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## KONSEKWENCJE EKONOMICZNE ZNISZCZENIA UKRAIŃSKIEJ INFRASTRUKTURY W WYNIKU ROSYJSKIEJ AGRESJI MILITARNEJ

### ECONOMIC CONSEQUENCES OF THE DESTRUCTION OF UKRAINE'S INFRASTRUCTURE AS A RESULT OF RUSSIAN MILITARY AGGRESSION

**ABSTRAKT:** W artykule omówiono skalę zniszczeń infrastruktury Ukrainy, a także określono regionalne cechy uszkodzeń w wyniku pełnoskalowej inwazji federacji rosyjskiej. Ustalono, że obiekty infrastruktury stały się jednym z głównych celów agresora, co doprowadziło do bezprecedensowych strat w sferach społecznej, transportowej, energetycznej, mieszkaniowo-komunalnej oraz cyfrowej. Całkowita suma bezpośrednich szkód, według wstępnych szacunków, wynosi 170 miliardów dolarów, co świadczy o głębokim kryzysie w zakresie zapewnienia infrastrukturalnego kraju.

Wyniki przeprowadzonych badań wykazały, że wśród obiektów sfery społecznej największe straty poniosły: sektor mieszkaniowy (60 mld USD), obiekty opieki zdrowotnej (4,3 mld USD), edukacji (7,3 mld USD), kultury, sportu i turystyki (4 mld USD). Zniszczono i/lub uszkodzono setki tysięcy budynków mieszkalnych, tysiące placówek oświatowych i medycznych, a także zabytki kultury, w tym obiekty wpisane do rejestru UNESCO. Infrastruktura transportowa poniosła straty w wysokości ponad 38,5 mld USD. Zniszczono dziesiątki tysięcy kilometrów dróg, setki mostów, dworców, lotnisk, obiektów portowych i środków transportu. Na szczególną uwagę zasługuje zniszczenie unikalnego ukraińskiego samolotu „Mrija” oraz zmasowane ataki na porty obwodu odeskiego po wstrzymaniu korytarza zbożowego.



Infrastruktura energetyczna stała się celem celowych ataków, co doprowadziło do zniszczenia wszystkich elektrowni ciepłych, elektrowni wodnych oraz elektrociepłowni na kontrolowanym terytorium. Bezpośrednie straty w sektorze energetycznym szacuje się na 14,6 mld USD.

Gospodarka mieszkaniowo-komunalna doznała znacznych zniszczeń, co spowodowało długotrwałe przerwy w dostawach wody, ciepła i świadczeniu podstawowych usług. Straty w tej sferze wynoszą 3,5 mld USD. Ucierpiała również infrastruktura cyfrowa: zniszczono tysiące stacji bazowych telefonii komórkowej, uszkodzono sieci dostępu do Internetu, co doprowadziło do spadku jakości komunikacji i utraty dostępu do usług cyfrowych w wielu regionach. Całkowite straty szacuje się na 1,2 mld USD.

W artykule podkreślono konieczność przeprowadzenia ekspertyz technicznych po zakończeniu aktywnych działań wojennych w celu dokładnego określenia skali zniszczeń i opracowania strategii odbudowy. Przeprowadzono analizę SWOT skutków ekonomicznych zniszczenia infrastruktury Ukrainy w wyniku agresji wojskowej federacji rosyjskiej, co pozwoliło na nakreślenie możliwych strategii rekonstrukcji, pozyskania pomocy międzynarodowej i odbudowy gospodarki kraju. Materiały badawcze mogą być wykorzystane do opracowania polityki państwowej w sferze powojennej odbudowy, planowania inwestycji oraz koordynacji działań humanitarnych.

**SŁOWA KLUCZOWE:** infrastruktura Ukrainy, agresja wojskowa, bezpośrednie straty, infrastruktura społeczna, transport, energetyka, infrastruktura cyfrowa, rekonstrukcja, odbudowa, straty regionalne, zasoby mieszkaniowe

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**ABSTRACT:** The article examines the scale of destruction of Ukraine's infrastructure and identifies the regional features of the damage resulting from the full-scale invasion of the Russian Federation. It has been established that infrastructure facilities have become one of the main targets of the aggressor, which has led to unprecedented losses in the social, transport, energy, housing and communal, and digital spheres. The total amount of direct damages, according to preliminary estimates, reaches \$170 billion, which indicates a deep crisis in the country's infrastructure provision.

The results of the conducted research showed that among the social sector facilities, the largest losses were incurred by: the housing sector (\$60 billion), healthcare facilities (\$4.3 billion), education (\$7.3 billion), culture, sports, and tourism (\$4 billion). Hundreds of thousands of residential buildings, thousands of educational and medical institutions, as well as cultural monuments, including objects on the UNESCO register, have been destroyed and/or damaged. Transport infrastructure suffered losses of over \$38.5 billion. Tens of thousands of kilometers of roads, hundreds of bridges, railway stations, airfields, port facilities, and vehicles have been destroyed. The destruction of the unique Ukrainian „Mriya” aircraft and the large-scale attacks on the ports of the Odesa region after the termination of the grain corridor deserve special attention.

The energy infrastructure has become a target of deliberate attacks, which has led to the destruction of all thermal power plants, hydroelectric power plants, and combined heat and power plants in the controlled territory. The direct damages to the energy sector are estimated at \$14.6 billion.

The housing and communal sector has suffered significant damage, resulting in prolonged interruptions to water supply, heating, and the provision of basic services. The losses in this area amount to \$3.5 billion. The digital infrastructure has also been affected: thousands of mobile communication base stations have been destroyed, and fixed-access Internet networks have been damaged, leading to a decrease in the quality of communication and loss of access to digital services in many regions. The total losses are estimated at \$1.2 billion.

The article emphasizes the need for technical inspections after the completion of active hostilities to accurately determine the extent of the damage and form reconstruction strategies.

