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INFRASTRUCTURE RESILIENCE AMID CRISES

Amid escalating global and regional crises – such as wars, economic upheavals, climate disasters, and pandemics – infrastructure resilience is becoming increasingly vital for economic stability, social security, and economic recovery. The relevance of this research is determined by the need to explain how different infrastructure policy models affect a country's ability to withstand crises. Ukraine, amid a full-scale war, faces severe challenges in the infrastructure sector, while Portugal, despite political stability, regularly deals with natural disasters, including large-scale wildfires. The research is based on the hypothesis that infrastructure resilience is

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ІНФРАСТРУКТУРНА СТІЙКІСТЬ В УМОВАХ КРИЗОВИХ ЯВИЩ

На тлі загострення глобальних і регіональних криз – таких як війни, економічні потрясіння, кліматичні катастрофи та пандемії – інфраструктурна стійкість набуває все більшого значення для економічної стабільності, соціальної безпеки й економічного відновлення. Актуальність цього дослідження зумовлена необхідністю пояснити, як різні моделі інфраструктурної політики впливають на здатність країни протистояти кризам. Україна, перебуваючи в умовах повномасштабної війни, стикається із серйозними викликами в інфраструктурному секторі, тоді як Португалія, попри політичну стабільність, регулярно має справу зі стихійними



determined by the ability of critical infrastructure to function effectively, adapt, and recover after emergencies through strengthening coordination among public, private, and international institutions. To achieve the goal, a combination of general scientific and special methods has been applied. Methods of systematization and generalization – to identify the key factors of infrastructure resilience in Portugal and Ukraine. Comparative analysis – to assess the infrastructure environment of both countries. The tabular method has been used to organize data regarding the effectiveness of infrastructure functioning and resilience policies. The infrastructure environment of Portugal and Ukraine was assessed using the CMS Infrastructure Index data for 2023. Portugal's position reflects a mature institutional system and stable public policy in the field of infrastructure development. Ukraine, despite significant difficulties, has the potential to improve its position through international support, structural reforms, and targeted restoration of critical infrastructure. Despite the different levels of infrastructure development, both Portugal and Ukraine face common challenges such as cyber threats, energy security, water resource scarcity, and risks associated with urban infrastructure operation. An integrated approach is needed to overcome these challenges, which includes coordination between government structures, the private sector, and international partners to enhance resilience and effectively respond to modern threats.

Keywords: critical infrastructure, resilience, institutional conditions, risks, crisis situation.

лихами, зокрема масштабними лісовими пожежами. Дослідження ґрунтується на гіпотезі, що інфраструктурна стійкість визначається здатністю критичної інфраструктури ефективно функціонувати, адаптуватися та відновлюватися після надзвичайних ситуацій завдяки зміцненню координації між державними, приватними і міжнародними інституціями. Для досягнення мети використано комбінацію загальнонаукових і спеціальних методів. Методи систематизації та узагальнення – для виявлення ключових факторів інфраструктурної стійкості в Португалії й Україні. Порівняльний аналіз – для оцінки інфраструктурного середовища обох країн. Табличний метод – для впорядкування даних щодо ефективності функціонування інфраструктури та політики стійкості. Оцінка інфраструктурного середовища Португалії й України проводилася на основі даних CMS Infrastructure Index за 2023 р. Позиція Португалії відображає зрілу інституційну систему та стабільну державну політику у сфері інфраструктурного розвитку. Україна, незважаючи на значні труднощі, має потенціал для підвищення своєї позиції завдяки міжнародній підтримці, структурним реформам і цільовому відновленню критичної інфраструктури. Попри різний рівень інфраструктурного розвитку, як Португалія, так і Україна стикаються зі спільними викликами: кіберзагрозами, енергетичною безпекою, дефіцитом водних ресурсів і ризиками, пов'язаними з функціонуванням міської інфраструктури. Для подолання цих викликів необхідний інтегрований підхід, що містить координацію між державними структурами, приватним сектором і міжнародними партнерами задля посилення стійкості й ефективного реагування на сучасні загрози.

Ключові слова: критична інфраструктура, стійкість, інституційні умови, ризики, кризова ситуація.

JEL Classification H54, L98, O18, Q54, R58, F52.

Introduction

In the context of an increasing number of global and regional crises – including armed conflicts, economic shocks, climate disasters, and pandemics – the issue of ensuring infrastructure resilience is becoming particularly important. Modern infrastructure is a crucial factor not only for the functioning of the economy but also for social stability, security, and rapid post-crisis recovery. The experience of various countries in strengthening infrastructure's capacity to adapt and respond to challenges makes it possible to develop effective approaches to building resilient systems.

The relevance of this research is primarily driven by the need to understand how different models of infrastructure policy management influence a country's ability to withstand crises. Ukraine, currently facing a full-scale war, is encountering unprecedented challenges across its entire infrastructure system, including energy, transport, and social sectors. At the same time, Portugal, despite its political stability, has its own experience in dealing with natural disasters, particularly regular large-scale wildfires. These not only cause significant ecological damage but also destroy infrastructure assets such as roads, power lines, housing, and communication systems. This requires the country to develop effective mechanisms for prevention, response, and recovery.

