk assessment reports per CSM RA (Common Safety Method on Risk Evaluation);
 - Hazard Identification and Hazard Logs (HAZIDs);
 - Mitigation strategies for residual risks;
 - Human factors and ergonomics assessments.
- H. System integration and interface management:
 - Interfaces between subsystems (e.g., infrastructure and energy, CCS and rolling stock);
 - Interoperability with existing national or EU railway lines;
 - Analysis of transitional solutions (e.g., dual-gauge sections).
- I. Compliance with National Rules (if applicable):
 - Evaluation of national technical rules (NNTRs) alongside TSI applicability;
 - Interface with Designated Bodies (DeBos) for specific national requirements.

The outcome of this phase is typically a Design Examination Report, which determines whether the project meets TSI requirements in theory and can proceed to implementation.

3. On-site inspection and verification.

Once construction or reconstruction begins, the NoBo performs systematic inspections to verify that:

- Implemented components (tracks, switches, catenary, platforms, etc.) match the approved design.

- Construction practices and materials meet the required quality and safety standards.
- Interfaces between subsystems (e.g., infrastructure and energy) are managed in compliance with TSI requirements.
- Any deviations or non-conformities are properly documented, justified, and resolved before moving forward.

These site verifications are usually conducted at critical milestones, such as after track laying, before electrification, and before commissioning.

4. Final Validation and Issuing of Certificate

After successful completion of the construction and verification stages, the NoBo performs a final assessment of:

- The technical file, containing all project documentation, test results, inspection records, and declarations.
- The overall conformity of the subsystem or project section with the relevant TSIs.

If all conditions are met, the NoBo issues the EC Certificate of Verification, which is necessary for the Authorization for Placing into Service (APIS) by the national safety authority or ERA.

5. Documentation and compliance register.

Each conformity assessment process is accompanied by:

- A technical documentation file, as per Annex IV of Directive 2016/797 [6].
- A declaration of conformity from the applicant.
- Registration in the European Register.

These records ensure traceability, transparency, and future compatibility with EU-wide upgrades or extensions.

In Ukraine, the absence of domestic NoBos limits internal capacity for conformity assessment. Therefore, modernization projects funded by the EU (e.g., via CEF) require early involvement of European NoBos, who supervise the process and issue relevant certificates. This increases the importance of harmonized procedures and proper training of project engineers to produce TSI-compliant documentation from the design stage.

4. *Implementation of the project and compliance with TSI*

The successful implementation of an infrastructure project under European financial instruments, particularly the Connecting Europe Facility (CEF), requires not only adherence to construction timelines but also full compliance with the Technical Specifications for Interoperability (TSIs). TSI compliance must be ensured at every stage of project implementation—from design to commissioning:

- Design and reconstruction of railway structures:

During the design phase, a key objective is to integrate the requirements of TSI INF, TSI ENE, and TSI CCS into all technical documentation. This includes the development of track geometry, platform layouts, bridges, tunnels, overhead line systems, energy supply elements, and signalling systems in accordance with the applicable TSI versions. The reconstruction of existing infrastructure aims to align legacy assets with EU standards, including the introduction of standard gauge (1435 mm), strengthening of structural components, noise mitigation, and accessibility improvements.

- Construction of infrastructure facilities:

Construction activities must follow the TSI-compliant technical solutions approved in the design stage. This includes track laying, installation of overhead contact systems, deployment of signalling and control-command infrastructure (interlocking, train protection), and establishment of safety-critical installations. Construction works must be accompanied by rigorous technical supervision and conformity checks.

- Audit and certification of TSI compliance:

In the final stage of the project, a comprehensive audit of technical documentation and physical infrastructure components is carried out. Notified Bodies (NoBos) are involved in this process, conducting conformity assessments according to selected TSI modules. Upon successful verification, an EC Certificate of Verification is issued, which forms the basis for authorization for placing the

subsystem into service. This certificate is a legal prerequisite for the operation of the infrastructure within the EU's TEN-T network.