A SWOT analysis of the economic consequences of the destruction of Ukraine's infrastructure as a result of the military aggression of the Russian Federation was carried out, which made it possible to outline possible strategies for reconstruction, attracting international assistance, and restoring the country's economy. The research materials can be used for the development of state policy in the field of post-war recovery, investment planning, and coordination of humanitarian efforts.

**KEYWORDS:** resilience; food security, rural economy, crisis management, agricultural innovation, agricultural sustainability

## INTRODUCTION

### Problematic situation

The armed aggression of the Russian Federation against Ukraine has caused unprecedented destruction of infrastructure, from residential buildings to digital networks, with far-reaching consequences for all sectors of the economy and social life. The scale of losses (direct damages to Ukraine's infrastructure), according to statistics from the T4P Global Initiative<sup>1</sup> and analytical reports from the Kyiv School of Economics (KSE)<sup>2</sup>, reached \$170 billion as of November 2024. This indicates a systemic destruction of critical infrastructure and complicates the processes of recovery, planning, and meeting the basic needs of the population. The lack of a complete picture of the damages due to active hostilities creates additional challenges for an effective response.

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<sup>1</sup> Statistics from the T4P Global Initiative War Crimes Database. Ukrainian Helsinki Union for Human Rights, *Shelling of Ukraine as a war crime committed by Russia*.

<sup>2</sup> T. Antonyuk. *Direct losses of Ukraine due to the war reached \$170 billion*, KSE assessment Institute, 2025.

In the current environment, the issue of protecting critical infrastructure has become exceptionally relevant. Critical infrastructure, defined by the Law of Ukraine «On Critical Infrastructure»<sup>3</sup> as a set of objects, systems, and networks that are vital for the functioning of society and the state, has become the main target of the enemy. Critical infrastructure is the foundation of the state's functioning, ensuring national security, sustainable economic development, and the well-being of the population. Its destruction or disruption leads to large-scale socio-economic, environmental, and humanitarian consequences. The destruction of these objects is part of a strategy aimed at destabilization, creating a humanitarian catastrophe, and the economic collapse of Ukraine. As Serhiy Ivaniuta et al. note<sup>4</sup>, «Russian military aggression against Ukraine is viewed as a direct threat to national and global security, requiring a systemic approach to risk assessment and the development of effective protection mechanisms».

In a global context, according to The Global Risks Report 2022<sup>5</sup> published by the World Economic Forum, threats to critical infrastructure are among the leading global risks, particularly in the areas of cybersecurity, energy, and healthcare, which are significantly exacerbated for Ukraine in a wartime environment. In their research, scholars also devote considerable attention to the environmental consequences of the war (Jakub Ber<sup>6</sup>, Oleksandr Bondar et al.<sup>7</sup>, Olena Kovtun<sup>8</sup>, Viktoria Miroshnychenko & Volodymyr Tyorlo<sup>9</sup>), socio-economic challenges (Yevhenii Kostyk & Anatolii Ovsiienko<sup>10</sup>, Ihor Yaroshenko & Iryna Semyhulina<sup>11</sup>, Maksym Khatser<sup>12</sup>), legal aspects (Iryna Kozak-Balaniuk<sup>13</sup>), as well as prospects for infrastructure restoration, specifically in tourism (Halyna Bohatyriova & Oksana Berezivska<sup>14</sup>) and innovation-investment (Liudmyla Sas et al.<sup>15</sup>).

<sup>3</sup> On Critical Infrastructure. Law of Ukraine No. 1882-IX of 16.11.2021.

<sup>4</sup> S.P. Ivaniuta, Ye.V. Panov, O.I. Ivanenko, S.V. Hapon. *Assessment of risks to Ukraine's critical infrastructure in the conditions of Russian military aggression*. Bulletin of Igor Sikorsky Kyiv Polytechnic Institute. 2024. Series: Chemical Engineering, Ecology and Resource Conservation. No. 2. pp. 47-61.

<sup>5</sup> The Global Risks Report 2022, 17th Edition, World Economic Forum.

<sup>6</sup> J. Ber. *War with nature. The impact of Russian aggression on the natural environment of Ukraine*. 2023-12-07.

<sup>7</sup> O. B. Bondar, Ye. Ye. Melnyk, O. M. Pohorielova, L. O. Bytsiura, & L. M. Holovatiuk. *Analysis of the results of the impact of military actions on the environment and infrastructure of Ukraine*. Scientific Bulletin of UNFU, 2025, no 35(1).

<sup>8</sup> O. M. Kovtun. *Environmental and legal aspects of the armed aggression of the russian federation against Ukraine*. Uzhhorod National University Herald. 2024. Series: Law, 2(83), 103–109.

<sup>9</sup> V. V. Miroshnychenko, V. O. Tyorlo. *The Influence of the Military Factor on the State of Infrastructure and the Natural Environment of Ukraine's Regions After the russian aggression*. Scientific Papers NaUKMA Economics, 2024, no 9(1), 66–71.

<sup>10</sup> Y. Kostyk, A. Ovsiienko. *Socio-economic risks of the full-scale war of the russian federation against Ukraine and stabilization measures to overcome them in the context of the initiatives of the President of Ukraine*. Economic Bulletin of the University. 2023. No. 57. pp. 113-120.

<sup>11</sup> I. V. Yaroshenko, I. B. Semyhulina. *Factors influencing the socio-economic development of regions (territories) of Ukraine in the conditions of threats and overcoming the consequences of military aggression*. Problems of Economics. 2024. № 3 (61), pp. 142-148.

<sup>12</sup> M. Khatser. *Socio-economic challenges of Ukraine in the war and post-war period*. *Management and Entrepreneurship: Trends of Development*, 2022, 4(22), pp. 86-95.

<sup>13</sup> I. Kozak-Balaniuk. *International Protection for Ukrainian Citizens in the Time of Russian Military Aggression*. Teka Komisji Prawniczej PAN Oddział w Lublinie, 17. 2024. 259-271.