A comparison of the two countries, with their different historical, economic, and security contexts, enables a deeper understanding of the structural factors behind infrastructure resilience and helps identify the strengths and weaknesses of management decisions. Furthermore, the research topic aligns with the priority directions of modern European policy, particularly the Green Deal, digital transformation, and strategic autonomy.

The issue of ensuring infrastructure resilience to external and internal shocks has been widely discussed in academic circles. Theoretical research and classification of existing approaches to understanding the infrastructure resilience has been made by Liu et al. (2022). The conceptual framework to assess the resilience of critical infrastructure by integrating existing best practices in organizational governance, enabling cross-sector and cross-border cooperation has been proposed by Cadete et al. (2017). Resilience curves in infrastructure resilience have been assessed by Poulin and Kane (2021). Methodology that assesses both technical and organizational resilience, using statistical analysis for evaluating the resilience of critical infrastructure elements has been proposed by Rehak et al. (2019).

Focus on improving the resilience of interconnected critical infrastructures in Europe, addressing systemic risks posed by natural hazards and complex cyber-physical-human threats has been made by Giunta et al. (2025) aiming to ensure the continuity of vital operations, reduce cascading disruptions, and protect populations and the environment.

The resilience of Ukraine's critical infrastructure examination in the face of Russia's invasion, highlighting the impact on energy, transportation, and communication sectors, with insights on the role of legislation, international aid, and domestic efforts in maintaining essential services during conflict has been made by Aebi et al. (2024). The study of energy security system of Ukraine and the policy to stimulate its development has been made by Mazaraki and Melnyk (2024).

Research on the importance of human capital in ensuring national security, that focuses on development of a multi-level national security and resilience system for critical infrastructure has been made by Nikolaienko et al. (2024).

The financial aspects of infrastructure resilience have been explored by Moghimi and Kashani (2025) who have proposed the framework for financing resilience improvements by taxing sectors that benefit from reduced losses due to improved infrastructure resilience.

The connection between cybernetics and resilience has been explored by Demmer et al. (2025) demonstrating how control theory can be used to enhance infrastructure resilience.

The study of resilience-building dynamics in response to climate variability has been made by Bizer et al. (2025). The findings suggest that experiencing disruptions alone is not enough to drive transformative adaptation, and emphasize the importance of eliminating silos, fostering networks, and reducing barriers to action to support climate resilience in critical infrastructure.

The study of macroeconomic impacts of infrastructure investment in Portugal from 1980 to 2019, underlining the importance in investing in sectors such as airports, ports, health, highways, water and railroads was made by Pereira and Rodrigues (2024).

The aim of the study is to characterize the factors and directions for ensuring infrastructure resilience in the context of crises, using the cases of Ukraine and Portugal.

The article's hypothesis is that infrastructure resilience is determined by the ability of critical infrastructure to function effectively, adapt, and recover after emergencies through enhanced coordination among public, private, and international institutions.

To achieve the aim of the research, a combination of general scientific and specific methods was used: methods of systematization and generalization were employed to identify the key determinants of infrastructure resilience across various sectors, as well as the organizational and legal frameworks governing resilience in Portugal and Ukraine. Comparative analysis was used to assess the infrastructure environments of Portugal and Ukraine. Tabular method was applied to organize and analyse data on the infrastructure systems in both Portugal and Ukraine, including infrastructure performance, historical disruptions, and existing resilience policies. This method facilitated a clear comparison between the two countries.

The structure of the article is as follows: the determinants of infrastructure resilience have been analysed in the first section; the infrastructure environment of Portugal and Ukraine has been assessed in the second section; the challenges and directions for ensuring infrastructure resilience in Portugal and Ukraine have been identified in the third section.

1. Determinants of infrastructure resilience

Infrastructure represents a functional and territorial combination of economic sectors that serve material production, the non-productive sphere, and the population directly. Economically, infrastructure is an intersectoral formation whose operation within the economy is aimed at meeting the diverse service needs of various sectors and the population.

A well-developed infrastructure promotes proportionality, balance, and efficiency in regional production, facilitates intersectoral linkages, and supports the resolution of environmental and social issues. At the same time,

it is a key factor in the development of industrial and social facilities, the state of demographic potential, and the rationality of settlement systems. The main task of infrastructure is to promote the further development of economic sectors, the integration of industries, and the improvement of population welfare.

From a territorial perspective, infrastructure is divided into national, regional, and local levels. *National infrastructure* in the framework of national resilience includes sectors and services that support the functioning of the economy as a whole such as unified transport systems, energy networks, telecommunications etc. (Umantsiv & Shkuropadska, 2023). *Regional infrastructure* includes facilities located within a specific territory that provide services such as product transport and storage, information transmission, mobility of people, and supply of material resources – such as water, heat, gas, and electricity – to enterprises, organizations, and the local population. *Local infrastructure* refers to services and facilities necessary for the productive activities of enterprises and organizations that are too costly for individual enterprises to develop independently and are thus provided by the state (water and electricity supply, freight transport etc).

Considering the territorial aspect of infrastructure development, *infrastructure resilience* can be understood as the ability of national, regional, and local infrastructure elements to maintain essential operational and developmental parameters under the influence of various factors at different levels. In general, infrastructure resilience encompasses a system's ability to adapt, recover, and maintain functionality during and after crises. As Liu et al. (2022) note: "A resilient infrastructure system is supposed to minimize the probability of failure, possess redundant connectivity, shrink the recovery time, and limit impact propagation, which corresponds to four properties including robustness, redundancy, rapidity, and resourcefulness".

