Transport Infrastructure Amid Protracted War: Challenges for Ukraine and Insights from International Post-War Reconstruction Practices

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Abstract: Stabilization during the war, and especially the post-war restoration of the transport and logistics infrastructure, is a critical element of Ukraine's economic and social stabilization. The experience of other countries shows that timely and high-quality restoration of logistics networks contributes to effective economic growth and integration of post-conflict territories. The purpose of this paper is to analyze international cases of post-war restoration of transport systems and identify best practices that can be adapted for Ukraine. The study uses case studies and comparative analysis to evaluate models of transport infrastructure and logistics recovery. The main findings point to the need for integrated spatial and transport planning, ensuring the sustainability of logistics routes, and balancing rapid recovery with system modernization.

Keywords: post-war reconstruction research, transport infrastructure, mobility, roads, street and road network, safety, public-private partnership, logistics resilience, public-private partnerships

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Introduction

Transport and transport infrastructure are a key component of the economic life of any country, both nationally and internationally, as part of the global transport and logistics system. Within its officially recognized UN borders, Ukraine is the largest country in Europe. Situated between Europe and Asia, Ukraine has a very developed transportation network of all kinds, which ensures the functioning of all sectors of the country's economic life: aviation, railways, roads, rivers and the sea. Several corridors of the trans-European transportation network (TEN-T) pass through the country.

For more than 10 years, there has been an active war in a European country which has disrupted supply chains and investments within Ukraine. For more than 3 years a full-scale war has led to hundreds of thousands of human casualties and hundreds of billions in destroyed and economically damaged infrastructure, including transport infrastructure.

Since February 24, 2022, Ukraine's airspace has been closed to non-military aircraft and drones, and maritime navigation in the Black and Azov Seas has been significantly restricted due to threats to navigation and damage to port facilities, prompting a reformatting of the commercial logistics and transportation systems, as well as mobility for the population. At the same time, the entire system is forced to focus on humanitarian and military purposes to ensure life in the frontline areas and to defend national interests and territorial integrity. To this end, the railroad infrastructure and road network has received a significant additional burden, which will requires quick solutions to maintain reliability after the war. Figure 1 shows the orientation of rail lines in relation to Ukraine’s key strategic mineral resources, along with the line of control in May 2025.

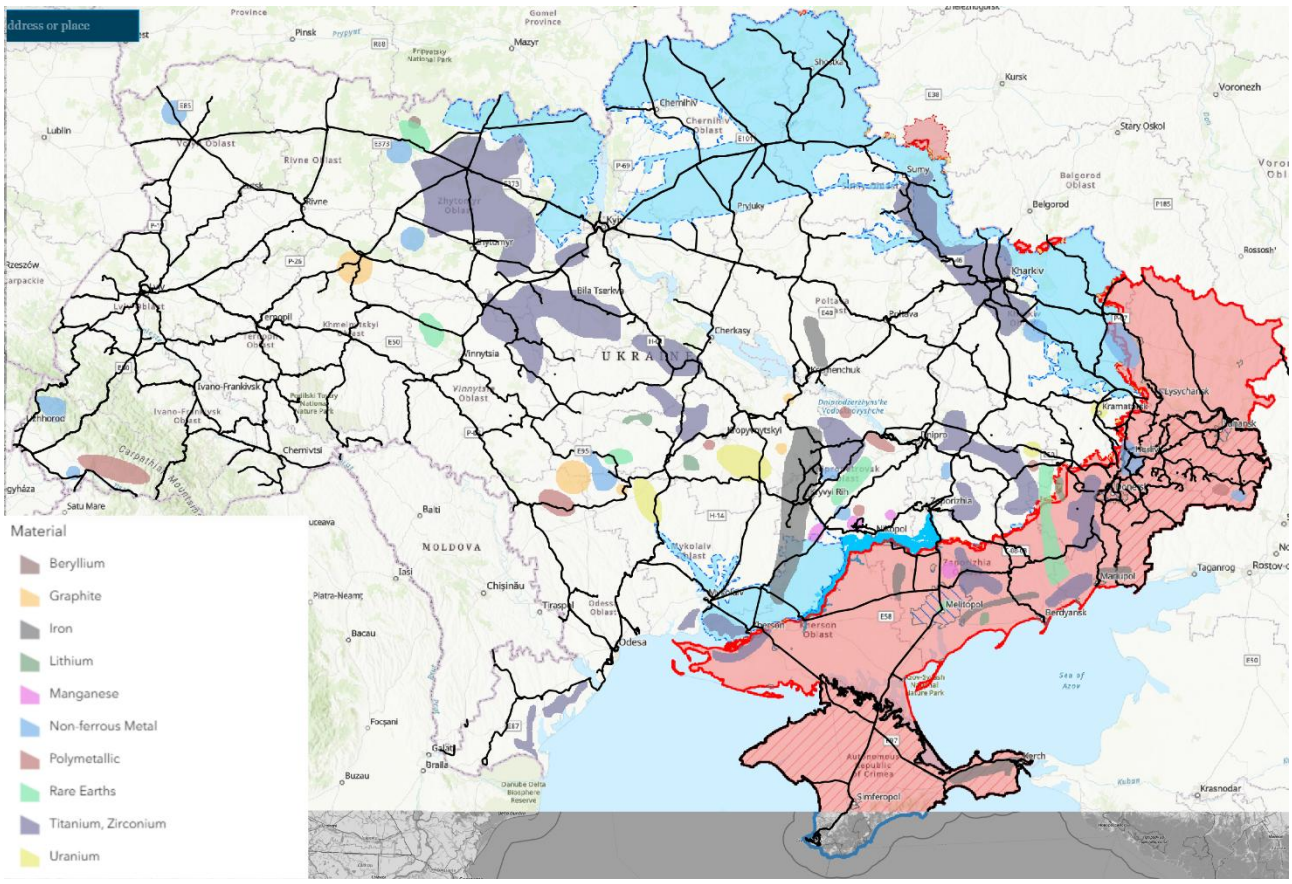


Figure 1 – Rail network and strategic resources in Ukraine (Source: Own development based on open data and GIS)

Transport and logistics infrastructure has a significant impact on the efficiency of economic activity. It enables supply chains for goods and services, ensures population mobility, and supports external trade and exports. Key sectors such as agriculture, metallurgy and heavy industry, energy, and wholesale trade are directly dependent on the quality of a country's transport and logistics infrastructure. The delivery of goods or raw materials takes place between points of production and ports, railway stations, and logistics centers using all modes of transport (Ukrinform 2024).

According to damage reports, as of 2025 more than 26,000 kilometers of roads and 344 bridge structures had been destroyed or severely damaged (KSE Institute 2025).

As of 2024, the transportation network (Ministry for Communities, Territories and Infrastructure Development of Ukraine 2024) consists of:

- 19,759 kilometers of railroad track;
- 163,300 kilometers of highways;
- 18 deep water seaports (6 are operating as of September 2024);
- 26 river and barge terminals;
- 18 airports (14 of which are international) none of which are serving commercial operations as of this writing.

According to the World Bank's Logistics Performance Index (World Bank 2023) Ukraine ranked 79th out of 139 countries in 2023, with a score of 2.7 indicating limited logistical efficiency, delayed border processes, and underdeveloped freight coordination systems.

According to the World Economic Forum's Global Competitiveness Report 2020 (World Economic Forum 2020), Ukraine ranked 92nd out of 141 countries in terms of overall transformation readiness, with a score of 54.7%, reflecting structural limitations in regulatory capacity, institutional agility, and long-term planning. At the same time according to the World Economic Forum (Schwab 2019), Ukraine's transport infrastructure ranked 59th place out of 141 ranked countries with the score of 55.5% from 100%.

Taken together, these figures highlight the fact that even before the full-scale invasion, Ukraine's transport sector was in need not only of physical rehabilitation but also of deep institutional reform and long-term strategic modernization. In this light, the current and upcoming post-war recovery period presents a unique opportunity—not merely to rebuild what was lost, but to address long-standing structural deficiencies and accelerate integration into European logistics and transport systems.

The year 2022 was the beginning of a new era for Ukraine, which will require a difficult recovery and decades of planning. In the context of post-war recovery, restoration and enhancement of transportation infrastructure is one of the Ukraine's most critical tasks as it underpins many other economic initiatives. The infrastructure investments in Ukraine also have the potential to positively impact connectivity and transport efficiency throughout Eurasia. Specific challenges include

The efficiency of transport infrastructure provides the basis for population mobility and logistics of goods and is an important prerequisite for sustainable economic development and European integration. The experience of post-war reconstruction over the past 100 years around the world shows us that decisions made about transport infrastructure can have long-term consequences for the trajectory of economic growth and opportunity, spatial development and quality of life of citizens. Poor transport access in a post-war recovery situation may mean that promising industries are not adequately developed (World Bank 2008).

Among the main threats and challenges facing Ukraine are the problems of an outdated regulatory framework in the field of road design and construction (transport infrastructure) Most of the existing regulations were developed decades ago during the Soviet era, which could be adapted to Ukrainian realities, but still do not meet modern trends, safety, rationality, integration of transport and spatial planning, which is the standard in the European Union (Anisimov, Smirnova and Dulko 2024). The absence of an integrated approach to spatial development, in terms of transport and land planning, leads to numerous cases of dense development directly along important

transport and logistics corridors, which significantly worsens traffic safety, reduces capacity, and significantly limits the possibility of further infrastructure development.

In addition to technical limitations, the challenge is the mismanagement of resources: large-scale infrastructure projects are often implemented without a thorough analysis of their economic efficiency and spatial impact. Instead, there are solutions that can achieve significant results at a lower cost through optimization.

The relevance of this study is determined by the need to study international experience in the post-war restoration of transport infrastructure, analyze current practices and adapt them to Ukrainian conditions, taking into account limited resources.

Research shows that the restoration of transport infrastructure and the processes accompanying post-war recovery in countries follow a phased model. Primarily, it is necessary to respond to emergencies in order to meet the basic needs of the population. The cases examined show that the speed and success of implementation are linked to institutional capacity, internal and external regulation of processes, and the level of international assistance involvement. At present, it is too early to draw comprehensive conclusions for Ukraine, but the country is showing a somewhat hybrid path to recovery, where the stages of emergency response and stabilization are taking place in conditions of active conflict. For successful long-term reconstruction, Ukraine must bring its regulatory framework into line with European standards and ultimately get rid of the Soviet legacy in its infrastructure.

Analytical question:

1) What strategies have other countries used for post-war reconstruction of transport infrastructure and logistics that are applicable to the Ukraine post-war reconstruction context?
2) What are the most critical existing gaps in transportation infrastructure that will constrain Ukraine's economic growth and diversification if not addressed?
3) What approaches and critical updates to the regulatory framework and cost optimization can be effective for Ukraine in minimizing cost and energy efficiency?
    - How to avoid conflicts and redundancy between different standards

Research design: Exploratory research using case studies of international experience and comparative analysis.

The paper is structured as follows: analysis of practices, comparative analysis of international cases, research findings, and recommendations for Ukraine.