<sup>14</sup> H. A. Bohatyriova & O. J. Berezivska. *Restoration of tourism infrastructure after the crisis: challenges and prospects for tourism development in Ukraine*. Academic Visions, 2024, no 38.

<sup>15</sup> L. Sas, I. Balaniuk, D. Shelenko, O. Levandivskyi, T. Kuzmin, M. Hamuliak. *Investment and innovation potential of enterprises as a component of managing socio-economic development and restoration of territorial communities*. Scientific

The Cabinet of Ministers of Ukraine has approved the National Plan for the protection, security, and resilience of critical infrastructure<sup>16</sup>, which includes a set of measures for risk assessment, threat response, and increasing the resilience of infrastructure systems.

The approved methodologies<sup>17 18 19</sup> for assessing damages provide a legal basis for documenting losses, calculating compensation, and ensuring international legal protection.

Infrastructure facilities have become one of the key areas that have been under the greatest attack by the aggressor since the unleashing of a full-scale war against Ukraine. Full information on the extent of damage and the possibility of restoring individual infrastructure components can only be established on the basis of technical surveys after active hostilities in the area where the relevant facilities are located.

According to preliminary data, the total amount of direct damage to Ukraine's infrastructure since February 2022 has reached almost \$170 billion, an increase of \$12.6 billion (8%) compared to the beginning of 2024, as a result of further damage caused by missile attacks and hostilities (Table 1). Housing, transport, and energy sectors have suffered the most.

The research focuses on the destruction of the following components of Ukraine's infrastructure:

- social infrastructure,
- transport infrastructure,
- energy infrastructure,
- housing and utilities infrastructure,
- digital infrastructure.

## RESEARCH OBJECTIVES

### Main research objective

To assess the scale of infrastructure destruction in Ukraine due to the war, determine priority areas for recovery, and develop recommendations for effective management of reconstruction processes.

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Perspectives. 2025. No. 2 (56).

<sup>16</sup> On the approval of the National Plan for the protection and ensuring the security and resilience of critical infrastructure". Order of the Cabinet of Ministers of Ukraine of September 19, 2023, No. 825-r.

<sup>17</sup> Methodology for determining damage and losses caused to enterprises, institutions, and organizations of all forms of ownership as a result of the destruction and damage to their property in connection with the armed aggression of the Russian Federation, as well as lost profits from the impossibility or obstacles in carrying out economic activities. Order of the Ministry of Economy of Ukraine and the State Property Fund of Ukraine dated October 18, 2022, No. 3904/1223.

<sup>18</sup> On Property Valuation, Property Rights, and Professional Valuation Activities in Ukraine. Law of Ukraine of 12.07.2001 No. 2658-III.

<sup>19</sup> Methodology for determining damage and losses caused to territories and objects of the nature reserve fund as a result of the armed aggression of the Russian Federation". Order of the Ministry of Environmental Protection and Natural Resources of Ukraine dated 15.10.2022 No. 424.

**Table 1**

Total estimated direct damage to infrastructure as of November 2024

Type of Property	Assessment of Direct Losses		Preliminary Estimate (as of early 2024)		Dynamics
	\$ млрд	%	\$ млрд	%	%
Residential Buildings	60,0	35,3	58,9	37,5	1,9
Infrastructure	38,5	22,7	36,8	23,4	4,6
Energy	14,6	8,6	10,0	6,4	46,0
Enterprise Assets, Industry	14,4	8,5	13,1	8,3	9,9
AgroComplex and Land Resources	10,3	6,1	10,3	6,6	0,0
Education	7,3	4,3	6,8	4,3	8,8
Forest Fund	4,5	2,7	4,5	2,9	0,0
Healthcare	4,3	2,5	3,1	2,0	32,3
Culture, Tourism, Sports	4,0	2,3	3,1	2,0	29,0
Housing and Utilities	3,5	2,0	3,5	2,2	0,0
Vehicles	3,5	2,0	3,1	2,0	12,9
Trade	2,8	1,7	2,6	1,7	7,7
Digital Infrastructure	1,2	0,7	0,5	0,3	140,0
Administrative Buildings	0,8	0,4	0,5	0,3	60,0
Social Sphere	0,2	0,1	0,2	0,1	0,0
Financial Sector	0,04	0,01	0,04	0,03	0,0
<b>Total</b>	<b>169,8</b>	<b>100</b>	<b>157,2</b>	<b>100</b>	<b>8,0</b>

Source : <sup>20 21</sup>**Specific research objectives**

1. To analyze the damage and destruction of infrastructure by sector (social, transport, energy, housing and utilities, and digital).
2. To examine the regional features of the destruction and their impact on the life of the population.
3. To define strategic approaches and directions for infrastructure recovery.

**RESEARCH PROBLEMS****Main research problem**

The lack of a comprehensive approach to assessing the scale of infrastructure destruction and planning its recovery in the context of an ongoing war and limited access to facilities.

**Detailed research problems**

1. Disparity of destruction across regions and sectors.
2. Lack of prompt access to accurate data due to hostilities.
3. Insufficient integration of digital solutions into monitoring and planning processes.

<sup>20</sup> Report on the direct damage to the infrastructure from the destruction caused by Russia's military aggression against Ukraine a year after the start of the full-scale invasion.

<sup>21</sup> Report on damages to infrastructure from the destruction caused by Russia's military aggression against Ukraine as of January 2024. April 2024. 39 p.

4. Limited financial and human resources for large-scale reconstruction.

## **RESEARCH HYPOTHESES**

### **Main hypothesis**

A systematic assessment of infrastructure damage and strategic planning for its recovery allows for the minimization of the social and economic consequences of the war.

### **Specific hypotheses**

1. Regions with a higher concentration of social infrastructure have suffered proportionally greater losses.
2. The implementation of digital technologies in recovery processes increases the efficiency of reconstruction.
3. International support is a critical factor for the successful recovery of transport and energy infrastructure.

## **RESEARCH METHODS**

In this research, the following methods were applied:

- content analysis of official reports, statistical data, and expert assessments;
- geospatial analysis for visualizing the scale of the destruction;
- comparative analysis of regional data regarding losses in various sectors;
- SWOT analysis of infrastructure destruction to develop recovery strategies.