Infrastructure resilience is the result of the interaction of numerous factors that determine a country's ability to ensure the uninterrupted operation of critical systems under extreme conditions, adapt quickly to change, and recover from shocks. In the cases of Portugal and Ukraine, these determinants differ significantly due to the specific geopolitical context, security situation, economic models, and institutional development (*Table 1*).

Table 1

Determinants to ensure infrastructure resilience in Ukraine and Portugal

Determinants	Ukraine	Portugal
Security environment	The main challenge to infrastructure resilience is the constant threat of destruction of critical facilities due to military actions	The main security challenges are natural disasters, primarily large-scale wildfires, which annually destroy significant infrastructure
Investment environment	The country financially unstable and depends on international aid, but shows strong potential for developing partnership projects and is committed to post-war reconstruction in line with European standards	The country has a stable macroeconomic environment, access to EU funds, and developed public-private partnership mechanisms that ensure sustainable infrastructure investment

End of Table 1

Determinants	Ukraine	Portugal
Political stability and institutional capacity	Despite extraordinary conditions, the country is implementing reforms, building institutions, and forming a new management architecture for critical infrastructure	A high level of political stability and effective governance supports long-term infrastructure development planning
The degree of digitalization and innovation	The country emphasizes digital transformation, particularly in monitoring systems, online services, and critical resource management	The country actively implements "smart" solutions in transport, energy, and urban infrastructure
Private sector involvement	Institutional foundations are being formed to engage business in reconstruction projects, particularly through PPP mechanisms and foreign capital attraction	Portugal has successful experience in attracting private capital for the construction and management of highways, hospitals, and energy facilities. The private sector is actively investing in renewable energy, especially solar and wind power

Source: composed by the authors.

The security environment is a key characteristic of a state's condition, reflecting the level of threats, risks, and challenges to its national security. Ukraine is facing one of the most severe security challenges in its history – a full-scale armed aggression by Russia. Accordingly, the main challenge to infrastructure resilience is the constant threat of destruction of critical facilities. This requires rapid response, the creation of backup capacities, logistics diversification, and the implementation of dual-use solutions (civil-military infrastructure).

Portugal, as an EU and NATO member state, enjoys a stable geopolitical position, yet it faces growing climate-related challenges that affect its internal security environment. Wildfires in the country pose a serious ecological and socio-economic problem, regularly intensifying during the summer months. Portugal is one of the European countries most affected by forest fires. Hot, dry summers contribute to the ignition and spread of fires. Eucalyptus and pine trees – highly flammable species – are widespread in Portugal and accelerate the spread of fire, while frequent winds complicate firefighting efforts. In September 2024, Portugal faced some of the largest wildfires in recent decades (Copernicus report, 2024).

Despite climate-related challenges, Portugal has a stable and mature investment environment supported by its participation in the EU and Eurozone. As a result, the investment environments of Ukraine and Portugal are at different stages of development. Portugal offers predictable conditions for investors and actively encourages capital inflow, while Ukraine is working to create new opportunities despite high risks. In the longer term, Ukraine's post-war reconstruction may become one of the largest investment

projects of the 21st century, but this will require further strengthening of the country's institutional capacity and security guarantees for investors.

Overall, political stability and institutional capacity are key factors that determine a state's ability to function effectively, implement infrastructure policy, and ensure stable economic development. Portugal's political stability is rooted in its strong democratic traditions established after the Carnation Revolution of 1974, which ended the dictatorship and launched the country's democratic transformation (UN News, 2024). Its institutional capacity is supported by an effective judicial system, a stable civil service, and EU membership, which drives continuous improvement in governance standards. Notably, the Council of the EU adopted the Directive on the Resilience of Critical Entities (effective as of January 16, 2023), which provides a framework to support member states in ensuring that critical entities can prevent, resist, absorb, and recover from disruptive incidents, including those caused by natural disasters, terrorism, insider threats, sabotage, public disorder, and public health emergencies.

In the case of Ukraine, the legal framework for critical infrastructure and its protection includes the Constitution of Ukraine, the Law of Ukraine "On Critical Infrastructure", the Cabinet of Ministers' resolution "On the Approval of the National Plan for the Protection, Security, and Resilience of Critical Infrastructure", and relevant international treaties. Overall, Ukraine's National Critical Infrastructure Protection System largely depends on the level of political stability in the country. Political stability ensures predictable decision-making, coordination among government bodies, an effective regulatory framework, and timely response to threats.

In Ukraine, political stability remains under constant pressure due to external aggression and reform-related challenges. However, institutional capacity has significantly improved since 2014 due to reforms in public administration, anti-corruption policy, and the judiciary. Nevertheless, it remains insufficient in many sectors.

Despite the ongoing war, Ukraine has demonstrated remarkable achievements in digital development. Since the start of the full-scale invasion, around 70 digital services have been launched, along with various tools under the "Diia" platform, used by about 20 million Ukrainians. These tools facilitate access to critical services, including (Diia Business, 2025):

- business registration and updating entrepreneur information;
- online vehicle re-registration;
- use of "resilience maps" showing shelters and resilience hubs;
- purchasing government bonds to support the economy;
- acquiring or upgrading digital skills, changing professions, and job searching through "Diia. Education" for those affected by the war;
- buying housing under preferential conditions for citizens who lost homes due to military action.