Literature review

Theoretical foundations of post-war infrastructure recovery

Post-war infrastructure recovery is a complex and multilevel process that includes not only the physical reconstruction of facilities but also the concurrent transformation of institutions, legal regulation, and spatial development strategies. In international practice, the recovery process is often divided into several phases:

- **Emergency Response** – The emergency response phase involves the immediate and rapid restoration of critical nodes and elements of the transport and logistics infrastructure. Such interventions are typically required to secure connections for the delivery of humanitarian aid, medical supplies, the evacuation of civilians, and access to frontline areas. Emergency actions are carried out under conditions of active combat and severe time constraints. Examples include emergency repairs of damaged railway lines, construction of temporary pontoon bridges in place of destroyed crossings, or road clearance to ensure mobility.
- **Stabilization Phase** - the primary goal of the stabilization phase is to minimize infrastructure vulnerability and enhance adaptability amid constant threats. For Ukraine, where missile strikes and attacks remain regular and unpredictable, this stage involves the establishment of reserve routes, physical protection of assets, use of alternative technologies, and deployment of mobile logistics hubs. Examples include the use of diesel locomotives instead of electric ones in case of damage to overhead catenary systems, or the activation of low-draft Danube ports to substitute for disrupted maritime corridors in the Black Sea (National Academies of Sciences, Engineering, and Medicine 2023).
- **Build Back Better Phase** - The phase of recovery with opportunistic quality improvements (build back better) focuses on rebuilding destroyed infrastructure while incorporating enhancements where possible that utilize modern trends, materials, and technological approaches. For instance, the reconstruction of previously hazardous road segments with improved safety features, integrated traffic management systems, segregated traffic flows, or upgraded engineering solutions that enhance asset durability (particularly in urban areas). In the railway sector, examples include rehabilitating stations with inclusive design and integrating renewable energy components into rail infrastructure systems;

- **Modernization and Future-Proofing Phase** – This long-term modernization is a forward-looking phase aimed at the deep and systemic transformation of the transport and logistics system, taking into account future economic needs, demographic changes resulting from the war, climate-related challenges, and integration with international transport networks—particularly the Trans-European Transport Network (TEN-T) (European Union 2024). Examples of modernization initiatives may include the development of infrastructure for electric transport (including both urban passenger and commercial vehicles), the modernization of inland waterway transport and port hubs, and the conversion of the railway system from the post-Soviet 1520 mm gauge to the European standard gauge of 1435 mm. Additionally, it is essential to establish innovative logistics hubs and to construct toll motorways that would serve as national-level transit corridors. Tolling would allow new corridors to better recapture maintenance costs.

Although these steps are typically approached in chronological sequence, in the case of Ukraine, what truly matters is which strategies are adopted for stabilization and how long-term modernization needs are addressed, even amid ongoing hostilities and during the early stages of recovery.

The United Nations in the Sendai Framework for Disaster Risk Reduction (UNISDR 2015) defines post-war (and post-crisis) recovery as a chance not only to rebuild what was destroyed, but also to "build back better" by creating more resilient, safer, and more inclusive infrastructure systems. This approach is an important guideline for countries emerging from war, including Ukraine, where a significant part of the transport infrastructure is subject not only to repair but also to a conceptual reassessment.

Approaches to transport logistics in post-conflict conditions

Post-war territories are experiencing profound changes in logistics: from the destruction of key transportation hubs to the complete restructuring of routes for the delivery of humanitarian aid, goods and critical resources (World Bank 2023). The restoration of transport logistics in such conditions has not only a technical but also a strategic dimension, as it affects the speed of stabilization of the region, the return of the population, the functioning of the economy, and access to services.

Integration of transport and land use

The integration of transport planning with spatial development and land use is a fundamental condition for the efficient, safe, and sustainable functioning of transport systems. In the modern approach, infrastructure is not considered in isolation, but as

part of a functional space that includes buildings, landscape, legal regime of land use, types of ownership, and development potential.

Regulatory framework in the transport sector and its updating

The quality and efficiency of transport infrastructure largely depend on the regulatory framework that governs the design, construction, operation, and safety of roads, railways, bridges, and other facilities (European Conference of Ministers of Transport 2004). In the international context, technical standards, engineering norms, and land use regulations are seen as the basis for sustainable mobility, integration of transport modes, and rational allocation of resources.

Research methodology

The research in this thesis, which focuses on post-war recovery and is mainly dedicated to transport infrastructure, is based on an applied qualitative methodology. The research is exploratory because it describes ongoing adaptations to an event in process- the war and immediate recovery process.

This study goes beyond merely reviewing existing models and examples, some of which were implemented, others that remain on paper. Its main goal is to explore how certain approaches can be adapted or newly introduced to fit Ukraine's current realities: a country facing a prolonged war and, at the same time, standing on the brink of an inevitable and large-scale post-war transformation. The core intention is to examine real-world cases and distill practical solutions that could work under Ukraine's constraints—limited resources, ongoing insecurity, and the strategic need for integration into the European Union. These efforts must take place amid continuing combat operations and the ever-present threat of further destruction from airstrikes.

The urgency of this research is rooted in the extraordinary conditions Ukraine is facing in the near future, as well as the broader international political and economic shifts. On the one hand, the country is grappling with an unprecedented level of destruction: hundreds of bridges destroyed, tens of thousands of damaged roads, shattered railway hubs, ruined terminals, airports, river ports, and logistics centers. Beyond the infrastructure that has been actively attacked, overall infrastructure quality will suffer from deferred maintenance due to military prioritization. On the other hand, Ukraine still relies heavily on inherited Soviet-legacy technical documentation procedures and outdated planning practices. While there have been steps to modernize legislation and align with international standards, these efforts are still far from complete and the imposition of martial law in 2022 arrested the development of reforms in many areas.

In this context, it would not be an exaggeration to say that Ukraine currently lacks a regulatory and methodological framework that is both effective and truly suited to the challenges of post-war recovery. That is why this research must combine practical,

experience-based analysis with academic and theoretical contextualization—In this way, it aims to offer concrete ideas for how to rebuild in a way that is both realistic and future-proof.

The type of research is exploratory, which is not only aimed at testing existing hypotheses, but also focuses on the formation of a new knowledge base, conceptualization of approaches that can be applied to Ukraine. In this regard, the study is based on qualitative methods of analysis, which involve considering infrastructure not only as engineering structures, but also as a socio-spatial and political phenomenon. This allows us to form new ideas about the problem through a detailed study of specific cases.

The methodology involves the following main approaches:

- Case studies as the main method for in-depth analysis of specific examples of recovery;
- Comparative analysis to compare models and approaches;
- Content analysis of official documents, analytical and technical reports, and regulations;

Selection of cases

The review of countries and cases for the study was selected based on several important criteria, the criteria used for selecting the case studies was as follows

1. The geographic scope of past wars that caused significant damage to transport infrastructure as a direct result of armed conflict;
2. The scale and intensity of destructive events, particularly those targeting transport and logistics systems;
3. Diversity in spatial, political, and institutional recovery approaches;
4. An economic geography comparable to Ukraine's—namely, large industrial and service-oriented economies with similarly structured multimodal transport networks.

Naturally, the selection was also shaped by the availability and accessibility of reliable sources, including official documents, verified reports, policy papers, and academic literature. Ultimately, the most decisive factor was whether the case offered a realistic and relevant perspective that could inform the Ukrainian context.

Five cases were selected for the study:

- Germany (1945-1960) - as an example of recovery in the context of market economy integration, Marshall Plan assistance, liberalization, and institutional mobilization. Germany also shows an example of a

reconstruction that occurred alongside the transition to democracy. While Ukraine was already a democracy before the war, the experience of Germany shows how post-war infrastructure recovery can strengthen democratic institutions and decision-making

- Poland (1945-1980) - a demonstration of centralized infrastructure reconstruction and complete restoration (e.g. Warsaw, Gdansk, Gdynia) Poland's reconstruction was ostensibly led by a top-down governance structure, but de facto also involved local decisionmakers. Another similarity to Ukraine's current situation (in the inverse) is that the Polish rail networks were reoriented from connections that integrated with the West to a network that prioritized connection to the east
- Great Britain (1945-1955) - reconstruction in the context of a lack of resources and austerity policy, planning of Greater London, limited investment in transportation. In this sense, the reconstruction of UK presents one possible scenario for Ukraine if it fails to receive adequate external support and/or reparations from the Russian Federation.
- Croatia (1991-2005) has experience after the long war for independence. Damage to Croatia's transport infrastructure was more limited when compared to that of Bosnia but included damage to ports. Suffered from breakdown of trade with former internal trading partners in the former Yugoslavia.
- Bosnia and Herzegovina (1991 – 2005) also experienced armed conflict, during which the country suffered significant destruction, especially in the transport sector. The war in Bosnia and Herzegovina was part of the Yugoslav Wars. The post-war reconstruction of Bosnia and Herzegovina is an example of recovery in a complex political environment, with serious and widespread destruction of infrastructure, dependence on international aid, and a long recovery period. The case of Bosnia highlights the challenges arising from fragmented governance, lack of coordinated planning, and significant dependence on external financing, which Ukraine could potentially face if effective governance and unified planning mechanisms are not properly established.

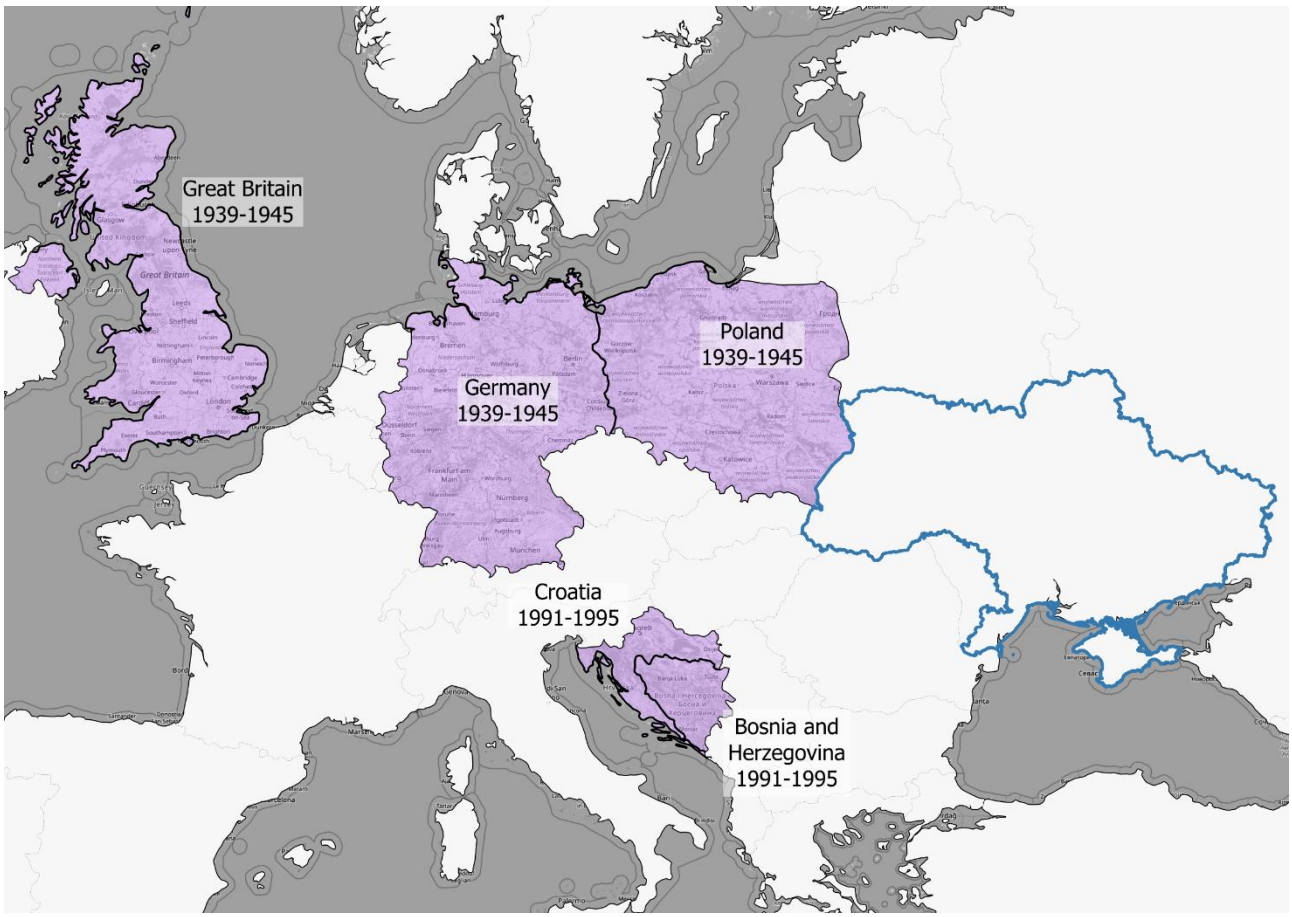


Figure 2 – Postwar recovery cases (Source: Own development based on open data and GIS)

Note: Real existing boundaries, not in the moment of war

This chronological, geographical, and political diversity allows for a comparative analytical model that highlights elements of policy, infrastructure planning, and resource management relevant to Ukraine.