The sources of the following information are (the following information is based on) official data (official data) of the Ministry of Communities and Territories Development, Ministry of Economy, Ministry of Infrastructure, Ministry of Agrarian Policy and Food, Ministry of Energy, State Statistics Service of Ukraine, Prozorro electronic public procurement system, military administrations, other relevant ministries, the National Bank and calculations made by the Kyiv School of Economics in accordance with the World Bank methodology.

### **1. SOCIAL INFRASTRUCTURE**

Social infrastructure includes:

- housing sector;
- healthcare facilities;
- education and science facilities;
- social protection facilities;
- culture, sports, and tourism facilities.

The war in Ukraine has caused large-scale destruction of social infrastructure, which directly affects the population's access to basic services – education, healthcare, culture, and sports – and

impacts citizens' quality of life and well-being. As Vita Andriieva and Myroslava Hofman<sup>22</sup> state, «damage and destruction of educational and healthcare institutions deprive the population of access to basic services, which is critically important for social recovery». According to IMPACT Initiatives<sup>23</sup>, in cities like Mykolaiv and Kherson, housing damage complicates access to medical services, education, and hygiene products, creating additional risks for vulnerable population groups. Educational institutions, particularly schools, kindergartens, and universities, have suffered significant damage, primarily in the Donetsk region, which has become an epicenter of destruction<sup>24</sup>.

### **1.1. Housing sector**

Damage to the housing sector amounted to \$60 billion. In particular, 236,000 residential buildings were destroyed or damaged, of which 209,000 were private houses, 27,000 were multi-apartment buildings, including 600 dormitories. Over 50% of the housing stock in a large number of cities and towns was damaged or destroyed. Regions that suffered the most damage to the housing sector: Donetsk, Kharkiv, Luhansk, Kyiv, Chernihiv, and Kherson regions.

### **1.2. Healthcare facilities**

Direct damage to healthcare facilities amounted to \$4.3 billion. A total of 1,554 healthcare facilities have been damaged or destroyed since the start of the war. Almost half of the direct damage to the healthcare sector is concentrated in Donetsk, Mykolaiv, and Kharkiv regions. Among the most high-profile destructions in this sector was one of the most powerful missile strikes on the capital of Ukraine on 8 July 2024, which targeted the largest children's hospital, Okhmatdyt, with more than 600 young patients.

### **1.3. Educational and scientific facilities**

Damage to educational facilities amounted to \$7.3 billion. About 4,000 educational institutions were damaged or destroyed as a result of the hostilities. Although active hostilities took place in 11 regions, educational institutions were damaged in 22 regions. The largest losses from the destruction and damage to educational institutions were in Donetsk, Kharkiv, Kherson, Mykolaiv, Dnipro, and Zaporizhzhia regions.

### **1.4. Social protection facilities**

Direct damage to the infrastructure of social services provided by the state amounted to USD 0.2 billion. As a result of the large-scale hostilities in different regions of Ukraine, 160 social protection facilities were damaged, including destroyed or damaged social centres, geriatric institutions, sanatoriums, children's camps and orphanages, and boarding schools.

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<sup>22</sup> V. Andriieva & M. Hofman. *Assessment of damages to property as a result of the armed aggression of the russian federation in Ukraine*. Scientific Notes of KROK University, 2025, no. (1(73)), 20–27.

<sup>23</sup> Shaping Practices Influencing Policies Impacting Lives.

<sup>24</sup> Centre for Information Resilience, «Digital investigations. Human stories».

## 1.5. Cultural, sports, and tourism facilities

Direct damage to the infrastructure of culture, religion and tourism amounted to \$4 billion. At least 3,921 cultural facilities, 399 religious buildings, 343 sports facilities, and 164 tourism facilities were damaged or destroyed. This is the largest destruction of the cultural sector in the history of independent Ukraine. One of the most painful losses of this war on the cultural front is the Holy Dormition Sviatohirsk Lavra, which is listed on the UNESCO World Heritage List.

## 2. TRANSPORT INFRASTRUCTURE

Transport infrastructure, including roads, bridges, railway tracks, and ports, is a key element of economic stability. The destruction of these facilities is aimed at obstructing logistics, the delivery of humanitarian aid, and the export of goods. Ukraine's transport infrastructure has been subjected to systematic and targeted attacks of a strategic nature, which not only disrupted logistical chains but also aimed to destabilize the economy, «directly affecting the socio-economic development of regions, creating obstacles for businesses and the population»<sup>25</sup>

The total amount of direct damage to transport infrastructure in Ukraine was \$38.5 billion. Among the transport infrastructure facilities:

- aviation infrastructure
- railway infrastructure
- road infrastructure
- vehicles
- port infrastructure
- postal operators

### 2.1. Aviation infrastructure

The aviation industry began to suffer losses from the military aggression even before it actually began. On 12 February 2022, global insurance companies informed Ukrainian carriers that they would stop insuring their aircraft due to the high threat of invasion by Russia.

With the outbreak of hostilities, the airspace over Ukraine was immediately closed, and air traffic was suspended. Russian troops began active rocket attacks on all key airfields in Ukraine. In the first weeks of the war, massive shelling of aviation infrastructure was carried out, primarily airfields not only for military but also for civilian and civil-military (dual) purposes - 19 out of 35 airfields were damaged, including 12 civilian and 7 dual-purpose airfields (excluding military airfields). Some of the airfields were subjected to repeated shelling.

According to preliminary estimates, the direct losses of the industry (airports, airfields, aircraft, air navigation equipment) amounted to around \$2.04 billion.

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<sup>25</sup> I. V. Yaroshenko, I. B. Semyhulina. *Factors influencing the socio-economic development of regions (territories) of Ukraine in the conditions of threats and overcoming the consequences of military aggression*. Problems of Economics. 2024. № 3 (61), pp. 142-148.