Thus, implementing a TSI-compliant project is a complex technical and regulatory process requiring cross-sectoral cooperation, strict adherence to legal frameworks, and integration of international expert bodies.

5. Challenges and barriers related to the absence of Notified Bodies (NoBos) in Ukraine

One of the key institutional challenges to the implementation of the Technical Specifications for Interoperability (TSIs) in railway infrastructure modernization projects in Ukraine is the absence of Notified Bodies (NoBos)—organizations officially authorized to carry out conformity assessment procedures under EU legislation.

According to the Law of Ukraine "On Technical Regulations and Conformity Assessment" [24], such procedures can only be conducted by bodies accredited by the National Accreditation Agency of Ukraine (NAAU) and officially designated by the competent authority. However, as of today, there are no entities in Ukraine with NoBo status in accordance with Directive (EU) 2016/797 [6] on the interoperability of the rail system within the EU.

Even though Ukrainian certification bodies may have the necessary technical capacity, they currently lack the legal grounds to function as NoBos because Ukraine is not a member of the EU and is not included in the NANDO (New Approach Notified and Designated Organisations) database [33]. As a result, conformity assessment procedures according to TSI modules cannot be conducted without involving accredited European structures such as TÜV Rheinland, CERTIFER and others.

The absence of NoBos compels beneficiaries - such as JSC "Ukrainian Railways" - to rely on foreign certification bodies, which significantly increases the cost of procedures, complicates logistics, and delays project implementation, especially under wartime conditions and limited site accessibility.

Compliance with TSI requirements - including those of TSI INF, TSI ENE, and TSI CCS - is a mandatory condition for the implementation of EU-funded infrastructure projects under the Connecting Europe Facility (CEF) programme. The lack of valid certificates issued by a NoBo presents risks of funding denial, delays in disbursements, and negative audit results during project progress assessments.

To address these challenges, Ukraine must implement a national strategy for integration into the European technical regulation system, including the following actions:

- create conditions for the accreditation of Ukrainian conformity assessment bodies in accordance with EU requirements, thereby strengthening national capabilities in the railway infrastructure conformity assessment sector;
- conclude mutual recognition agreements with EU Member States to facilitate Ukraine's integration into the common European railway market;
- deepen cooperation with European NoBos through joint projects, personnel exchanges, and training programmes to develop national expertise and gain practical experience aligned with EU standards;
- ensure a multidisciplinary approach to infrastructure project assessment—combining engineering, legal, environmental, and forensic-expert perspectives to comprehensively evaluate compliance with current requirements;
- incorporate TSI provisions into national construction norms, technical regulations, and industry instructions to ensure internal legal harmonization.

These tasks are reflected in Ukraine's National Transport Strategy to 2030 and the Action Plan for the Development of the Technical Regulation System until 2025 [34], which outline key steps toward adapting to EU norms and enhancing the national conformity assessment infrastructure.

Effective implementation of these measures will reduce dependence on external actors, accelerate the adoption of European standards, enhance Ukraine's institutional capacity in technical regulation, and strengthen the country's readiness for full integration into the EU transport system.

6. CEF-funded projects in Ukraine: focus on the Mostyska–Lviv section

The project "Modernisation of the Railway Connection from Mostyska to Lviv" was selected for EU co-financing under the CEF Transport Call 2023 and marks one of the first large-scale railway

infrastructure initiatives supported by the Connecting Europe Facility (CEF) on Ukrainian territory. Its main objective is to enable uninterrupted railway connectivity between the Ukrainian network and the EU system, adapted to the European standard gauge of 1435 mm.

The project covers the following activities:

- Design and technical preparation for the reconstruction of the Mostyska II – Sknyliv section;
- Feasibility studies and technical design according to the requirements of the Technical Specifications for Interoperability (TSIs);
- Preliminary environmental impact assessment (EIA);
- Development of technical documentation for conformity assessment with EU norms.