Table 1 Comparative Characteristics of Post-War Recovery Contexts and Frameworks in Selected Countries

Case	Year	Conflict type	Level of income by world standards	Level of transport-related physical damage	Rebuilt framework (democratic, capitalist)	International involvement	Dependent on overland freight transport
Germany	1945 - 1960	WW2	high	30%	Capitalist transitional democracy	Marshall Plan	Strong
Poland	1945-1980	WW2	middle	38%	State socialist (centralized)	Limited (domestic COMECON support)	Strong
Great Britain	1945-1955	WW2	high	10%	Parliamentary capitalist democracy	UNRRA aid, loans	moderate

Croatia	1991-1995	Internal + civil	middle	10%	Capitalist democracy	EU, WB	moderate
Bosnia	1992-1995	Civil + external	middle	70%	Hybrid	WB, EU, UNDP, USAID	Strong
Ukraine	2014 - ….	external	middle	35%	Democratic, capitalist	EU, WB, IMF, USAID, partners	Strong

Operationalization and variables

For the purpose of comparative analysis, key variables have been identified that allow for comparison of cases from different countries and ensure analytical comparability with Ukrainian realities. These variables are structured according to functional and institutional parameters that reflect the most important characteristics of post-war recovery processes.

Institutional model of recovery

Covers the configuration of management authority and coordination of reconstruction processes:

- The centralized model, which implies the dominance of state structures, and directive planning;
- The decentralized model includes the role of municipalities or regional authorities;
- A hybrid model, including public-private partnerships (PPPs), in which the private sector is involved in the financing, design, implementation and operation of infrastructure facilities on the basis of contractual obligations with the state. In the modern rehabilitation of transport infrastructure, PPPs have become a necessary alternative to direct public funding (World Bank n.d.).

Sources of funding

The war has had a catastrophic impact on the financial capacity of the warring countries. During the period of hostilities, the state must simultaneously ensure the reliable functioning of both ordinary civilian transport processes and those of military importance. For both areas, the state and quality of infrastructure is key. At the same time, the financial aspect has a significant impact on stability and the tendency to recovery. Undoubtedly, the top priority for the state during wartime will continue is to finance the country's vital functions and ensure reliable defense and territorial integrity. In such difficult conditions, Ukraine must rely on a variety of both levels and sources of funding. Other exacerbating factors includeperistent limited resources, population outflow and ongoing internal migration, a dynamic and shifting line of contact and constant shelling which increases the level of damage. From this perspective, Ukraine should focus on different levels of funding, including

- Budgetary state funding support;
- International assistance (e.g., technical assistance from UNDP, the World Bank, EIB, German Marshal Fund);
- Mixed financing, including commercial loans and investment funds;
- PPP mechanisms, which also create financial hybridity and transfer some of the risks to the private partner.

Functions of transport infrastructure in the recovery

In this study, the transport infrastructure is considered not only as a set of nodes and segments of roads, streets, and bridges, but also as a component of the architecture and ecosystem of the state. In the post-war reconstruction context, the role and functions of transport infrastructure become the foundation for future effective economic development, ranging from rapid emergency actions through stabilization to full-fledged modernization of existing gaps.

The role of the transportation system can change significantly:

- Population mobility, which ensures both daily movements of the population in areas away from the front line and evacuation to safe areas, as wellas providing mobility for returning populations after de-occupation;
- Supply logistics covering humanitarian corridors, military logistics, and the supply of goods and services throughout the country;
- Stimulation of economic activity includes access to markets and resources, employment, and investment attractiveness);
- Reintegration of territories through the development of key hubs such as airports, railway junctions and freight logistics centers

Legal and regulatory framework

The state and quality of the legal environment in which the remediation process takes place plays an important role:

- The application of existing standards, which in the case of Ukraine may impede progress result, as only part of the DBN is adapted to the present, while the other is outdated or a continuation of Soviet approaches of the last century. It is thereby important to consider each of these elements in isolation from each other;
- Implementation of international practices and norms (such as EU acquis, ISO Mobility Framework);
- Adapting best practices to specific local conditions.
- Regulatory reform - updating urban planning documentation, simplifying permitting procedures and digitalizing control.

Recovery efficiency

The key indicator in this study is the effectiveness of recovery implementation. The final variable allows us to assess the results of the strategies according to the following criteria:

- The level of implementation of the final result corresponds to the initial plans (unless an announced change of objective occurred while the project was underway
- The speed of implementation in months or years in comparison with standardized implementation schedules;
- Cost of projects in relation to pre-war GDP or budget;
- Long-term effect - the degree of adaptability, innovation and resilience of infrastructure to new challenges: environment, security, demography and the extent to which these innovations are incorporated into standard practices;
- Stakeholder engagement - the level of transparency and inclusiveness of planning processes.

Methods of data collection and analysis

The information was collected through documentary analysis, bibliographic search, study of public policies and academic literature. Main groups of sources:

- Academic journals: E.G. Journal of Contemporary History, Urban Studies, Cities, Planning Perspectives;
- Official reports: World Bank RDNA, UNDP Early Recovery Frameworks, OECD Post-War Infrastructure Guides;
- Recovery plans: Marshall Plan, County of London Plan, UNRRA documentation;
- Regulations and technical documents: DBN, TEN-T Regulation, ISO Mobility Framework;

The content analysis was accompanied by thematic coding in the following categories: financing, regulatory framework, role of transport, and spatial planning.

A separate role is played by transferability, i.e., the extent to which specific institutional solutions, legal frameworks, or financial models can be adapted to the current Ukrainian environment, taking into account the context of war.

The main tool for comparison is the comparative matrix, which allows for an objective assessment:

- Nature and duration of recovery;
- Quality of spatial solutions;
- Participation of citizens and the private sector;

- Sustainability of infrastructure results;
- Impact on mobility and logistics.

In addition, the principles of triangulation (multi-source) were used to reduce distortions in interpretations and increase the reliability of the analysis.

Limitations of the study

Despite the wide base of sources, the study has certain limitations:

- The level of data detail in different cases is uneven
- The political and institutional context differs significantly (in particular, between Poland, and Germany);
- Some archival data, especially in the case of the UK and Germany, are incomplete or closed;
- Lack of direct quantitative verification of the effectiveness of some measures.
- However, to overcome these challenges, we used analytical extrapolation, the logic of analogies, and a focus on the qualitative rather than quantitative dimension of the assessment.

Expected result

Within the scope of the study of post-war transport and logistics infrastructure recovery practices in selected cases, the expected outcome is the formation of a comprehensive understanding of effective approaches to infrastructure recovery. Identification of successful and unsuccessful principles and steps during recovery. The review of experience should help to form a list of strategically effective approaches based on international experience, with subsequent adaptation to the Ukrainian context. A comparative analysis of the experience of countries with different economic potential, scales of destruction, and resource capabilities will help identify key patterns in policy and planning processes that affect the quality and speed of infrastructure restoration. This study can serve as a practical recommendation and a foundation for further research and the formation of an updated, adapted regulatory, legal, and technical framework that takes into account current challenges and threats.

International experience in post-war recovery

The restoration of transport infrastructure after large-scale military conflicts has become a determining factor in spatial, economic, and social reorganization for many countries of the twentieth and twenty-first centuries. In the post-war period, transport not only serves as a means of population mobility or resource logistics, but also as a critical infrastructure that ensures basic integration of territories, reintegration of displaced people, economic stabilization, and lays the foundation for long-term development. Each country that has gone through a period of military destruction has

developed its own model of recovery, depending on the political regime, level of available resources, institutional maturity, and ideological priorities. This section analyzes five in-depth cases: Germany, Poland, the United Kingdom. Each case is presented in the following logic: historical context, scale of destruction, initiation and planning of recovery, institutional structure of implementation, financing mechanisms.

Germany

Historical context

The Second World War (1939–1945) is regarded as the most extensive conflict of the 20th century. It affected more than 60 countries, and estimates of total human casualties range from 50 to 80 million. Beyond the loss of human life, the war inflicted immeasurable physical destruction. Six years of warfare, artillery exchanges, and repeated carpet bombings devastated both small military settlements and entire cities such as London, Gdańsk, Warsaw, Berlin, Coventry, Cologne, and Dresden. These catastrophic losses significantly influenced the post-war development of many countries, particularly in the transport sector.

It is important to note that even before WWII, Germany possessed one of the most advanced road infrastructures in the world. Germany was a pioneer in highway construction—its famous autobahns, known for their speed-unrestricted lanes and lack of intersections, were seen as technological marvels. By 1939, more than 3,800 km of autobahns had been completed, connecting major cities and economic regions while serving strategic military logistics functions (Vahrenkamp 2010).

Figure 3 – The German road network in 1939 (Source: https://www.quora.com/)

After the war's end in 1945, Germany lay in infrastructural ruin and geopolitical division. The country was divided into four occupation zones controlled by the United States, the United Kingdom, France, and the Soviet Union. This division eventually evolved into the separation of the Federal Republic of Germany (FRG) and the German Democratic Republic (GDR), which influenced post-war reconstruction and future transport policies.

The FRG, formed in 1949 under Western administration, soon became an emblem of the "economic miracle" (Wirtschaftswunder), largely due to Marshall Plan aid and deep institutional reforms in economic and transport policy, as well as through a profound transformation of institutional and transportation policies. This is confirmed by the in-depth analysis of economic transformation in the work of Tooze (Tooze 2007). The Marshall Plan aimed to rapidly restore European economies, modernize industry, reduce trade barriers, and limit Soviet influence in the post-war region.

Scale of Infrastructure destruction

It is therefore evident that Germany's transport infrastructure was a primary target for the Allies and consequently suffered extensive damage. Germany's infrastructure suffered massive destruction due to aerial bombardment, artillery shelling, and the targeted dismantling of transport hubs. The devastation was both economic and symbolic—Germany lost a system once seen as exemplary across Europe. According to Hogan (1987) and Milward (1984), by 1945, over 20% of the railway network was unusable, more than 10,000 bridges had been destroyed, and much of the urban road network was impassable. Around 50% of locomotives and 60% of freight vehicles were also destroyed (Hogan 1987) (Milward 1984) .

High-density infrastructure cities—Berlin, Frankfurt, Dresden, and Cologne—lost nearly all transport functionality. Ports like Hamburg, Bremen, Kiel, and the inland port of Duisburg sustained heavy damage. Over 60% of port cranes, cargo terminals, railway access, and storage facilities were rendered non-functional. Some ports were mined or blocked by sunken vessels until as late as 1947. Key logistics regions such as the Ruhr were paralyzed, while river networks (Rhine, Elbe) and canal systems required full-scale rehabilitation.