## **2.2. Railway infrastructure**

After the attacks on aviation infrastructure, the next targets of active attacks were railway infrastructure, including power substations.

Since the outbreak of the war, the Ukrainian railway has demonstrated its role as a critical infrastructure facility, providing free evacuation of millions of Ukrainian citizens and businesses in the war zone, delivery of critical materials and equipment. In response, the Ukrainian railway has become an active target for Russian shelling and attacks.

According to preliminary estimates, the total length of the damaged railway line is 507 km; the number of damaged railway stations and yards is 126, of which more than 53 were damaged or destroyed in government-controlled areas and the rest in uncontrolled territories. More than 700 km of railway tracks are located on the temporarily occupied territory. There is reason to believe that all the movable property of Ukrzaliznytsia that was not removed from these territories in time can be considered completely lost (destroyed or stolen by the aggressor country's troops). Thus, the total direct losses in this sector are estimated at \$4.3 billion.

## **2.3. Road infrastructure**

Road infrastructure facilities suffered the greatest damage among the components of the transport infrastructure, both in absolute and value terms. Firstly, they are naturally targeted during artillery attacks, and secondly, Russian tanks have been actively moving along Ukrainian roads throughout the entire period of military aggression.

An inspection of the state of roads in the de-occupied regions (Chernihiv, Kyiv, Sumy, and Kharkiv oblasts) confirmed significant damage to the road structure caused by the passage of tanks and other heavy military equipment, which will require reconstruction.

26,000 km of roads and 344 bridges and bridge crossings of state, local, or municipal importance have been destroyed, amounting to \$28.3 billion, taking into account the weighted average cost of road reconstruction.

## **2.4. Vehicles**

In the territories and cities where the fiercest fighting took place, public transport infrastructure was destroyed, and people were left without private vehicles that were damaged/destroyed as a result of rocket and artillery shelling.

The direct losses incurred by utilities and private carriers, including destroyed vehicles, amounted to \$0.83 billion, including destroyed trolleybuses, trams, and buses. Direct losses to private passenger vehicles amounted to 260,000 cars, with a monetary value of approximately \$2.2 billion.

The greatest damage to municipal property, including public transport, was caused in Luhansk and Donetsk regions, as well as in the city of Kharkiv. The enemy used heavy weapons against

civilian infrastructure, which resulted in the loss of about 60% of public transport in the Donetsk region and over 70% in the Luhansk region.

Among the losses of vehicles, it is worth mentioning the destruction of a Mriya aircraft worth \$300 million, and the cost of building a new aircraft of this model could be much higher.

Also, 1629 firefighting vehicles worth \$89 million were lost. Significant damage was caused to citizens as a result of the explosion of the Kakhovka hydroelectric power station. In particular, 4,000 cars were destroyed, and the damage was estimated at \$37 million.

The actual losses of air passenger transport are higher due to the possible destruction of other civilian/cargo aircraft during the shelling of Ukrainian airfields, but in the absence of detailed information on the location of such aircraft at civilian airfields, such an assessment is currently impossible.

## **2.5. Port industry**

Russian attacks on ports intensified in 2023-2024, after the completion of the grain corridor agreed with Russia. In July-October 2024 alone, the enemy carried out almost 60 attacks on the ports of the Odesa region. Almost 300 infrastructure facilities, 177 vehicles, and 22 civilian vessels were destroyed or damaged. The shelling of the ports in October 2024 caused \$30-40 million in damage. This is a deliberate terrorist tactic aimed at destroying Ukraine's export potential.

Since the beginning of the war, property in four ports has been destroyed or damaged. The grain terminal in Mykolaiv's Nika-Tera port was destroyed, and Nibulon's terminals were also damaged.

The aggressor hijacked and used its own and friendly cargo ships to export stocks of grain, ferrous metals, etc., and needed working ports to do so. There is information about the theft of 400-500 thousand tonnes of grain (worth hundreds of millions of dollars) from the four occupied southern regions, which is more than a third of local stocks, as well as about the occupiers' plans to export 200 thousand tonnes of products worth \$170 million from Mariupol's factories.

The total direct damage to port infrastructure and related businesses is estimated at \$0.85 billion.

## **2.6 Postal operators**

Since the beginning of the war, several hundred post offices, dozens of terminals/depots and vehicles, as well as a large number of parcels for which the operators are financially responsible, have been destroyed or damaged. The total direct losses of postal operators are estimated at \$13 million.

### 3. ENERGY

Attacks on energy infrastructure are one of the main tools of military pressure. Specifically, Serhii Balaniuk<sup>26</sup> notes that «the destruction of energy infrastructure is part of a strategy aimed at the destruction of the Ukrainian nation by creating a humanitarian crisis».

The UN Human Rights Monitoring Mission<sup>27</sup> reports that as a result of the attacks, 9 GW of generating capacity has been destroyed – almost half of Ukraine’s winter needs. Furthermore, 73% of thermal power plants have been put out of commission, leading to power outages, disruptions in business operations, and creating threats to the lives of the civilian population during the winter period.

In addition, the attacks have a transnational dimension. As Interfax-Ukraine<sup>28</sup> reports, Russia struck a compressor station that provided LNG supplies from the USA and Azerbaijan, which threatens the energy security of not only Ukraine but also Europe as a whole.

The electricity generation and transmission sector suffers the most from Russian aggression. Between October 2022 and February 2023, Russia carried out targeted and large-scale attacks on such facilities. Since the beginning of the full-scale invasion, all thermal power plants and hydroelectric power plants controlled by Ukraine, as well as 20 combined heat and power plants, have been affected. Regular and targeted shelling of energy infrastructure in the frontline regions continues.

Kakhovka and Dnipro hydroelectric power plants (HPPs), Trypillia and Zmiiv thermal power plants (TPPs) were destroyed, Kharkiv CHPP-5 was almost completely destroyed, and Trypillia TPP in the Kyiv region was actually lost. Other generating capacities, high-voltage substations, and oil and gas infrastructure were also damaged. The power units of Burshtyn and Ladyzhyn TPPs (over 4 GW) were put out of action.