A notable digital initiative supporting Ukraine during the war is the fundraising platform United24, created for centralized donations from anywhere in the world. It unites charitable organizations, international partners, donors, and public figures. United24 ensures transparency in fund usage and allows resources to be rapidly directed toward the most urgent needs – defense, humanitarian aid, healthcare, and the restoration of critical infrastructure (RISE, 2025).

Digital technologies not only optimize governance but also serve as a foundation for post-war recovery in Ukraine. Portugal, in turn, demonstrates a sustainable model of integrating digital and green solutions in infrastructure development. The country actively implements smart energy grids, expands the network of electric vehicle charging stations, and modernizes ports using digital technologies for cargo flow management. The "Portugal Digital" program promotes the digitalization of small and medium-sized enterprises, while investments in green hydrogen and renewable energy enhance energy independence and environmental resilience (Portugal Digital, n. d.). Thus, Portugal aligns digital transformation with climate goals, ensuring long-term benefits for the economy and society.

Development of modern infrastructure is also impossible without active private sector involvement. Public-private cooperation mobilizes additional resources, enables the implementation of innovative solutions, and increases the efficiency of large-scale project execution. Private investment in infrastructure is particularly relevant for countries undergoing modernization or post-crisis recovery, like Ukraine, and for countries seeking to enhance their global competitiveness, like Portugal.

2. Assessment of the infrastructure environment

The assessment of the infrastructure environment is the process of analysing and determining the level of development and efficiency of a country's infrastructure based on various criteria. For example, the international law firm CMS Cameron McKenna Nabarro Olswang calculates the Infrastructure Index (the CMS Infrastructure Index – further on), which evaluates the attractiveness of 50 countries for infrastructure investment. The goal of the CMS Infrastructure Index is to help investors understand the environment they may encounter in different jurisdictions and to identify potential advantages and opportunities for the successful implementation of investment projects.

The CMS Infrastructure Index is measured on a scale from 0 to 100, where 100 represents the best possible performance and 0 the worst. The data from 50 jurisdictions using nine key criteria have been analysed in the index in 2023:

- economic status (21%);
- political stability (15%);
- private participation (13%);
- infrastructure environment (10%);

- protectionism (10%);
- ease of doing business (10%);
- market size (9%);
- sustainability and innovation (6%);
- tax environment (6%).

A country's overall score is calculated by summing the scores for each indicator, weighted according to its importance. In this way, the index presents a comprehensive picture of a country's attractiveness for infrastructure investment.

The CMS Infrastructure Index covers various regions of the world (Europe, Asia, North and South America, Africa). The countries at different levels of economic development are included – from highly developed economies (such as Germany and the United Kingdom) to developing countries (such as India and Brazil). In 2023, the CMS Infrastructure Index also includes countries that are actively developing national infrastructure strategies, implementing large-scale projects, and attracting foreign investment (*Table 2*). For example, Ukraine is mentioned in the report due to the urgent need to rebuild its infrastructure following the war aftermath.

Table 2

The CMS Infrastructure Index in 2023

Rank	Country	Score	Rank	Country	Score
1	Germany	77.0	26	Hungary	56.3
2	Netherlands	75.8	27	Chile	56.2
3	United States	74.5	28	Kuwait	54.6
4	United Kingdom	74.4	29	Saudi Arabia	53.4
5	Singapore	73.6	30	Bulgaria	53.0
6	Finland	72.2	31	India	51.2
7	Japan	72.0	32	Malaysia	50.8
8	Australia	71.8	33	Romania	50.7
9	Canada	71.5	34	Philippines	50.6
10	France	71.4	35	Indonesia	50.4
11	Sweden	69.8	36	Thailand	49.4
12	Austria	68.4	37	Oman	49.4
13	Czech Republic	68.4	38	Peru	48.0
14	Norway	67.3	39	Colombia	47.8
15	Hong Kong	67.1	40	Mexico	47.7
16	South Korea	65.9	41	South Africa	43.8
17	Belgium	64.9	42	Morocco	43.2
18	UAE	64.7	43	Brazil	42.2
19	Slovakia	63.7	44	Uzbekistan	41.2
20	China	62.3	45	Turkey	38.8
21	Portugal	62.1	46	Ukraine	38.0
22	Spain	62.1	47	Kenya	37.0
23	Italy	61.3	48	Egypt	33.2
24	Poland	58.0	49	Angola	28.3
25	Qatar	56.4	50	Mozambique	28.0

Source: CMS LEGAL (2023, November 7).

Leaders in Infrastructure Development scored over 70 points. The top of the ranking is dominated by advanced economies with robust infrastructure: Germany, the Netherlands, the United States, the United Kingdom, Singapore, Finland, Japan, Australia, Canada, and France. These countries demonstrate balanced development across all infrastructure sectors, including transport, energy, IT, and finance. Their high scores indicate institutional maturity, a favourable regulatory environment, and well-developed public-private partnerships.

Countries with Stable Medium Attractiveness received between 60 and 69 points. These are mostly European nations and highly developed Asian economies: Sweden, Austria, the Czech Republic, Norway, Hong Kong, South Korea, Belgium, the UAE, Slovakia, China, Portugal, Spain, and Italy. These countries have a solid level of infrastructure development but may face regulatory and environmental challenges.