This project is strategically aligned with the expansion of the Trans-European Transport Network (TEN-T), revised in response to geopolitical changes following Russia's full-scale invasion of Ukraine. It is located along the core Baltic Sea - Black Sea - Aegean Sea Corridor, which connects Poland with southern regions of Ukraine.

According to the CEF Work Programme, priority is given to eliminating cross-border bottlenecks, increasing line capacity, and enabling 740-meter freight trains. In this context, the Mostyska-Lviv line serves as a pilot zone for EU railway integration, aiming to demonstrate a scalable model for other border connections.

Due to the absence of Notified Bodies (NoBos) in Ukraine authorized to carry out conformity assessment procedures in line with the Technical Specifications for Interoperability (TSI), we propose the implementation of a structured model of international technical cooperation within the framework of this project. This model may include the following practical steps:

- engagement of technical experts and consultants from EU Member States;
- preparation and submission of a comprehensive technical file for the certification of the "Infrastructure" subsystem in accordance with TSI INF requirements;
- application of conformity assessment modules SB, SH1, and SD as defined in Regulation (EU) No 2010/713 [20];
- establishment of cooperation with European Notified Bodies to carry out independent external audits of infrastructure solutions.

We also propose the adoption of a partnership-based interaction model, which foresees coordination between Ukrainian stakeholders (JSC Ukrainian Railways, the Ministry for Development of Communities and Territories of Ukraine, and national design and expert institutions) and European certification entities (Notified Bodies, consultancy firms, and the European Union Agency for Railways - ERA). The key principles of this model include:

- institutional support from EU bodies, in particular CINEA [35] and ERA;
- the formation of bilateral technical working groups to ensure information exchange and procedural harmonization;
- a phased approach, which allows for initial conformity assessment by EU-recognized bodies while simultaneously building national human and procedural capacity.

The implementation of this model will not only provide official confirmation of TSI compliance but also foster the systematic development of Ukraine's professional capacity in the field of railway certification. We consider the proposed model a pilot cooperation framework, which we recommend testing within the Mostyska–Lviv project and subsequently applying to other infrastructure initiatives under the TEN-T and CEF programmes.

Successful implementation of such a model will enhance Ukraine's technical reputation as a reliable EU partner and lay the groundwork for further mutual integration in the field of technical regulation for railway transport.

The proposed international cooperation model, piloted within the "Mostyska–Lviv" modernization project, can serve as a methodological template for the future implementation of EU technical standards by national infrastructure operators. Successful application of the model creates an opportunity for its replication in other key TEN-T railway sections in Ukraine.

Table 1. Key steps of the TSI conformity model in a CEF project

Step	Description	Responsible Actors
1. Identification of TSI requirements	Defining applicable TSI (e.g., INF, SRT)	Ukrzaliznytsia, design institutions
2. Preparation of technical file	Comprehensive technical documentation	Designers, technical consultants
3. Engagement with NoBo	Contracting a notified body	Ukrzaliznytsia, NoBo
4. External audit	Evaluation of documentation and infrastructure	NoBo, independent auditors
5. Conformity conclusion	Issuance of certification or recommendations	NoBo
6. Addressing comments	Revisions of documentation or designs	Ukrainian project stakeholders
7. Final conformity confirmation	Certification approval	NoBo, Ukrzaliznytsia

A core condition for scaling up is the development of national capacity for railway conformity assessment with TSI requirements. This includes:

- establishing qualified technical centers and training safety auditors;
- developing a regulatory framework for the future notification of Ukrainian bodies;
- creating sustainable mechanisms of coordination with ERA and CINEA;
- incorporating safety assessment procedures into infrastructure modernization plans.

In the medium term, this model supports the development of Ukraine's technical self-sufficiency, reduces reliance on foreign certification, and fosters alignment of the national regulatory system with EU standards. It also lays the foundation for a domestic market of railway conformity and safety assessment services, contributing to deeper integration with the European transport system.