The territories occupied by Russia after 24 February 2022 include Vuhlehirsk, Zaporizhzhia, Kurakhovo, and Luhansk TPPs, as well as Slaviansk TPP, which is close to the front line and regularly undergoes shelling by the aggressor.

The total amount of direct damage to the Ukrainian energy sector was estimated at \$14.6 billion.

In particular, the current direct losses of thermal power generation are estimated at \$3.8 billion (thermal power plants), \$1.6 billion (combined heat and power plants), and \$2.5 billion for hydroelectric power plants and pumped storage power plants. At the same time, the cost of restoring the lost capacities of such power plants may significantly exceed the damage assessment due to significant physical wear and tear and technological obsolescence of the damaged and destroyed equipment. Direct losses from the destruction of the Kakhovka HPP, which was blown up and

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<sup>26</sup> S. Balaniuk. *Economic Losses from Russia's Missile Attacks on Ukrainian Critical Infrastructure with the Aim of Destroying the Ukrainian Nation*. The Journal of Development Studies, 2023. Vol. 4. pp. 59-70.

<sup>27</sup> Website Human rights for everyone everywhere. «Monitoring the Human Rights Situation in the Country Since 2014».

<sup>28</sup> Website Interfax Ukraine.

completely destroyed by the Russians in early June 2023, were estimated at \$586 million. The cost of building a new hydroelectric power plant of similar capacity will be about \$1 billion.

Renewable energy producers have suffered significant losses. According to the Energy Charter Secretariat, 13% of solar generation capacity is located in the occupied territories, and 8% has been damaged or destroyed; about 80% of wind generation is occupied and part of it has been damaged by shelling; 2% of bioenergy capacity is under occupation. There are 4 biogas plants known to have been damaged. Direct losses of renewable electricity producers are estimated at \$281 million. This business also suffers significant indirect financial losses. The occupied facilities have not been generating electricity for more than a year, generating no revenue. Such losses are multiplied by the impossibility of commissioning new unfinished facilities in which resources, including loans, have been invested. According to industry associations, by the end of 2022, only wind farms with a total installed capacity of about 800 MW should have been completed and commissioned.

The massive shelling by the Russian Federation resulted in damage and destruction of electricity transmission and distribution facilities. According to preliminary estimates, the amount of direct damage caused by the full-scale invasion to the electricity transmission system operator is estimated at \$2.2 billion, and to distribution system operators at \$826 million.

In the first months of the full-scale invasion, Russia targeted oil and oil product processing and storage facilities. As of 24 February 2022, 32 oil refineries and the fuel stored there were damaged or completely destroyed. The direct damage to the fuel storage sector amounted to almost \$266 million. The aggressor repeatedly shelled the facilities of the only major oil refineries that were active – Shebelynka (Kharkiv region) and Kremenchuk (Poltava region) (over \$2.1 billion in damage).

Direct damage to heat supply facilities (excluding CHP plants) is estimated at almost \$1 billion. Destroyed and damaged heat generation facilities endangered the winter and heating seasons and led to interruptions in the supply of heat and hot water.

As a result of the hostilities and massive attacks, 925 boiler houses were partially damaged or completely destroyed, most of them in Kharkiv, Kyiv, Chernihiv, Donetsk, and Mykolaiv regions. 214 central heating stations were partially damaged or completely destroyed, and more than 354 linear kilometres of heating networks were completely destroyed.

## **HOUSING AND UTILITIES SECTOR**

Water supply, sewerage, heating, and gas supply systems have also suffered significant damage as a result of the Russian Federation's military aggression. As Oleksandr Bondar et al.<sup>29</sup> note, «military actions have caused serious damage to housing and communal infrastructure, creating a threat to meeting the basic needs of the population». The restoration of these systems is one of the top priorities, as their functioning is critically important for the life of cities and towns.

<sup>29</sup> O. B. Bondar, Ye. Ye. Melnyk, O. M. Pohorielova, L. O. Bytsiura & L. M. Holovatiuk. *Analysis of the results of the impact of military actions on the environment and infrastructure of Ukraine*. Scientific Bulletin of UNFU, 2025, no 35(1).

The infrastructure of housing and communal services was one of the targets of missile and artillery strikes by the Russian Federation.

The constant shelling and hostilities made it impossible or significantly complicated to carry out repairs, which led to the prolonged shutdown of water supply systems. Residents did not receive utility services for a long time and did not have proper access to drinking water.

Due to the damage to the water supply system, most districts of Mykolaiv were left without a centralised water supply for a long time. The water supply system was restored only after the liberation of Kherson in November 2022, and until then, the city had only technical water, with drinking water delivered from other cities in bottles. In addition, the housing and utilities sector of cities under heavy artillery shelling suffered significant damage. The water supply sector experienced constant interruptions in the cities due to forced power outages and a drop in voltage on equipment, which led to the need to install generators and accelerated the deterioration of assets.

As a result, 925 boiler houses, 214 heating points, and 354 km of heating networks were destroyed. Direct losses to water supply and sewerage facilities and household waste management amounted to \$3.5 billion.

## **DIGITAL INFRASTRUCTURE**

Digital infrastructure, including communication networks, data centers, and cybersecurity facilities, plays a key role in the modern world. Its destruction is aimed at disrupting communication, spreading disinformation, and complicating the coordination of defense efforts. As Serhiy Ivaniuta et al.<sup>30</sup> emphasize, «digital infrastructure is not only an element of the economy but also a critical component of national security, requiring adequate protection from cyberattacks and physical destruction». Damage to this infrastructure complicates access to government services, banking operations, and information, which is part of a hybrid war.

Ukraine is demonstrating a high level of adaptability by switching to cloud solutions and satellite internet, and the Diia app has become a key tool for digital resilience, providing access to government services even in the war zone. In addition, Ukrainian intelligence is actively using cyber tools. A large-scale attack was carried out on Gazprom, as a result of which more than 390 databases and SCADA system servers were destroyed, indicating a new level of cyber operations in modern warfare.