Countries with Growing Potential scored between 50 and 59 points: Poland, Qatar, Hungary, Chile, Kuwait, Saudi Arabia, Bulgaria, India, Malaysia, Romania, the Philippines, and Indonesia. Most of these countries are experiencing dynamic growth and have developed government programs for infrastructure modernization; however, they may need to improve administrative transparency and financial resilience.

Countries with Developing Infrastructure scored between 40 and 49 points: Indonesia, Thailand, Oman, Peru, Colombia, Mexico, South Africa, Morocco, Brazil, and Uzbekistan. These countries are gradually improving their infrastructure by attracting foreign capital, but they still need to address legal security and institutional effectiveness.

Countries Facing Infrastructure Challenges scored below 40 points. These are mostly nations with limited resources or socio-political instability: Turkey, Ukraine, Kenya, Egypt, Angola, and Mozambique. Their low levels of infrastructure development are due to political instability, lack of funding, corruption risks, or the consequences of armed conflicts. In particular, Ukraine shows a significant decline due to the full-scale war and requires large-scale reconstruction with the support of international partners.

An analysis of the Infrastructure Index for Portugal and Ukraine by structural components is presented in *Table 3*. Comparing Ukraine with Portugal is appropriate, as both countries are located on the geopolitical periphery of Europe – one on the western coast, the other on the eastern frontier. Both play strategic roles as transport and logistics hubs and as "gateways" to broader regions: Portugal to the Atlantic, and Ukraine to the Black Sea basin. Both also have relatively limited domestic markets, which encourages them to focus on exports, attract foreign investment, and develop infrastructure aimed at international integration.

Table 3

The CMS Infrastructure Index for Portugal and Ukraine in 2023

Infrastructure Index	Portugal		Ukraine	
	Score	Rank	Score	Rank
Overall	62.1	21	38.0	46
Economic status	68.5	23	9.3	50
Sustainability & innovation	64.6	24	55.7	27
Tax environment	27.7	47	76.9	6
Ease of doing business	73.8	19	41.2	45
Infrastructure environment	64.3	23	45.0	38
Private participation	70.1	12	51.6	37
Political stability	73.5	15	31.5	47
Protectionism	79.4	2	75.3	10
Market size	3.8	44	5.5	36

Source: CMS LEGAL (2023, November 7).

The CMS Infrastructure Index overall score for Portugal is 62.1 (ranked 21st), while Ukraine scores only 38.0 (ranked 46th). This clearly reflects Portugal's significant advantage in terms of overall infrastructure development. Portugal is characterized by a stable economy with a well-established governance system, developed transport, energy, and digital infrastructure, and a favorable environment for attracting private investment. Ukraine, by contrast, is undergoing deep socio-economic transformations in the context of a full-scale war, which explains its lag across most critical indicators.

One of the most striking contrasts is in the Economic Status indicator, where Portugal scored 68.5 points (23rd place), while Ukraine scored only 9.3 points (50th place). This gap is explained by differences in GDP per capita, the stability of macroeconomic policy, and the extent of financial support from the state and external partners. Ukraine's economy has suffered a significant blow due to industrial and agricultural losses, internal displacement, and the destruction of logistics infrastructure caused by Russian military aggression.

Nonetheless, Ukraine shows a competitive position in the area of sustainability and innovation, scoring 55.7 points compared to Portugal's 64.6. Ukraine's performance reflects the preservation of its scientific and technological potential, the activation of the digital sector, and progress in energy efficiency and environmental initiatives. Even during wartime, the Ukrainian government is implementing policies to support innovative businesses, the IT sector, and digital services.

Ukraine received its highest score in the tax environment – 76.9 points (6th place), significantly outperforming Portugal's 27.7 points (47th place). This reflects Ukraine's investor-friendly conditions, including a simplified tax system for small and medium-sized enterprises, numerous tax incentives for relocated businesses, and deregulatory efforts. Portugal's tax system, despite its overall stability, remains complex for small businesses and foreign companies.

In the Ease of Doing Business category, Portugal ranks 19th with 73.8 points, while Ukraine ranks 45th with 41.2 points. A challenging regulatory environment, frequent legislative changes, unpredictability in

government decisions, and corruption risks affect confidence in Ukraine's business climate. However, in recent years, Ukraine has actively reformed permitting procedures, digitized public services, and launched initiatives such as Diia City.

In terms of the infrastructure environment – which includes accessibility of logistics routes, energy capacity, and utility services – Portugal scores 64.3 points, while Ukraine scores 45.0. A significant portion of Ukraine's infrastructure has been destroyed or damaged due to hostilities, and many regions face urgent needs to modernize rail connections, energy systems, and communication networks.

Private participation in infrastructure projects is supported in both countries, but Portugal scores significantly higher – 70.1 points (12th place) versus Ukraine's 51.6 (37th place). Despite martial law, Ukraine has seen a rise in public-private partnerships, particularly in the energy, construction, and IT infrastructure sectors.

Political stability remains a critical factor, where Portugal (73.5 points, 15th place) clearly outperforms Ukraine (31.5 points, 47th place). Security risks, external aggression, martial law, and a lack of predictability in domestic politics undermine investor confidence in Ukraine's long-term projects.