Start of recovery

Immediately after Germany's surrender, the urgent need to restore logistical capacity became evident. Military engineering units, especially from the U.S. zone, led early recovery efforts—clearing railways, repairing tunnels, and constructing temporary bridges. Civilian labour, including former soldiers and mobilised locals, also supported these efforts. By mid-1946, basic rail links between major cities in West Germany had been reestablished using provisional solutions.

Institutional approach

After the capitulation, the first steps in the new world order, and the formation of the new German government in 1949, the newly formed Federal Ministry of Transport became the key coordinator of the reconstruction, which still exists today in a slightly different format. At the regional level, the ministries of the Länder were responsible for developing terms of reference and local programs at the appropriate level. Municipalities were restoring urban infrastructure, including tram networks, transport depots, and train stations. A multi-level cooperation was established, which allowed for the rapid scaling of modernization programs. In 1948, the Credit institution for reconstruction (ger: KfW[1] - Kreditanstalt für Wiederaufbau) was established and became a key financier of postwar reconstruction transport projects.

[1] www.kfw.de

Financing

Sustainable restoration required immense capital investment. The funding model included: (1) Marshall Plan aid exceeding $1.4 billion; (2) federal investment stimulus programs; (3) municipal co-financing. Concessional freight mechanisms were also used. Each project underwent a feasibility assessment, regional approval, and federal validation. Since then, the co-financing principle (municipality–state–federation) became standard practice.

Strategic planning

The full-scale industrialization of the 1950s was accompanied by the development of highways, the reconstruction of railway junctions (e.g., Hamburg, Frankfurt), and the creation of logistics hubs. In the 1950s, the FRG government launched the first national transport plan (Bundesverkehrswegeplan), which set priorities for investments in roads, railways, and waterways (Federal Ministry of Transport and Digital Infrastructure (Germany) 2003). Standardized technical norms were introduced for bridges, stations, and logistics hubs. Spatial planning (Landesplanung) was synchronized with infrastructure development, enabling new urban zones and industrial clusters. The growth of trade stimulated the need for multimodal hubs. Spatial planning was combined with the development of new residential areas and industrial zones based on transport accessibility. After the creation of the Federal Republic of Germany, national standards were actively developed, which in many cases exceeded the level of pre-war planning. This concerned the load axles of bridges, axle loads in road construction, highway widths, etc. Subsequently, these standards became the basis for European standards.

Implementation

The reconstruction of transport infrastructure in Germany can be broadly divided into stages corresponding to the previously mentioned phases. These stages were shaped by a logic of progression from basic technical survival to medium-term planning and eventual modernization. The breakdown reflects shifts in institutional development (from external military governance to sovereign policy-making in the FRG), levels of financial access (from military resources to grants and banking instruments), and the scale and complexity of implementation.

- Emergency Response phase between 1945–1946 focused on immediate reaction to destruction. The goal was to rapidly clear transport corridors, reconnect territories, and enable at least minimal movement of food and essential goods. Allied engineering units built temporary bridges, repaired rail lines, and restored basic communications, particularly in major urban areas;
- Stabilisation period 1947–1949 of institutional consolidation and early strategic direction. The foundation for long-term transport

governance was laid, including the creation of KfW, which played a decisive role in financing regional programs. During this time, policy priorities began to align between the areas and the emerging federal government;

- During Strategic Planning 1950–1955 the adoption of the first nationwide transport plan—Bundesverkehrswegeplan—marked the beginning of structured investment strategies. National norms were established for design, materials, and technical parameters. Railway hubs, industrial road corridors, and logistics clusters were rebuilt or expanded. Planning integrated spatial development with transport infrastructure;
- The final stage was the modernization of 1956-1960, thanks to which Germany increased the volume of capital investment, which in turn allowed the implementation of large-scale projects: electrification of railways, construction of highways in a slightly new form and understanding, renewal of the locomotive and car fleet, and integration of logistics chains with sea and inland ports.

In general, World War II gave an incredible boost to all sectors of life. The comprehensive reconstruction of Germany's transport infrastructure was a key structural factor in the “economic miracle”. The consistent logic from immediate response to strategic modernization made it possible to create an institutionally qualitatively new transport system.

Today, Germany boasts one of the most advanced and integrated transport systems worldwide. Its autobahn network exceeds 13,000 km, and its railway system operated by Deutsche Bahn is among Europe’s busiest. Within the TEN-T framework, Germany functions as a central transit hub connecting the North and Baltic Seas to the Alps, the Mediterranean, and Eastern Europe.

Germany is also a leader in developing multimodal freight platforms, intelligent transport systems (ITS), digital railway modernization, and green logistics. The transport sector contributes roughly 8% of the national GDP, with Hamburg, Duisburg, Frankfurt, and Munich serving as key logistics hubs for global trade.

Poland

Historical context

Poland's geographical and geopolitical position during the Second World War played a tragic role, as the country became the primary battleground between Axis powers and the Allied coalition. In many respects, this situation mirrors present-day Ukraine, which acts as a gateway between democratic Europe and actors attempting to restore Soviet-style spheres of influence. After WWII, Poland emerged as one of the most devastated countries in Europe. The 1945 Yalta Agreement significantly altered its

borders: Poland gained German territories in the west while losing eastern lands. The reestablishment of statehood occurred under Soviet supervision, and by 1947, Poland had adopted an authoritarian political system.

In this context, transport infrastructure was viewed not only as a tool for economic development but also as an instrument of centralized control, military mobility, and ideological integration of the new western territories..

Destruction

According to Polish historians and international sources, around 38% of infrastructure was destroyed or severely damaged (Kaminski 2010). Warsaw alone suffered destruction of up to 85%. Total transport infrastructure losses included over 4,000 km of rail lines, 370 stations, 2,400 bridges, and accompanying systems such as electrification and signalling (Davies 2005). Like German cities, ports in Gdansk and Gdynia were partly destroyed or mined.

Emergency response

Poland established the Bureau for the Reconstruction of the Capital (BOS), which not only led efforts to rebuild Warsaw but also shaped the capital's transport framework. Temporary railway sections between major cities were restored, and bus routes using military vehicles were launched. Key agencies included BOS and the Ministry of Communications. Reconstruction occurred in several phases: emergency response (1945–1947), systemic rebuilding and modernization (1947–1955), and industrial infrastructure expansion (1956–1965) (Davies 2005).

Particular attention was given to Gdansk and Gdynia as strategic port cities. Their infrastructure was restored and expanded to support Poland's export strategy. Gdynia underwent massive reconstruction, including expansion of sea port facilities, cargo warehouses, and railway terminals. In Gdansk, cranes, docks, and rail access lines were restored (Ministry of Maritime Economy and Inland Navigation n.d.).

Institutional Measures

The first step was the creation of the Bureau of Capital Reconstruction (Biuro Odbudowy Stolicy - BOS) in 1945, which played a key role in coordinating the reconstruction of the city, including the transport component. At the same time, the Ministry of Communications (Ministerstwo Komunikacji) functioned in parallel, responsible for the national level of transport policy (Kaminski 2010).

Key institutions included the Ministry of Communications, the Ministry of Reconstruction, and the Central Planning Office. Regional planning committees coordinated local needs with central directives. Municipalities had limited autonomy but were responsible for local recovery efforts: roads, public transport, bus terminals. Warsaw, Gdańsk, and Kraków received expanded powers under special development plans. Poland introduced a regulatory system combining Soviet and domestic technical

standards. The concept of "development axes" (oś komunikacyjna) guided trunk planning, and protective zones around critical transport nodes were established to prevent obstruction of future expansion (Ministry of Communications of the Polish People's Republic n.d.).

Financing

As a Soviet satellite, Poland was excluded from the Marshall Plan and its financial or engineering assistance, especially amid the Cold War competition. Instead, five-year plans starting in 1946 became the primary mechanism for recovery. Funding was distributed through the State Bank according to sectoral quotas. Some infrastructure was financed through Soviet assistance in the form of equipment, railway materials, and technical resources.

Strategic planning

In 1949, Poland adopted its first National Spatial and Economic Plan, covering rail restoration, road construction, port modernization, and public transport development. This plan also carried an ideological aim: connecting newly acquired western territories with the national center.

Technical standards resembling Soviet SNIPs were introduced to regulate track widths, concrete types, and bridge designs. BOS and PKP (Polish State Railways) developed site-specific engineering solutions.

In the first years after the war, Poland actually adopted the Soviet model of regulatory regulation. However, in the 1950s, the process of creating its own regulatory framework began. For example, in 1956, the first unified road standard "PN-56/D-96000" was adopted, which defined the parameters of roadway width, turning radius, axle loads, etc. (Polish Committee for Standardization 1956).

Implementation

Implementation of post-war recovery in Poland reflected the evolution of administrative capacity, resources, and technological sophistication within a centrally planned economy. The shift from emergency response to long-term planning was accompanied by increased capital investment and specialization. According to the Polish Ministry of Transport, between 1950 and 1980, investments in transport accounted for 7–12% of state capital spending, peaking at 20 billion zloty annually (Ministry of Communications of the Polish People's Republic n.d.).

- 1945–1947: Emergency Response. Railway demining, temporary bus services, and repair of over 2,500 km of rail lines. By 1946, 40% of intercity routes and more than 60 key bridges (e.g., on the Vistula and Oder) were restored.
- 1948–1955: Stabilization. Five-Year Plan (1950–1955) prioritized reconstruction of major corridors: Warsaw–Gdańsk, Katowice–Łódź.

Over 500 km of rail were electrified, eight major stations modernized, and twelve depots created. Infrastructure investment in 1954 reached 8.3 billion zloty.

- 1956–1965: Strategic Planning. National Transport Program launched with focus on freight corridors and port integration. Development axes and protection zones were introduced. New junctions in Łódź, 900 km of roads upgraded.
- 1966–1980: Modernization. During the third and fourth five-year plans, transport investment peaked. Intermodal hubs opened in Poznań, Szczecin, and Silesia. Gdynia gained a new container terminal. By 1980, 22% of railways were electrified, and road density reached 88 km per 1,000 km^2 (Polish Central Statistical Office 1980).

Post-war restoration in Poland laid the foundation for a national infrastructure network suited to a centralized economy, supporting transport of coal, metals, and agricultural goods. Rail remained dominant. Gdansk and Gdynia became vital export gateways; by the 1970s, they handled over 40 million tons of freight annually (Ministry of Maritime Economy and Inland Navigation n.d.). Industrial logistics axes between Upper Silesia, Lodz, and Warsaw became core transport corridors.

Today, Poland is a key logistics hub on the EU's eastern flank, particularly in relation to Ukraine. Integrated into the TEN-T network, Poland boasts a modernized road and rail system. Projects like Rail Baltica and the Central Communication Port (CPK) highlight Poland's role as a transit state. Gdansk and Gdynia now handle over 100 million tons of cargo annually. Poland's European-standard infrastructure, including high-speed controlled-access motorways and standard gauge lines extending to Ukraine's border, signals preparation for full integration of both countries' transport systems.

Great Britain

Historical context of restoration

On the eve of World War II, Great Britain was considered to have one of the most developed transportation systems in the world. The total length of roads reached about 300,000 km. The railroad network covered more than 32,000 km of tracks (British Ministry of Transport 1940) (British Ministry of Transport 1940). About 120 major railway stations, more than 1,000 freight stations, 280 ports, including hubs such as Liverpool, London, Southampton, Glasgow, and Newcastle (Port of London Authority 1938). The bridge infrastructure included more than 18,000 engineering bridges and structures, of which 20% were strategically important for interregional communication (British Rail n.d.). The United Kingdom's transport sector was an essential factor in facilitating its global economic reach despite, as an island, its comparatively isolated status.