The sphere of electronic communications includes Internet networks of fixed-line operators, radio networks of mobile operators, backbone networks, and electronic communications equipment. Almost a thousand fixed-line operators of electronic communications suffered losses as a result of the hostilities. After the de-occupation of the settlements, the destruction of networks reached 100%. Thousands of mobile base stations were destroyed. At least 726 operators

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<sup>30</sup> S.P. Ivaniuta, Ye.V. Panov, O.I. Ivanenko, S.V. Hapon. *Assessment of risks to Ukraine's critical infrastructure in the conditions of Russian military aggression*. Bulletin of Igor Sikorsky Kyiv Polytechnic Institute. 2024. Series: Chemical Engineering, Ecology and Resource Conservation. No. 2. pp. 47-61.

of electronic communications with fixed access to the Internet suffered losses as a result of hostilities. After the de-occupation of the settlements, the destruction of networks reached 100%. Across the country, the quality of data transmission over fixed-line Internet access networks has decreased by an average of 13%.

In 12.2% of settlements, there is no access to mobile communications, and in 3.1% - it is partially available. 3,534 base stations of mobile operators are out of service, which is almost 11% of the total. The quality of data transmission over mobile Internet access networks in the country has decreased by an average of 26%. Thus, direct losses to digital infrastructure are estimated at \$1.2 billion.

All of the above amounts of damage are approximate. They can only be determined accurately after the end of hostilities. In addition, we understand that infrastructure damage causes collateral damage to the users of this infrastructure, including reduced production, reduced work and services, which in turn affects people's incomes, purchasing power, tax payments, etc.

To identify priority areas and strategies for the recovery of Ukraine's infrastructure, a SWOT analysis of the economic consequences of the destruction caused by the Russian Federation's military aggression was conducted (Table 2).

**Table 2**

SWOT Analysis of the Economic Consequences of Ukraine's Infrastructure Destruction as a Result of the Russian Federation's Military Aggression

Strengths	Weaknesses
High level of international support and solidarity with Ukraine (financial, technical, and humanitarian aid).	Large-scale destruction of critical infrastructure, complicating the basic functioning of the economy.
Mobilization of internal resources, volunteer movements, and civic activism.	High level of losses in the housing stock and the transport, energy, and social sectors.
Rapid adaptation and flexibility in crisis conditions.	Limited financial resources of the state for independent recovery.
Potential for modernizing infrastructure to contemporary standards (green technologies, digitalization).	Loss of human capital due to migration, deaths, injuries, and psychological trauma.  Decline in investment attractiveness due to security risks.

Opportunities	Threats
Attracting international investments and donor funds for reconstruction.	Ongoing hostilities and repeated attacks on reconstructed facilities.
Implementing new technologies in the reconstruction process (energy efficiency, digital solutions, risk resilience).	Delays in project financing and implementation due to bureaucracy or corruption. High costs for infrastructure security and protection.
Developing new economic clusters around reconstruction (construction, logistics, IT, energy).	Loss of investor confidence in the event of political instability.
Forming a new economic model with a focus on security, decentralization, and resilience.	Deepening social inequality between regions that recover faster and those that remain destroyed.
Increasing the role of territorial communities in project planning and implementation.	

Source: Author's analysis.

Based on the SWOT analysis, here are possible strategies for development and reconstruction:

#### **S–O Strategies (Using Strengths to Seize Opportunities):**

1. Integrating international aid with internal resources: Create national platforms to coordinate donor funds, volunteer initiatives, and government programs.
2. Modernizing infrastructure through technology: Use the experience of adapting to crises to implement energy-efficient, digital, and resilient solutions in transport, energy, housing, and utilities.
3. Forming new economic clusters: Develop the construction industry, logistics, IT, and green energy as drivers of economic growth.

#### **W–O Strategies (Overcoming Weaknesses through External Opportunities):**

1. Attracting investment to compensate for financial losses: Create a favorable investment climate through security guarantees, transparency, and anti-corruption mechanisms.
2. Educational and personnel programs: Launch government and international programs for retraining and training personnel for reconstruction and the management of infrastructure projects.
3. Developing digital infrastructure: Restore and modernize telecommunication networks, considering new standards for cybersecurity and accessibility.

#### **S–T Strategies (Using Strengths to Counter Threats):**

1. Strengthening infrastructure security: Implement protection systems, backup power, and decentralized energy solutions.
2. Civilian participation in planning: Actively involve communities in reconstruction processes to reduce social tension and increase the effectiveness of decisions.
3. International advocacy: Use partner support to pressure the aggressor, protect the rights of victims, and hold those responsible for the destruction accountable.

### **W–T Strategies (Minimizing Weaknesses and Threats):**

1. Anti-corruption reform in reconstruction: Establish independent oversight bodies and digital platforms for monitoring expenditures.
2. Insuring infrastructure risks: Develop mechanisms for insuring reconstructed facilities against repeated attacks or natural disasters.
3. Balanced regional development: Ensure a balance between regions in project funding and implementation to avoid social inequality.

The armed aggression of the terrorist state has caused destruction and the occupation of parts of the territories, the deaths of people, the destruction of homes and infrastructure components, and has had a negative impact on the environmental situation. As a result, this has led to forced migration of the population, which could not help but affect socio-economic and investment security. The introduction of martial law in Ukraine has influenced the life of society, necessitating adaptation to new conditions and the development of effective financial development strategies to ensure economic stability.

Olha Hrynkevych et al.<sup>31</sup> note that «investments in the system of socio-economic security are a key factor in the economic recovery of Ukraine’s regions». Andrii Vozniuk and Mariia Hryha<sup>32</sup> emphasize that damage assessment is a crucial stage for subsequent compensation and reconstruction. This work, based on assessment methodologies, will allow for the documentation of the scale of destruction and the presentation of substantiated claims to international institutions. Ukraine has agreed with the IMF on a four-year support program of 11.6 billion Special Drawing Rights (about 14.4 billion euros). The goal of this program is to consolidate policies that support fiscal, external, price, and financial stability, promote economic recovery, improve governance, and strengthen institutions to foster long-term growth in the context of post-war reconstruction and Ukraine’s path toward EU membership.