On a positive note, both countries received high scores in openness to foreign trade. Portugal ranks 2nd with 79.4 points, while Ukraine ranks 10th with 75.3. Both are actively integrating into international economic structures, opening their markets to investment and technology. For Ukraine, this is especially crucial in the context of post-war recovery.

The market size indicator remains relatively low for both countries: Portugal scores 3.8 and Ukraine 5.5. This is due to limited domestic demand. However, Ukraine's market has higher potential owing to its larger population and strategic location at the crossroads of key transport corridors.

In conclusion, Portugal currently demonstrates a well-balanced infrastructure policy characterized by high stability, effective private sector engagement, and a favorable business environment. Ukraine, despite severe challenges, retains potential for recovery and growth – especially in innovation, tax flexibility, and openness. To improve its position in global infrastructure rankings, Ukraine should focus on enhancing political stability, safeguarding investor rights, modernizing logistics, and actively attracting private capital to support post-war reconstruction.

3. Challenges and directions for ensuring infrastructure resilience

Infrastructure resilience is a key factor in ensuring national security and sustainable development. Portugal, as a country with diverse geographical and economic characteristics, faces a number of challenges in this area. The main challenges include climate change, seismic risks, energy dependence, cyber threats, aging transport and urban infrastructure, and water supply issues (*Table 4*).

Table 4

Challenges and directions for ensuring infrastructure resilience in Portugal

Challenges	Directions for Enhancing Resilience
Cyber threats and attacks on critical infrastructure	Expanding cybersecurity within the NIS2 framework, strengthening cooperation with ENISA
Climate change (wildfires, droughts, sea level rise)	Investing in sustainable energy infrastructure, developing water-saving technologies, wildfire prevention programs
Seismic risks and tsunamis	Strengthening building standards, developing early warning systems, improving evacuation plans
Energy security (dependence on energy imports)	Developing renewable energy sources (wind and solar), creating strategic energy reserves
Water supply and scarcity	Optimizing water supply systems, constructing desalination plants, improving water conservation infrastructure
Urban infrastructure risks (aging buildings, increasing urbanization)	Building renovation programs, "smart" urban planning, development of Smart Cities concepts

Source: composed by the authors.

With the digitalization of society, cyber threats are becoming a serious issue. There was a historic surge in cyberattacks, intensifying threats to critical infrastructures around the globe in 2024. Portugal, too, was shaken by one of the EU's most severe ransomware incidents when cybercriminals breached the Agência para a Modernização Administrativa (AMA). This attack disrupted essential platforms like Autenticação.gov and Gov ID – services integral to Portuguese citizens and businesses for authenticating on government systems. Their temporary shutdown stalled the delivery of vital public digital services, underscoring the critical role these platforms play. Cybersecurity risks are not limited to ransomware alone; state-sponsored groups, often linked to countries like China and Russia, also pose severe threats to critical infrastructures (Vasconcellos, 2024). The response to these challenges includes strengthening cybersecurity measures under the NIS2 directive, as well as cooperation with the European Union Agency for Cybersecurity (ENISA).

Portugal is increasingly affected by extreme weather events, including wildfires, droughts, and sea level rise. To mitigate these risks, the country is investing in sustainable energy infrastructure, developing water-saving technologies, and implementing wildfire prevention programs. As part of its wildfire response strategy, Portugal established the Integrated Fire Management Agency (AGIF), which brings together representatives from nature conservation, the police, the military, and private forestry companies to optimize wildfire prevention and suppression efforts. Portugal's efforts to reform its fire management system have attracted interest from other regions facing similar challenges, including California, South Africa, and Australia (Gill, 2022, July 15).

Portugal lies near the boundary between the Eurasian and African tectonic plates, making the region prone to seismic activity. High-risk areas include the Azores and Madeira islands, as well as the southern part of mainland Portugal, including the Algarve region. Both municipal and national authorities are working to improve infrastructure and early warning systems to minimize potential future losses. Key safety measures include

strengthening building standards, developing early warning systems, and enhancing population evacuation plans (The Lisboner, n. d.).

Due to its significant dependence on energy imports, Portugal is actively expanding its use of renewable energy sources, particularly solar and wind power, and is creating strategic reserves of energy resources. Portugal has achieved a historical milestone in the production of renewable energy, since it supplied 89% of consumption in 2024, while it supplied 61% of electricity consumption in 2023. Portugal's sources of renewable energy for the first quarter of 2024 were composed of 47% from hydroelectric power, 31% from wind power, 6% from photovoltaic power, and 5% from biomass. It is to be noted that, in 2024, Portugal ranks 6th EU country using the highest share of renewable energy according to Eurostat. Portugal's success story in the renewable energy sector is such that the country's energy sector is no longer the main source of CO₂ emissions, since the main source of carbon emissions is now the transport sector (AICEP Portugal Global, 2024, April 3).

It is worth noting that within the framework of REPowerEU, EU countries are updating their recovery and resilience plans with new measures for energy saving and diversification of the EU's energy supply. Accordingly, reforms and investments in the plan of Portugal, approved by the Council on 13.07.2021, help it become more sustainable, resilient and better prepared for the challenges and opportunities of the green transition and digital transition (European Commission, n. d. a).