Destruction

Although the United Kingdom was not subjected to land occupation, its transportation system was systematically attacked. According to various estimates, during the Blitz (1940-1941)

- about 5,600 km of railroad tracks,
- over 12,000 bridges and tunnels were partially damaged,
- more than 1,500 railroad cars were destroyed,
- more than 300 thousand square meters of port warehouses (UK National Archives 1946).

Problems with the transport infrastructure were combined with the demobilization of the population, the need for resettlement and modernization of the urban environment. The old railroad network (fragmented into numerous private operators), inefficient bus service structure, and lack of coordination between modes of transport all required not just reconstruction, but transformation (Gourvish 1986).

First response

The first major step was the adoption of the reconstruction program, where transport was included in the overall logic of state intervention in the economy. In 1947, the Transport Act of 1947 was passed, which nationalized key transport assets and created the British Transport Commission (BTC), the main coordinating body for infrastructure. The aim was to integrate the rail, bus, maritime, and freight transportation sectors with each other. Although the initial reforms were aimed at recovery, in the 1950s the focus was on modernization and efficiency. Nationalization was aimed at reducing duplication of functions, increasing intermodal transportation, and centralizing capital investment.

The BTC, reporting to the Ministry of Transport, coordinated projects on bridge reconstruction, renewal of railway rolling stock (locomotives, wagons), port modernization, and road reconstruction.

A separate role was played by the London County Council, which was responsible for transport planning for the metropolis and the implementation of the 1943 London County Plan, one of the most ambitious postwar spatial documents in Europe (Abercrombie 1945).

Measures

After the war, there was a vast reconcentration of population and economic opportunity in London, which became the basis for the city's transport zoning. For the first time, the concept of “ring roads” was introduced which expanded the areas that could be officially served, as well as the hierarchy of the street network, the creation of restricted traffic zones and priority for public transport. In particular, the development of orbital arteries and the formation of green belts - areas where construction was

limited by easement requirements to control the spread of urban development. (Hall 2014).

In the case of railways, the focus was on electrification and centralized dispatching. By 1960, more than 30% of suburban routes were electrified, and automated signal systems were extended to the busiest junctions (Bagwell 1988). In the longer term, the UK government used new town planning coupled with transport investment to spread investment and opportunity beyond the greater London area.

Financing

Obviously, like the rest of the world outside of the United States after the Second World War, in 1945-1951, the UK experienced severe economic difficulties and austerity. The postwar recovery was financed mainly by:

- domestic bond issues,
- cuts in defense spending,
- budget redistribution.

During 1946-1952, only 2.7%-3.4% of the state budget was allocated to transport infrastructure. Large systemic investments were postponed until the early 1960s. The program for the overhaul of bridges and roads was adopted only in 1954, while the main part of the railway modernization began in 1955 (British Railways Board 1955). Financing was provided by government grants, government debt bonds, and special funds. Over the period 1948-1956, more than £1.2 billion was allocated to the transportation industry (equivalent to more than £30 billion in 2023 prices).

Implementation

The four-stage approach is based on an analysis of government reports, modernization plans, and the timeline of key institutional and infrastructure decisions. This division is a reconstruction based on the phases of functional change: from rapid response to long-term modernization. This structure is widely used in studies of urbanism, transport, and postwar reconstruction.

After the war, a four-stage approach to reconstruction was applied:

Emergency response (1945-1947)

During this period, the minimum necessary facilities were restored: damaged tracks were welded, port cranes were repaired, and temporary warehouses for grain and coal were created. Bridges were repaired by military engineers. The priority was humanitarian transportation, evacuation of civilians and stabilization of food logistics (Ministry of Works 1947).

Stabilization and reorganization (1947-1951)

This period saw profound institutional transformations: the creation of the British Transport Commission (BTC), which consolidated the management of railways, canals, road transport, and the underground. The nationalization of railroad companies was carried out, which allowed to optimize tariff policy, standardize engineering approaches and reduce operating costs. In addition, the Transport Act of 1947 was passed, which laid the foundation for regional transport councils and gave BTC the authority to conduct strategic planning.

In 1947, the British Transport Commission was established to coordinate the entire national transportation system. Regional transport councils were introduced, and in 1948, railroad companies were nationalized. Basic documentation for the inspection of facilities and identification of critical nodes was formed.

Strategic planning (1952-1955)

Based on previous reviews and consultations with municipalities, the government began implementing the Greater London Plan, which included the reconstruction of transport axes, the introduction of new street standards, the reservation of bus lanes, and the creation of green areas around the city. Planners, such as Patrick Abercrombie, promoted spatial zoning with an integrated transport structure (Abercrombie 1945).

Modernization (1955-1965)

A program of railroad modernization, electrification of lines, and the launch of diesel locomotives was approved. The road network began to adapt to the growth of private transportation. The London Underground and bus systems have been upgraded. More than 800 outdated bridges were replaced and 60% of pre-war port cargo handling was restored (House of Commons 1965).

Today, the UK has one of the most stable and digitized transport and logistics systems in Europe. The road network is more than 394,000 km, of which more than 70,000 km are classified as national roads (Department for Transport (UK) 2023). Railways reach 16,000 km, including two high-speed lines (HS1, partially HS2 under construction). There are more than 100 seaports, including Felixstowe, London, and Southampton. Large logistics clusters are associated with the airports of Heathrow, Manchester and Birmingham (Heathrow (SP) Limited 2023).

Croatia

Context

The war for Croatian independence at the end of the 20th century is a relatively recent and large-scale conflict in terms of losses and destruction on the European continent. Before the war for independence in 1991, Croatia had a well-developed infrastructure system that was part of the Yugoslavial. Prior to the Croatian War, the country had a transport system consisting of:

- about 28,000 km of motorways, of which 1,100 km were highways;
- over 2,700 km of railway network, partially electrified (35%);
- the key seaports such as Rijeka, Split, and Dubrovnik;
- 9 regional airports, of which 3 are international (Zagreb, Split, Dubrovnik).

The country's location provided a strategic link between Central Europe and the Mediterranean. The case of Croatia is a benchmark for Ukraine, as the country is currently a member of the EU and NATO, which Ukraine also aspires to join.

Destruction

The destabilization following the breakup of Yugoslavia, territorial claims by self-proclaimed Serbian entities in Croatia, and massive military intervention by the Yugoslav People's Army (JNA) and paramilitary formations led to significant damage to transport and logistics infrastructure. As everywhere else, roads, bridges, logistics hubs, and corridors are key to supplying the parties to the conflict with necessary goods, as well as providing humanitarian supplies to the civilian population.

One of the goals of destroying critical infrastructure is to destabilize transport links, isolate regions, and limit the mobility of the warring parties. According to the Ministry of Transport, shelling, mining, and blockades have caused serious damage and destruction:

- more than 3,000 km of roads have been destroyed or damaged;
- up to 90% of the railway infrastructure in the temporarily occupied territories has been put out of operation;
- about 100 bridges have been destroyed, especially in the north of the country;
- the ports of Rijeka and Dubrovnik were shelled, and logistics facilities, warehouses, and docks were destroyed.

According to estimates by the Croatian government and the World Bank, by 1996, more than 10% of the country's transport infrastructure had been put out of action.

First response

After signing the Dayton Accords in 1995, the Croatian government, with support from the World Bank and the European Bank for Reconstruction and Development (EBRD), started the Emergency Transport and Mine Clearance Program, which included clearing roads of mines, temporarily restoring traffic, rebuilding bridges, and setting up temporary railway crossings.

Institutional approach

After the end of hostilities in 1995, the Croatian government adopted a National Reconstruction Program, which became the starting point for the recovery process.

During the post-war recovery period, newly established entities such as the Ministry of Maritime, Transport, and Infrastructure Development, the Central Agency for Financing and Contracting EU Projects (SAFU), and municipalities responsible for local recovery initiatives played an important role.

Financing

It is evident that the country's financial capabilities were extremely limited in the post-war period. Moreover, after the war, the country was in a phase of economic recession, with GDP falling by more than 30%, which significantly limited the state's ability to cover the costs of full-scale national reconstruction. During the post-war recovery process, Croatia was forced to resort to external sources of financing, such as World Bank loans and EU technical assistance programs (Phare, CARDS).

Croatia has been on a course towards European integration since the late 1990s. The use of funds from EU funds, in particular CARDS (Community Assistance for Reconstruction, Development and Stabilisation), made it possible to synchronise the regulatory framework with EU directives, in particular TEN-T.

The World Bank played a decisive role by financing over $100 million through the Croatia Transport Rehabilitation Project (1998–2003) to rebuild roads, bridges, and railways (World Bank 2006). This was part of a broader post-conflict recovery strategy in the Balkans.

> *"The proposed project will support Croatia's efforts to restore critical transport infrastructure damaged during the conflict, reduce isolation of war-affected areas, and facilitate economic reintegration."*
> *— World Bank, P008285 Project Overview*

Implementation

The Croatian recovery process was based on international standards and approaches to post-conflict recovery (UNDP, World Bank) and was adapted to the national context. Based on functional priorities for restoring transport links for the delivery of goods and humanitarian aid, as well as the critical importance of access to logistics corridors, and of course political factors, the stages for the Croatian case are outlined below.

As emergency response the first steps (1995–1996) were clearing roads of mines and temporarily restoring bus and rail connections between regions. At this stage, more than 1,500 km of roads and 300 km of railways were cleared, 48 temporary bridges and pontoon crossings were installed, including crossings over the Kupa and Sava rivers, and the Zagreb-Split connection via Knin was restored.

The stabilization period (1996–2000) in post-war Croatia brought useful changes in the form of the reintegration of the transport system into a single network: main corridors and bridges on them. The Croatian government regained control over ports and railway junctions, reconstructed railway stations in Osijek and Karlovac, and

rebuilt 17 depots. Simultaneously with the restoration of the ports of Rijeka, Ploče, and Split, the Croatian government launched the first package of modernization projects with the support of the EU.

The next important period was to align the country's course with the EU. During period of the Strategic planning (2000–2005), the National Transport Strategy until 2010 was adopted, and projects were developed to restore the Budapest–Sarajevo–Ploče (Vc) and pan-European corridors (Vb, X). In addition, Croatia successfully integrated into the European Union's TEN-T network, along with the rapid development of multimodal logistics and large hubs, for example in Zagreb or Split.

The extended period of modernization (2005–2015) allowed post-war Croatia to reach a new, better level of transport infrastructure. The motorway network was expanded from 1,100 to 1,600 km, key railway lines were fully electrified, and control centers and security systems were digitized.

Croatia managed to achieve such high transport and logistics infrastructure performance in a relatively short period (from 1995 to 2024) thanks to a systematic approach, external assistance, and unwavering commitment to its goals. Centralized bodies were established with a mandate for long-term planning, monitoring, and implementation of infrastructure projects. In particular, the Croatian Ministry of Transport coordinated nationwide programs. Today, Croatia is a transit country for the southern flank of the EU, connecting the Baltic and Adriatic Seas. According to the Global Competitiveness Index, it ranked 36th among 141 countries in 2019 (Schwab 2019). As of 2024, Croatia has more than 1,650 km of motorways and over 2,600 km of railways, 45% of which are electrified, 12 seaports of international importance, and 6 international airports.