As part of the implementation of the Ukraine Facility Regulation (EU) 2024/792<sup>33</sup> of February 29, 2024, which was adopted by the European Parliament and the Council, consultations on reforms and investments were held with local and regional authorities, social partners, civil society organizations, enterprises, and business associations. To strengthen the capacity of territorial communities, the government and its development partners will work to create mechanisms for enhancing the competencies of local government representatives in areas such as strategic planning, anti-corruption, project management, urban planning, digitalization, investment, and collaboration with development partners.

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<sup>31</sup> O. Hrynkevych, V. Buniak, S. Kvack, V. Hrynkevych. *Investments in the system of factors of social and economic security and reconstruction of the economy of ukraine’s regions*. Visnyk of the Lviv University. Series - Economics. 2023. Issue 64. pp. 33–44.

<sup>32</sup> A.A. Vozniuk, M.A.Hryha. *Expert support for determining the amount of damage and destruction of buildings, structures and other infrastructure objects as a result of the armed aggression of the russian federation*. Scientific Bulletin of Uzhhorod National University. 2020. No. 73 pp. 123-130.

<sup>33</sup> Plan for the Ukraine Facility 2024-2027, p. 380.

According to the Ukraine Facility Regulation (EU) 2024/792, territorial communities are key beneficiaries of the recovery results. They are responsible for developing planning documents, establishing communication with international partners, and implementing recovery projects for their respective territories based on an inclusive approach that involves and consults with local civil society. Loan interest for businesses, including small, medium, and micro-enterprises, will be partially or fully compensated by the Business Development Fund. Fees for financial leasing and factoring agreements with businesses will be partially compensated by the Entrepreneurship Development Fund.

A significant portion of the legal framework for implementing the Ukraine Facility Regulation (EU) 2024/792 of February 29, 2024, has already been established. However, it still requires regulatory changes to the Budget and Tax Codes to improve the mechanism for crediting personal income tax to local budgets in line with European practices and to refine (or review) the mechanism for horizontal equalization of local budgets.

Some work has already been carried out to restore roads and bridges, including the reopening of 78 artificial structures on national roads in 2022 in Kyiv, Chernihiv, and Kharkiv regions; cleaning of 2,200 km of state and municipal roads in Kharkiv, Mykolaiv, and Kyiv regions.

In addition, partner countries have «taken patronage» of some regions of Ukraine in the reconstruction process. Preliminarily, 15 countries have pledged to assist in the future reconstruction, including with partial financial assistance (see Fig. 1).

**Fig. 1.**

International support from partner countries for the future reconstruction of specific regions of Ukraine.



- Italy → Rivne
- Germany → Chernihiv
- Canada → Sumy
- USA and Turkey → Kharkiv
- Czech Republic, Finland, and Sweden → Luhansk
- Belgium → Mykolaiv
- Sweden and Netherlands → Kherson
- Switzerland → Odesa
- Norway → Kropyvnytskyi
- Latvia → Zaporizhzhia
- Poland and Italy → Donetsk

Source:<sup>34</sup>

Unfortunately, despite all international treaties and agreements, active hostilities continue in a large part of Ukraine, with targeted massive shelling by the Russian Federation continuing to damage and destroy all types of infrastructure, and most terribly, the deaths of children and civilians...

<sup>34</sup> Ukraine today. «Post-war reconstruction plan: Switzerland will help rebuild the Odessa region, Belgium – Mykolaiv region, Sweden and the Netherlands – Kherson region».

## SUMMARY

The analysis of destruction caused by the Russian Federation's military aggression indicates catastrophic losses to infrastructure that require a multi-level response. The housing sector, transport infrastructure, and energy have suffered the most significant damage. Recovery will demand considerable investment and efforts aimed at reconstruction and modernization. It must be based on prioritizing, transparency, and the participation of international partners, with the digital transformation of reconstruction processes serving as a key factor for efficiency. The creation of a unified platform to coordinate recovery, taking into account regional needs, is of great importance.

The scale of the destruction requires unprecedented international investment and long-term recovery programmes. Ukraine is actively working to raise funds from partners, international organisations, government subsidies, and business investment to reconstruct infrastructure and restore the economy.

The State Agency for the Reconstruction and Development of Infrastructure of Ukraine is holding meetings with representatives of the World Bank, the European Union, the European Investment Bank, the United Nations Office for Project Services (UNOPS), and other organisations to secure the support of European partners.

Therefore, the directions for rebuilding Ukraine's infrastructure and fostering economic shifts lie in the following areas:

**Infrastructure Modernization.** Involves a shift from simple reconstruction to creating a resilient, energy-efficient, and digital infrastructure. It also includes implementing the „Build Back Better“ principle, which means building with future risks in mind and integrating modern technologies into construction, energy, transport, and digital infrastructure, as well as restoring and developing telecommunications, mobile communication, the Internet of Things, and cybersecurity.

**State and International Partnerships.** Involves creating transparent mechanisms for attracting international aid and forming special funds and platforms to coordinate donor resources.

**Institutional Reform and Regional Decentralization.** Includes establishing new institutions to manage reconstruction, attract investments, and monitor efficiency. It also means granting regions more autonomy in planning, implementing, and overseeing reconstruction, while stimulating local economies by supporting small and medium-sized businesses.

**Development of an Innovative Economy.** Involves using the IT sector, digital services, logistics, and green energy to stimulate the transition to renewable energy sources, eco-friendly transport, and sustainable construction. This will also create new jobs in reconstruction-related fields.

**Social Integration and Support.** Involves restoring social infrastructure while considering the needs of affected groups, providing psychological rehabilitation, and implementing educational and support programs for internally displaced persons.

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