Water quality plays a crucial role in public health and environmental sustainability. In recent years, water quality in Portugal has attracted increasing attention due to environmental issues, aging infrastructure, and growing concerns about climate change. According to recent reports, approximately 98.5% of the population has access to safe drinking water that meets the standards established by EU regulations. However, there are still some disparities in water quality between urban and rural areas. While cities like Lisbon and Porto have well-developed water supply systems, some rural regions still face issues with access and water quality. This disparity highlights the need for continuous improvement of infrastructure and water treatment processes to ensure that all communities in Portugal benefit from the same level of water safety and cleanliness (Ion Exchange, n. d.). The main measures include the construction of desalination plants, optimization of water conservation systems, and the development of water supply infrastructure.

It is worth noting that the European Regional Development Fund (ERDF) supports projects aimed at improving water efficiency, digitalizing water infrastructure, and mitigating the effects of desertification in accordance with the "Urban Waste Water Treatment Directive". This emphasis on water resource management acknowledges that future challenges cannot be overcome without effective water infrastructure.

Housing also remains a key issue for many EU citizens – 23% of respondents in the latest Eurobarometer survey identified the lack of affordable housing as an urgent problem (European Commission, 2025, April 2). Aging housing stock and increasing urbanization rates create additional

challenges in Portugal. To address them, building renovation programs, smart urban planning, and the development of the Smart Cities concept are being implemented (European Commission, 2022, December 9). Urban renewal involves the reconstruction of areas within the city, often to address urban decay or meet new economic and social needs. Numerous urban renewal projects have been implemented in Portugal, aimed at revitalizing cities, improving infrastructure, and enhancing the quality of life for residents (Talkpal, n. d.).

It is worth noting that international partnerships, public programs, and innovative technologies play a significant role in the process of ensuring Portugal's infrastructure resilience. In particular, industrial innovations depend on greater investment in critical technologies – such as those identified through the Strategic Technologies for Europe Platform (STEP): clean technologies, biotechnologies, and deep-tech innovations (European Commission, n. d. b). Considering the central role of large enterprises in the development of innovation and technology transfer, the European Commission offers them cohesion policy support in critical sectors such as defense, strategic technologies, and decarbonization. This support helps businesses build local supply chains and technological clusters, equipping the EU with infrastructure and technological capacity to face future challenges.

Overall, the European Commission actively responds to the new challenges faced by EU Member States in the context of dynamic geopolitical changes – particularly the war of Russia against Ukraine, climate change, and the energy crisis. The adaptability and flexibility of EU policy means that Ukraine, in forming its own national infrastructure policy, should take into account modern European approaches and new priorities. The challenges and directions for ensuring Ukraine's infrastructure resilience are presented in *Table 5*.

Table 5

Challenges and directions for ensuring Ukraine's infrastructure resilience

Challenges	Directions for Ensuring Resilience
Military threats and shelling of critical infrastructure	Development of protected infrastructure, restoration of facilities based on resilience standards, diversification of energy supply
Cyber threats and attacks on critical infrastructure	Strengthening cybersecurity of critical infrastructure, expanding cooperation with NATO and the EU, implementation of NIS2 standards
Energy security (dependence on external suppliers, attacks on the energy system)	Decentralization of energy grids, development of RES, integration into ENTSO-E, strengthening protection of energy facilities
Destruction of transport infrastructure (roads, bridges, railways due to war)	Restoration of transport routes, modernization of rail transport, development of alternative logistics routes
Water supply and water shortage	Construction of backup water intakes, modernization of water supply systems, implementation of water-saving technologies
Financial risks and lack of funds for urban recovery	Expansion of international aid, attraction of investment, creation of funds for the recovery of cities and critical infrastructure

Source: composed by the authors.

One of the greatest challenges for Ukraine is military threats and the destruction of critical infrastructure. Russian aggression has caused significant damage to energy, transport, communication, and housing infrastructure. Their restoration requires the usage of modern resilience standards, the creation of backup electricity and water supply systems, as well as diversification of energy supplies and logistics routes. Currently, more than 100 cities and communities in Ukraine are restoring municipal infrastructure under two European Investment Bank (EIB) recovery programs after the Ukrainian government allocated EUR 161 million to local budgets. These funds open the path to recovery, including: 155 projects under the "Ukraine Recovery Programme" and 66 projects under the "Emergency Credit Programme for the Recovery of Ukraine". The projects focus on restoring social infrastructure: hospitals, educational institutions, social housing, water supply and sewage systems in de-occupied and frontline territories, particularly in Kyiv, Odesa, Sumy, Kharkiv, Mykolaiv, and Zaporizhzhia regions.

Since the beginning of the full-scale invasion, the EIB has provided Ukraine with EUR 2 billion in support for the urgent repair of infrastructure damaged by Russian bombings (European Investment Bank, 2024, March 8). Through the "EU for Ukraine" initiative and the "EU for Ukraine Fund", the EIB is committed to scaling up its activities in Ukraine in close cooperation with the European Commission, the European Parliament, EU Member States, and international partners.

Countering cyber threats is now considered one of the top security priorities and a key factor in ensuring infrastructure resilience. Massive cyberattacks on critical infrastructure networks, telecommunications, and financial institutions since the start of Russia's invasion have heightened awareness of these threats. However, the implementation of best practices into national cybersecurity legislation and information protection remains fragmented, which also hampers the development of an overall cybersecurity culture in both the private and public sectors. To strengthen cyber resilience, it is necessary to implement international security standards, deepen cooperation with NATO, the EU, and ENISA, and increase investment in cybersecurity technologies and personnel training.