7. *Benefits of TSI compliance*

Compliance with the Technical Specifications for Interoperability (TSIs) provides a number of strategic advantages for railway infrastructure projects, particularly in the context of Ukraine's integration into the EU transport system:

1. Enhanced Safety and Reliability

TSI implementation ensures the application of uniform safety standards throughout all stages of infrastructure design, construction, and operation. Requirements such as those in TSI INF (Infrastructure), TSI CCS (Control-Command and Signalling), and TSI ENE (Energy) prescribe harmonized technical parameters and safety procedures. This reduces the likelihood of operational failures and accidents, improves system resilience, and contributes to the overall safety culture in rail transport.

2. Interoperability with European Railway Systems

One of the key objectives of the TSI framework is to facilitate seamless cross-border operations across the EU. For Ukraine, aligning infrastructure and subsystems with TSI allows for technical and operational compatibility with neighboring railway networks. This is essential for freight corridors and international passenger services and enables full integration into the Trans-European Transport Network (TEN-T). Standardization of track gauge (e.g., 1435 mm), electrification systems, and signalling interfaces supports efficient interaction between Ukrainian and EU railway operators.

3. Economic and Environmental Advantages

TSI-compliant infrastructure promotes long-term operational efficiency by reducing maintenance costs, minimizing downtimes, and enabling higher capacity utilization. Interoperability reduces logistical bottlenecks at border points, leading to faster and more predictable transit flows. Furthermore,

the shift to electrified and standardized railway lines, as encouraged by TSI ENE, supports climate goals by reducing CO₂ emissions and dependence on diesel traction. This aligns with broader EU Green Deal objectives and the climate-oriented priorities of the CEF programme.

Overall, TSI conformity is not only a regulatory obligation within CEF-funded projects but also a key enabler of Ukraine's modernization, competitiveness, and sustainable integration into the European railway space.

8. *Impact of track superstructure failures on safety indicators and TSI compliance in infrastructure modernization projects*

In the implementation of railway infrastructure modernization projects, it is essential not only to ensure that design solutions meet the requirements of the TSIs, but also to guarantee that actual operating conditions align with the expected safety parameters. This is especially relevant for track superstructure elements - rails, sleepers, fastenings, ballast, and turnouts - whose failure can cause serious disruptions to train operations and pose significant risks to passenger and operational safety.

In this context, expert analysis methods and the assessment of the technical condition of track components play a vital role. These approaches are being developed as part of the research project "Development of a methodology for the forensic examination of railway track components" (State registration number: 0123U101166), conducted by the Lviv Scientific Research Institute of Forensic Expertise.

The analysis identifies common failure mechanisms, including:

- degradation of the elasticity of sleepers and ballast;
- wear or mechanical damage to rails;
- deformation and stiffness loss in turnout components;
- damage to fastenings affecting track stability.

Such defects directly influence the dynamic and loading characteristics of the infrastructure and, consequently, its compliance with the parameters established by the Infrastructure TSI (e.g., EN 13848, TSI INF 2023). These factors must be considered not only during the design phase but also during technical inspections and conformity verification prior to placing the infrastructure into service.

Introducing early detection procedures for potentially hazardous defects, along with the integration of forensic technical tools into the TSI conformity assessment process, can significantly enhance the objectivity and reliability of safety evaluations. This supports the practical implementation of the safety management principles outlined in Regulation (EU) 2018/762 [19] and Directive (EU) 2016/798 [17].

Thus, the synergy between forensic expertise on infrastructure failures and institutional practices in TSI conformity assessment forms a solid foundation for developing national approaches to ensuring railway safety in the context of Ukraine's integration into the European railway system.