Bosnia and Herzegovina

Context of recovery

The war in Bosnia and Herzegovina (1992–1995) was one of the most destructive conflicts in Europe since World War II. The war in Bosnia and Herzegovina in the early 1990s was part of the war in Yugoslavia, as was the Croatian War of Independence. Overall, prior to the war, Bosnia and Herzegovina had a moderately developed transport system, which consisted of:

- Approximately 21000 km of roads
- Approximately 1000 km of railways
- international airports in Sarajevo, Tuzla, Mostar, and Banja Luka;
- riverports.

The country's geographical location made it an important transit point between Central Europe, the Mediterranean, and the Balkans, so the destruction during the war affected everyone.

Destruction

During the conflict, transport infrastructure was part of the supply chain from military personnel to the delivery of goods and services, and therefore transport infrastructure was an important target of military operations. According to data from the World Bank (World Bank 1997) and the government of Bosnia and Herzegovina, the following was destroyed in 1996:

- approximately 70% of roads;
- the railway network, which was damaged by almost 80%, especially in the Sarajevo, Doboj, and Mostar areas;
- major bridges, over 250);
- airports, including those in Sarajevo, Mostar, and Banja Luka, which were rendered unusable and suffered significant damage.

First response

Following the signing of the Dayton Peace Accords in 1995, emergency response programs were immediately launched with the support of the international community (the World Bank, the EBRD, and the EU):

The Emergency Reconstruction Project was immediately implemented and carried out, with the aim of demining and urgently repairing roads and bridges. This step helped to restore basic connections along the main transport corridors.

Instution approach

The 1995 Dayton Accords influenced further institutional changes in the post-war period, which significantly affected the organization, management, and implementation of infrastructure projects. At the national level, the Ministry of Transport and Communications of Bosnia and Herzegovina was established, whose main functions are coordination with international partners and implementing reconstruction programs.

Financing

Given the almost complete lack of internal financial resources after the war, external financing played a key role. The World Bank played a key role, providing a total of over $200 million for the Emergency Reconstruction Project (World Bank 1996). The European Union also played an important role with its PHARE, later CARDS, and IPA (Instrument for Pre-Accession Assistance) programs, which provided financial support for infrastructure reconstruction.

Implementation

Emergency response as a typical first stage began immediately after the signing of the Dayton Peace Accords in 1995. With the support of international partners, the Government of Bosnia and Herzegovina implemented demining programs covering more than 1,800 km of roads and about 300 km of railway tracks. Several dozen

temporary bridges were built to restore basic transport links between major population centers, including Sarajevo, Zenica, and Tuzla.

The Emergency Reconstruction Project, financed by the World Bank, was the first large-scale effort aimed at reintegrating the country's logistics corridors.

The second phase, stabilization, covers the period from 1997 to 2000. The key objective of the stabilization period was to create conditions for the safe and predictable operation of major transport hubs. During this time, dozens of important bridges were rebuilt, including the symbolic bridge in Mostar, destroyed in 1993, which was completely restored in 1998. Railway connections were restored on the Sarajevo-Doboj and Banja Luka-Tuzla routes.

The strategic planning phase began with the adoption of the National Transport Strategy in 2001. The main instrument for implementation was the integration of Bosnia and Herzegovina into the European infrastructure, namely the TEN-T corridor network. Projects were developed to reconstruct the Pan-European Transport Corridor Vc, which passes through Sarajevo and Mostar and leads to the port of Ploce. In 2003–2005, the government, together with the EU, began a technical and economic feasibility study of individual sections of the motorway and harmonized road and rail legislation with EU standards.

The modernization lasted from 2005 to 2015. The most visible result was the construction of over 200 km of new motorways along the Vc corridor, including the Vjetarnik tunnel, the bridge over the Neretva River, and the Sarajevo bypass. Railway junctions in Doboj, Sarajevo, and Banja Luka were also modernized, and related railway infrastructure, such as signaling systems and control centers, was upgraded.

Table 2 Comparative Overview of Transport Infrastructure Damage in Post-War Contexts

Metric	Germany (1939–1945)	Poland (1939–1945)	Great Britain (1939–1945)	Croatia (1991–1995)	Bosnia and Herzegovina (1992–1995)
Conflict duration	1939–1945	1939–1945	1939–1945	1991–1995	1991–1995
Estimated transport damage	~$25 billion (1945 USD)[1]	>38% of transport infrastructure[2]	~10% of transport/urban systems[3]	$3–4 billion[4]	$7–10 billion[5]
Road & rail damage	~25% rail network destroyed; 10,000+ bridges lost[1]	4,000+ km railways, 2,400 bridges[2]	~5,600 km railway affected, 12,000 bridges damaged[3]	High in war zones[4]	Near-total in many areas[5]
Port damage	Heavy damage to Hamburg,	Gdansk & Gdynia mined/damaged[2]	Docks in London and Liverpool bombed[3]	Partial (e.g. Dubrovnik)[4]	No seaports (landlocked)

	Kiel, Bremen[1]				
Port damage	Heavy damage to Hamburg, Kiel, Bremen[1]	Gdańsk & Gdynia mined/damaged[2]	Docks in London and Liverpool bombed[3]	Partial (e.g. Dubrovnik)[4]	No seaports (landlocked)

Note: The table is based on publicly available estimates of damage to transport infrastructure, including data from the World Bank (1999, 2023), UNDP (1996), Davies (2005), House of Commons UK (1965), and Hogan (1987).

Ukrainian context

«The government in Ukraine is already thinking about how Ukraine will rebuild after the war»

V. Zelenskyi, March 5, 2022

Although the Russian–Ukrainian war has been ongoing since 2014, its most acute and destructive phase began with the full-scale invasion in 2022. Prior to that, the damage to Ukraine's transport and logistics infrastructure was largely concentrated in the occupied areas of Donetsk, Luhansk, and Crimea, as well as adjacent frontline territories. After 2022, however, the destruction became systemic and nationwide—affecting major highways, railways, bridges, airports, ports, and urban transport systems across the country (World Bank 2023).

Within its recognized borders, Ukraine has a huge state-owned and privately owned transport and logistics network. The overall state of the infrastructure is considered to be average, ranging from well-developed to neglected components of the transport sector. In total, there are 118,155 km of roads in Ukraine, of which 47,421 km are of national importance (national network), and over 19000 km of railways. According to various news agencies, Ukrainian rail transport plays a key role in passenger transportation, accounting for over 50% of all passenger traffic, while railways handle about 80% of freight transportation. The railway network consists of about 22,000 km, 45% of which is electrified. There are 1,500 stations and 128 main railway stations in the country, from which long-distance trains, suburban diesel trains, and electric trains depart every day. One of the key shortcomings of Ukraine's railway network is its gauge of 1,520 mm, while in Europe the gauge is 1,435 mm. The difference in gauge affects operations and causes lost time when re-equipping cars at the border.

In addition, Ukraine has many rivers and the Black and Azov Seas. Today, Ukraine's port system has 18 seaports, 13 of which are located on the mainland, and 5 ports are in the temporarily occupied territory of the Autonomous Republic of Crimea. The total capacity of mainland ports and terminals is 313.3 million tons (Ministry for Communities, Territories and Infrastructure Development of Ukraine n.d.). Ukraine also has enormous potential for river transport, with three navigable rivers currently

available, two of which are among the top five largest rivers in Europe, with 16 river ports and terminals with a throughput capacity of 60 million tons per year.