Energy security remains another strategic aspect, as attacks on Ukraine's energy system threaten the stability of electricity and heat supply. During the Ukraine Recovery Conference in London, Ukraine's "Energy Strategy to 2050" was presented. It envisions the restoration of the sector using cutting-edge technologies, enhancing the resilience of the system, and strengthening energy security for both Ukraine and Europe. A key objective is to transform Ukraine into a European energy hub, enabling full independence from Russian fossil fuels through the replacement with clean energy generated in Ukraine. The strategy highlights the existing capacity for expansion: solar power – up to 94 GW; specialized storage – up to 38 GW; nuclear power – up to 30 GW; thermal power and bioenergy – up to 18 GW; hydropower – up to 9 GW. In total, the strategy estimates investment

opportunities for new generation facilities at USD 383 billion. Simultaneously, the "Economic Strategy of Ukraine until 2030" also identifies decarbonization and the development of renewable energy as major priorities in line with the European Green Deal and efforts to improve energy efficiency (YC Market, 2024, February 2).

In the transport infrastructure sector, the war has caused destruction of bridges, roads, and railways, complicating logistics and export. More than 26 000 kilometers of roads have been damaged or destroyed, amounting to losses of USD 28.3 billion. Railway losses total USD 4.3 billion, port infrastructure – USD 0.85 billion, and the aviation sector – USD 2 billion. Direct losses of private vehicles are estimated at USD 2.2 billion – with 260 000 cars destroyed or damaged (Hromadske, 2025). To restore critical transport routes, it is necessary to construct new infrastructure considering security risks, expand alternative routes, and increase the role of multimodal transportation. The World Bank Board of Directors has approved a support package "Building Resilient Infrastructure in a Vulnerable Environment in Ukraine (DRIVE)" worth USD 432 million (Burych, 2025, March 31).

The war has also severely impacted critical water infrastructure. Currently, about 8.5 million Ukrainians face limited access to quality water (Ministry of Environmental Protection and Natural Resources of Ukraine, 2025, March 25). This crisis not only endangers public health but also has serious environmental consequences. Addressing it requires building backup water intakes, introducing modern water purification and conservation systems, and using water recycling technologies.

International cooperation, technological innovation, and effective resource management remain to be the key priorities in ensuring infrastructure resilience. An implementation of these measures will determine the future stability and development of Ukraine as a whole.

Conclusions

The study of infrastructure resilience in the context of crisis phenomena, based on the examples of Ukraine and Portugal, has shown that ensuring the continuous functioning of critical infrastructure depends on a number of factors. Among them, the security environment, investment attractiveness, political stability, and institutional capacity of state authorities play a decisive role. Equally important are the levels of digitalization and innovation in infrastructure development, as well as the active involvement of the private sector in processes aimed at ensuring infrastructure resilience.

In the cases of Portugal and Ukraine, the influence of these factors differs significantly: for Ukraine, the main challenge remains ensuring infrastructure resilience in the context of military aggression, while Portugal is primarily focused on strengthening its infrastructure in the context of natural disasters.

The assessment of the infrastructure environment in Portugal and Ukraine was conducted through analysis of the CMS Infrastructure Index.

Portugal's position in 2023 reflects a mature institutional system and consistent public policy in the field of infrastructure development. High scores in indicators such as political stability, private sector involvement, ease of doing business, and openness to international trade show the country's ability to effectively manage long-term investment processes. However, relatively low scores in the tax environment and the small size of the domestic market highlight the need to further improve conditions for small and medium-sized enterprises and to work more actively on attracting foreign capital. It is important for Portugal not only to maintain its current achievements but also to focus on digitalization, environmental sustainability, and adapting infrastructure to new global challenges.

Ukraine belongs to the group of countries facing infrastructure difficulties and scored 48 out of 100 possible points. Despite the challenging situation, Ukraine has the potential to improve its position through international support, reforms, and targeted rebuilding of critical infrastructure. The CMS Infrastructure Index analysis also indicates that Ukraine scores relatively high in certain indicators – particularly in the tax environment, openness to investment, and sustainable development – creating a unique "window of opportunity" for the structural transformation of the country. If an adequate level of security, political predictability, and an effective recovery strategy are ensured, Ukraine has every chance to become an attractive center for international infrastructure projects in Eastern Europe. This would require not only the restoration of what has been destroyed, but also an innovative approach to the development of a new, resilient, and competitive infrastructure that meets modern European standards.

Despite the differences in infrastructure development levels, both countries face common challenges, including cyber threats and cyberattacks on critical infrastructure, energy security, water supply and water scarcity, and risks related to urban infrastructure functioning. Therefore, ensuring infrastructure resilience in both countries requires an integrated approach that involves coordination between government institutions, the private sector, and international organizations to respond effectively to contemporary threats and strengthen the capacity of infrastructure systems. Thus, the findings confirm the research hypothesis.

In the context of future scientific inquiry, studying the adaptability of urban infrastructure to multi-crisis situations, characterized by the simultaneous impact of military, energy, and climate threats, will be of particular relevance.

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