9. *Bridging education and practice: the contribution of master's research to infrastructure modernization in line with EU requirements"*

In the process of implementing TSI requirements in infrastructure projects, the training of specialists capable of working at the intersection of technical regulation, transport safety, and European interoperability standards plays a crucial role. In preparing this article, research results developed within the framework of the second-level higher education program "Functional Safety of Railway Transport" (specialty J7 "Railway Transport") at Lviv Polytechnic National University were used. The thematic focus of master's theses—particularly in the areas of risk assessment and infrastructure adaptation for the 1435 mm gauge—directly corresponds to the challenges Ukraine faces in the context of TSI implementation and integration into the TEN-T system. This highlights the relevance of aligning academic training with the practical needs of infrastructure modernization under EU requirements.

Conclusions. The integration of Ukraine's railway infrastructure into the European Union transport system requires not only modernization of physical assets but also systematic alignment with EU legal and technical requirements. The implementation of the Technical Specifications for Interoperability (TSIs) is central to this process, serving as the foundation for achieving seamless, safe, and interoperable railway operations along cross-border and TEN-T corridors.

The case of the Mostyska–Lviv section, supported by the Connecting Europe Facility (CEF), demonstrates the practical challenges and solutions for ensuring TSI compliance under conditions where Ukraine lacks nationally accredited Notified Bodies (NoBos). This situation necessitates structured cooperation with European conformity assessment institutions and the application of established conformity assessment modules such as SB, SH1, and SD.

The analysis confirms that compliance with TSI requirements not only unlocks access to EU funding but also improves the technical robustness, safety, and environmental sustainability of infrastructure projects. In this context, safety remains a cross-cutting priority, especially in terms of design reliability, risk management, and conformity assessment. Environmental safety, in particular, should be more systematically integrated into planning and evaluation procedures.

Academic and expert research — such as that conducted within the Master's programme "Functional Safety of Railway Transport" — plays a critical role in developing applied methodologies for risk assessment, forensic analysis of infrastructure, and adaptation to the 1435 mm standard gauge. This knowledge base should be actively used to inform future project design, certification, and policymaking.

Ultimately, a pilot model of cooperation between Ukrainian stakeholders and European certification bodies, as proposed in this study, offers a scalable mechanism for advancing TSI compliance. Institutional support from ERA and CINEA, combined with technical dialogue, national capacity building, and a multidisciplinary evaluation framework, will be essential for Ukraine's full participation in the EU rail transport ecosystem.

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Впровадження вимог TSI у проєктах модернізації залізничної інфраструктури України в контексті інтеграції до транспортної системи ЄС

Стаття присвячена аналізу технічних та інституційних аспектів імплементації вимог Технічних специфікацій взаємозамінності (TSI) у проєктах модернізації залізничної інфраструктури України за фінансової підтримки Європейського Союзу в межах програми «Механізм «Сполучення Європи» (CEF). Проаналізовано чинну нормативну та інституційну базу, визначено бар'єри й ризики, запропоновано моделі співпраці з європейськими органами сертифікації. Основну увагу приділено проєкту «Модернізація залізничного сполучення Мостиська–Львів» як репрезентативному прикладу інтеграції до мережі TEN-T. У статті обґрунтовано доцільність впровадження пілотної моделі співпраці між українськими інституціями та європейськими сертифікаційними органами задля підтвердження відповідності проєктних рішень вимогам TSI. Особливу увагу приділено питанням забезпечення безпеки руху, управління ризиками, екологічної безпеки та дотримання стандартів функціональної безпеки, що є критично важливими для сертифікації інфраструктурних об'єктів та отримання фінансування з боку ЄС. Запропонована у статті пілотна модель співпраці між українськими учасниками та європейськими сертифікаційними структурами може стати масштабним інструментом забезпечення відповідності TSI. Інституційна підтримка з боку ERA та CINEA, технічний діалог, нарощування національного потенціалу та мультидисциплінарний підхід до оцінювання проєктів є визначальними умовами повноцінної участі України в європейській залізничній системі.

Ключові слова: TSI, CEF, TEN-T, залізнична інфраструктура, безпека, екологічна безпека, оцінка відповідності, сертифікація, європейська інтеграція.