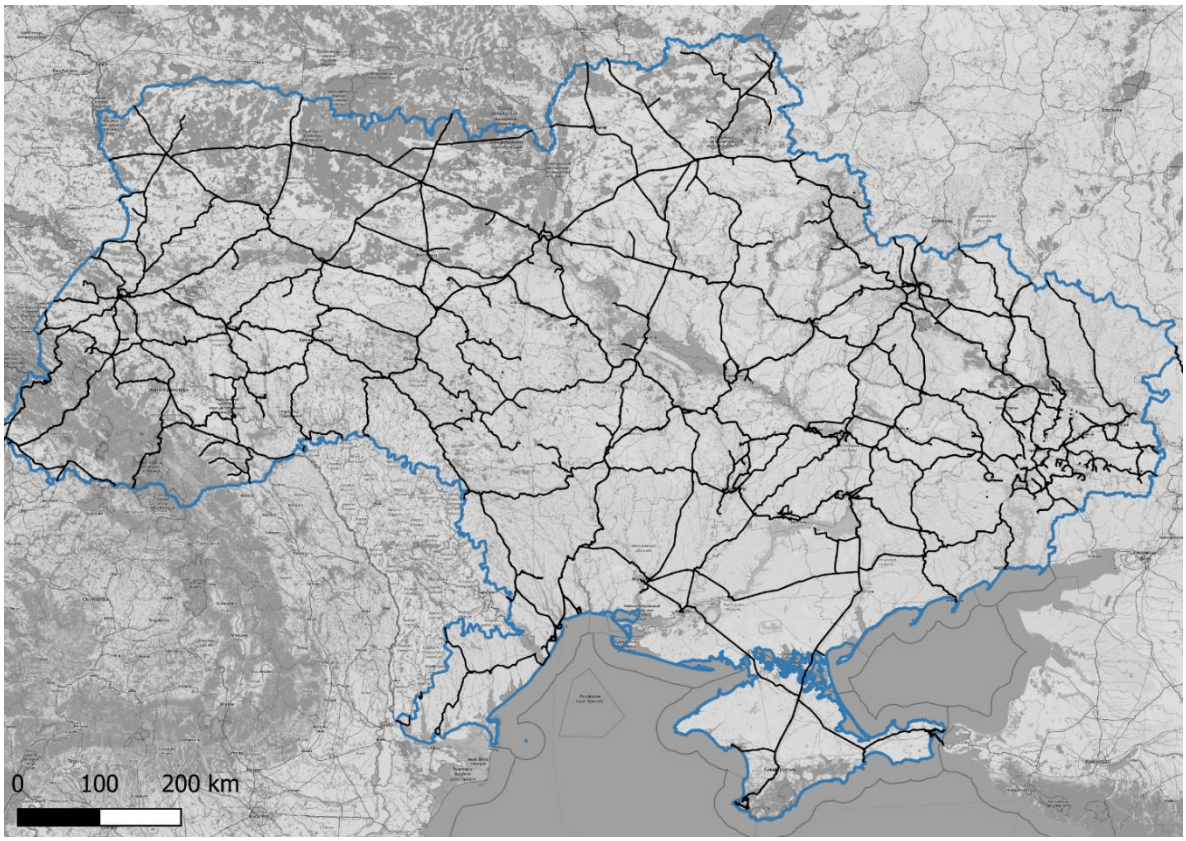


Figure 4 - Rail network

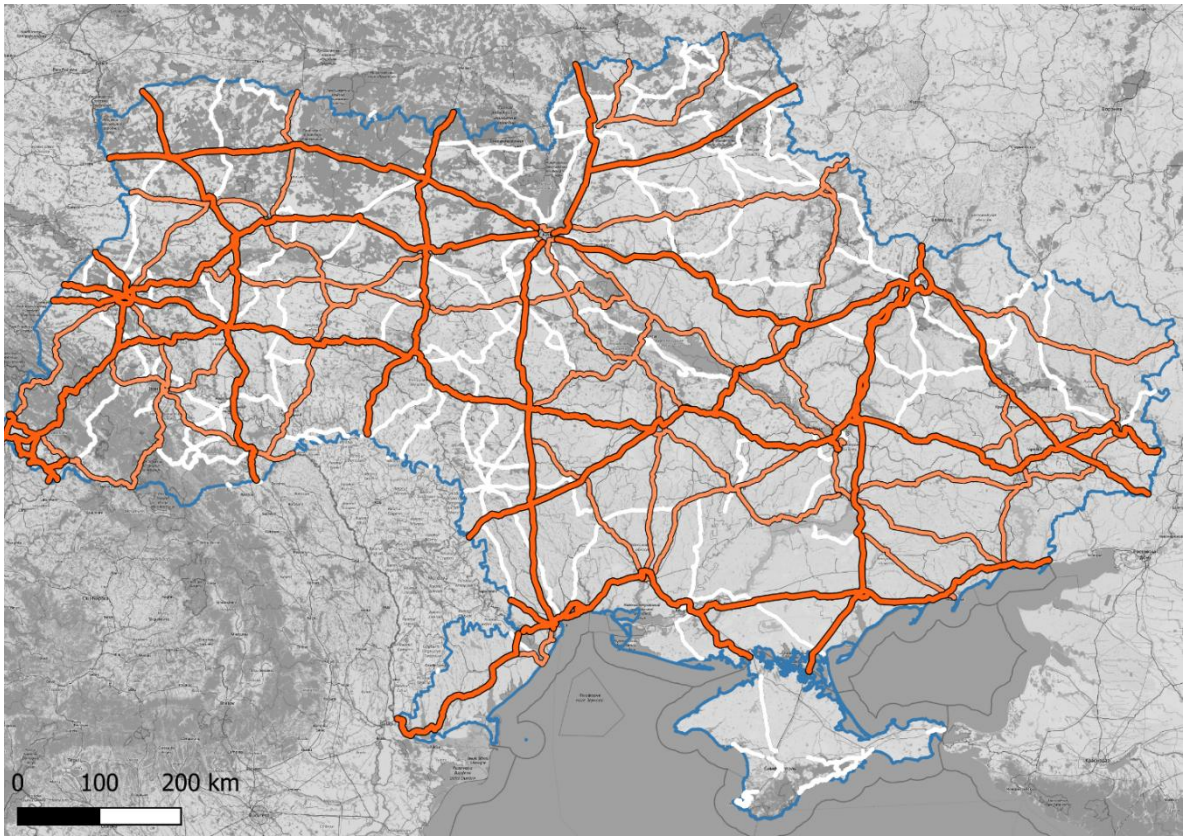


Figure 5 - National highway network

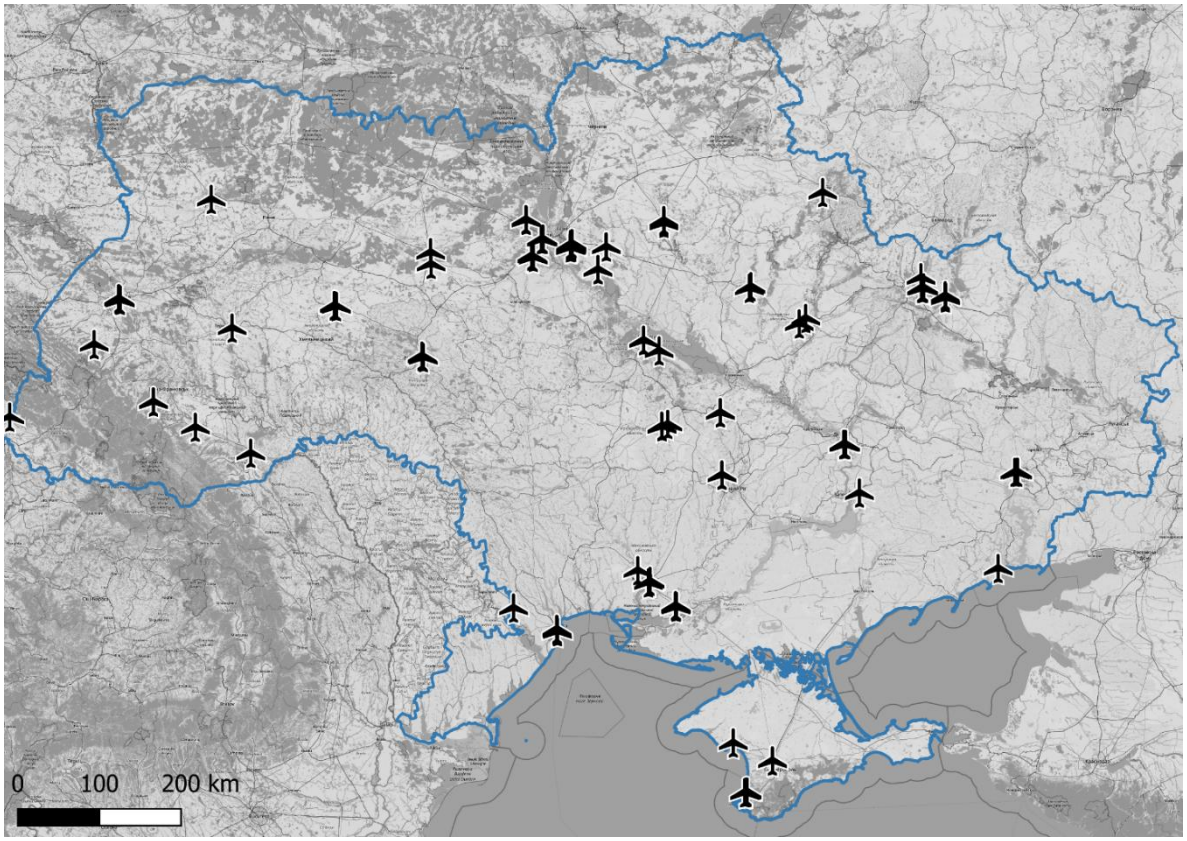


Figure 6 - Airstrips

Figure 7 – Seaports

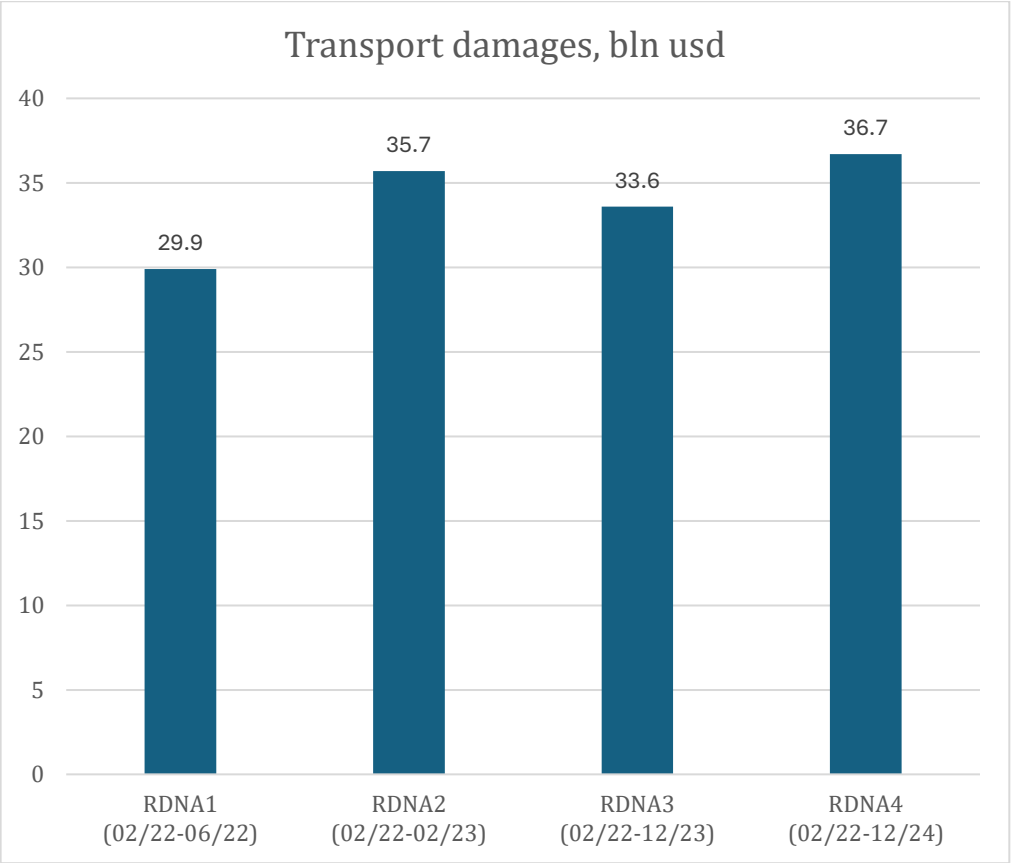
Inland water transport is also not ideal and has problems that limit its development and potential use to its full capacity. Among the many problems, the key ones include imperfect, outdated, missing, and undeveloped infrastructure (including locks, navigation, and vessel dimensions), which does not ensure effective logistics, including full participation in multimodal transport, insufficient involvement of private infrastructure, and an aging fleet.

Following the liberation of the Kyiv region and the exposure of the scale and severity of the damage, Ukrainian authorities quickly announced plans for immediate recovery efforts. These early reconstruction projects aimed not only to facilitate the return of displaced populations but also to send a broader signal that the situation was under control.

Destruction

At every phase of the conflict, it has been extremely difficult to accurately assess the scale of destruction or estimate the resources required for full recovery. Nevertheless, as the extent of the 2022 invasion became clear, both national and international actors mobilized to evaluate the damage and develop strategies for rebuilding. Since 2022, Ukraine has declared a clear ambition: to “build back better” than before.

Given the fluid nature of the front line and the continued volatility of the war, the World Bank and its partners have produced a series of Rapid Damage and Needs Assessments (RDNAs) to guide planning and international coordination. As of June 1, 2022, damage to the transport infrastructure was already estimated at 29 bln USD. Graphic 1 according to RDNA1, with subsequent updates in RDNA2, RDNA3, and RDNA4 provide more detailed and refined estimates of damages based on reports from World Bank (World Bank 2023).



Graphic 1 - Estimated cost of damages

Institutions

After realizing the consequences of the ongoing full-scale war, Ukraine faced the question of establishing a single body that would be responsible for and regulate post-war recovery activities. In 2022, thanks to the reorganization, expansion, and merger of institutions, the Agency for Infrastructure Restoration and Development of Ukraine was created, formerly known as the State Agency of Automobile Roads of Ukraine (Ukravtodor), which was responsible for the road sector.

Its reorganization and expansion of powers took place within the framework of a nationwide policy of centralized response to the consequences of armed aggression. As a result of this transformation, the newly created Agency became a key executive body responsible not only for the restoration of transport infrastructure, but also for the implementation of international projects, coordination with donors, fundraising, the introduction of modern standards and digital management, and has a direct mandate to implement reconstruction projects at the national and regional levels. Currently, the Agency reports to the Ministry of Recovery (full name: Ministry of Community, Territorial and Infrastructure Development), which was formed in 2022 by merging several sectoral ministries.

Thanks to its status, the Agency for Reconstruction has become a single window for projects from the World Bank, EBRD, JICA, EIB, and USAID. Institutional continuity.

The Road Agency, which was responsible for road management, had stable personnel, technical, and organizational infrastructure, which allowed the Agency for Reconstruction to respond quickly to needs in its new status. The new agency has deployed public and closed internal monitoring systems for recovery, geoportals for damage and reconstruction dynamics (e.g., DREAM).

At present, it is difficult to assess the effectiveness of the new agency due to the short period of time and the active phase of the war and, accordingly, the damage, but as the cases of Germany and Croatia have shown, effective recovery is only possible with cooperation with regions and local authorities. In Ukraine, there is a risk of excessive concentration of powers in a single center, without sufficient delegation of functions to local authorities.

Financing

The ongoing hostilities and the need to provide the defense forces with adequate resources require Ukraine to make unconventional and, in some cases, painful decisions. According to RDNA estimates, as of June 1, 2022, the cost of these needs is estimated at over US$349 billion, which exceeds Ukraine's GDP in 2021 by more than 1.6 times. According to the Ministry of Finance website, the total amount of financial assistance to Ukraine from all possible sources is estimated at US$207.162 billion. Ukraine expects additional sources of funding from Russian assets as reparations. Among the key financial assistance measures, we could be highlighted the involvement of the World Bank through the Repairing Essential Logistics Infrastructure and Network Connectivity (RELINC) and Develop Resilient Infrastructure in Vulnerable Environments in Ukraine (DRIVE) projects.

According to reports on the government portal, Ukraine has received grant assistance for the restoration of critical infrastructure.

> *According to the decision, the Ministry for Communities, Territories and Infrastructure Development will receive UAH 912 million 204 thousand under the new budget programmes for the restoration of railway networks. The State Agency for Restoration and Infrastructure Development will receive UAH 916 million 226 thousand to restore road networks.*

In March 2025, the World Bank approved $432 million in aid for transport infrastructure (Ministry for Communities, Territories and Infrastructure Development of Ukraine 2025).

In addition to financial assistance, Ukraine received significant intangible support in the form of funding and direct participation in the development of plans to restore transport corridors. Ukraine was given access to digital damage monitoring systems, including satellite mapping and artificial intelligence damage assessment. The involvement of French partners, who provided prefabricated bridges to ensure

logistical connections in the shortest possible time, was a significant help. This step can be seen as an emergency response, but not by Ukraine itself.

This approach is absent in the post-war reconstruction cases of the countries discussed above, but another promising direction for attracting financial resources to the reconstruction of Ukraine's transport infrastructure could be the involvement of private companies through public-private partnership (PPP) mechanisms, in particular the creation of a network of toll roads. Ukraine has already taken the first steps in this direction by adopting relevant regulatory and legal acts that allow for the implementation of large-scale infrastructure construction projects with the participation of the private sector. For several years now, the media has been reporting on plans and specific sections of motorways that are planned to be implemented as toll roads with the involvement of private companies. Under this approach, private investors will be granted the right to build, operate, and maintain certain sections of highways, which will reduce the burden on state authorities and accelerate the implementation of important transport projects.

Implementation

The experience of post-war reconstruction can be compared to the stages of Ukraine's recovery, but for obvious reasons, the stage of full-scale infrastructure modernization should be excluded at this point.

The Ukrainian authorities are successfully coping with the emergency recovery stage. Every day, there are shellings and destruction within Ukraine's territory. In a very short period of time, emergency decisions are being implemented to restore network connectivity and meet the needs of the defense forces and civilians. One example is the bridge on the M-01 highway on the approach to the regional center, the city of Chernihiv.

At the beginning of the full-scale invasion, the bridge was destroyed to complicate logistics and cut off enemy forces.

Figure 8 - Destroyed bridge on M-01 (Source: Agency for restoration in Chernihiv region)

A pontoon bridge was set up to keep people connected and get stuff and services to the regions, as well as to meet military needs during the first few weeks after de-occupation.

Figure 9 - Temporary pontoon bridge (Source: mil.in.ua)

The pontoon bridge was obviously unable to cope with the load, so during its operation, the restoration of the bridge was initiated according to the build back better principle. And in 2024, the restored bridge was opened and put into operation. Taking into account the principle that is voiced at the national level and the result of the bridge construction, it can be assumed that they do not correspond to each other. After all, with the start of full-scale war, freight traffic in the north and northeast has decreased significantly, so there is no need to rebuild the bridge exactly as it was, i.e., with wide lanes, a certain number of lanes, etc., which directly affected the cost of the work. In addition, the geographical location indicates that the bridge is located on the bypass of the regional center, where there are also smaller settlements with direct access to the road, and the bridge does not take into account the conditions for people with limited mobility and vulnerable road users. It is reasonable to assume that a simplified version of the restored bridge would have been more appropriate, but the way it was implemented is required by current design regulations.

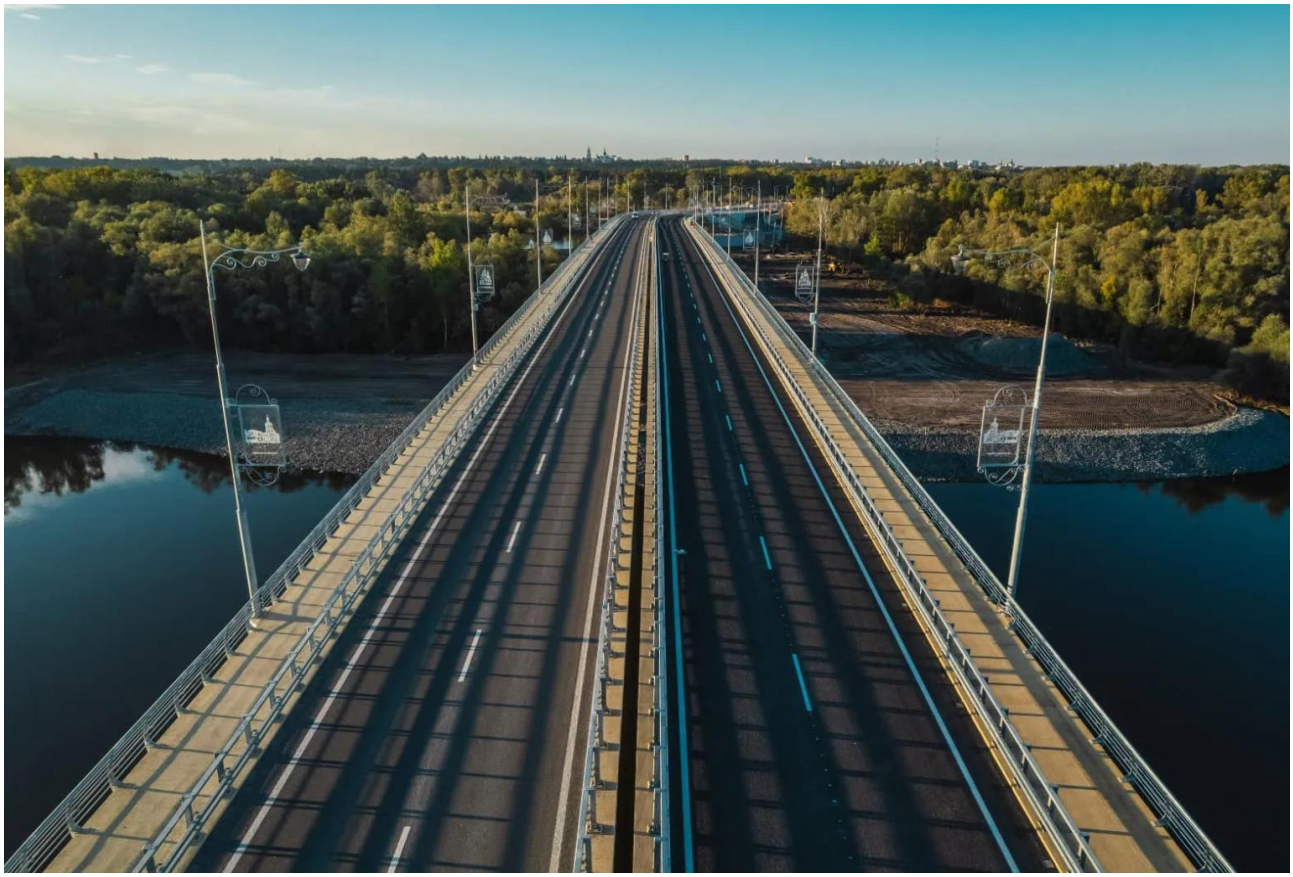


Figure 10 - Restored bridge on M-01 (Source: Maksym Shkil/ Facebook)

The stabilization phase began in 2023 and took on the characteristics of a systematic approach. Within this phase, the development of recovery plans was initiated in coordination with the Ministry of Recovery, and targeted reconstruction of strategically important nodes began, such as railway stations for grain transshipment, logistics centers near the western border, the restoration and improvement of sections of international corridors near Lviv, Uzhhorod, and Chernivtsi, and the improvement of railway infrastructure. Much of the work was accompanied by technical assistance and the involvement of project management mechanisms from international partners.

The strategic planning phase is currently in the formation stage. The basic documents that have been developed, the “Plan for the Recovery of Ukraine” provide for the creation of a National Transport Strategy 2050, the final inclusion and integration of infrastructure into the TEN-T, full integration with the EU logistics network, and the digital transformation of infrastructure management.

Modernization in the full sense of the term has not yet begun. Some projects, such as new approaches to the construction of multifunctional border crossing points or the development of digital network load indicators, are still in the preparatory stage. Those projects that are currently being implemented and that relate to border crossing points are mostly being completed after a long wait for funding.

Although the stages of full-fledged strategic planning are only gaining momentum, and it is too early to talk about full-fledged modernization, there are a number of critical issues that limit and may in the future prevent the development of transport and logistics infrastructure. Among the most serious challenges in the field is uncontrolled development along transport corridors. The essence of the problem is that the motorways themselves are owned by the state, while the land on either side may be privately owned. Private owners open and develop businesses directly alongside the road. This approach makes it impossible to further develop the corridors by increasing the number of lanes or even transforming them into toll roads. The processes of alienation, redemption, and demolition of buildings and structures can take years, while the population's needs for mobility and logistics exist on a daily basis. One possible tool that can help overcome the problems of uncontrolled development along corridors is the use of easements. Easements, as a special type of property right, allow the state or local authorities to temporarily restrict or use land plots belonging to private individuals or legal entities for the construction of roads, railways, and other critical transport infrastructure.

Results and conclusions

Research into post-war transport infrastructure recovery practices reveals both common patterns and context-dependent differences. The main empirical findings include the universality of the recovery structure, as evidenced by the case descriptions, all countries went through similar stages of recovery: emergency response, stabilization, strategic planning, and modernization. The duration and scope of each stage varied depending on resources, institutional capacity, and the involvement of external assistance.

The restoration of the transport and logistics infrastructure, on which the functioning of the state depends, determined the speed of economic recovery throughout the country. The main obstacle was the regulatory framework; in post-socialist countries, outdated technical standards significantly hampered the implementation of projects. Despite the active phase of hostilities, Ukraine implemented extraordinary measures and achieved partial stabilization. However, the dominance of centralized management, limited autonomy of local authorities, and the weakness of public-private partnerships remain challenges.

As a result of studying models of post-war transport infrastructure recovery in an international comparison, a number of key conclusions for Ukraine have been formulated:

A comparison of international experience in post-war transport infrastructure recovery allows us to formulate key conclusions:

First, transport infrastructure is a basic tool for connecting and integrating territories, stimulating the economy, and ensuring the mobility of the population. Its absence complicates recovery processes, including contributing to depopulation and isolation of regions.

Second, institutional capacity is crucial for successful, effective, and rapid recovery. For Ukraine, this means the need to evolve the newly created Recovery Agency from a centralized to a network model with delegated regional powers.

In addition, regulatory flexibility is critical for recovery in line with current conditions and needs. Overly regulated Soviet-based standards must be abandoned in favor of adaptive, functional, and European standards. Finally, recovery must take into account the strategic vision from the outset and be combined with future modernization. Rebuilding “as it was” is a catastrophic mistake, especially with limited resources and ongoing hostilities on Ukrainian territory. The principles of “Build Back Better” should define all stages — through adaptation to climate challenges, digitalization, energy efficiency, and multimodal logistics solutions.

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