

STAGES OF RECONSTRUCTION AND RENEWAL OF UKRAINE'S INFRASTRUCTURE IN THE WAR AND POST-WAR PERIOD, TAKING INTO ACCOUNT EXPERIENCE AND SECURITY

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Abstract. The article provides statistical data on the damage to critical and road infrastructure as a result of the armed aggression of the Russian Federation against Ukraine. Also, taking into account the constant missile attacks and destruction make it impossible to restore and operate sections and systems of communication routes, which leads to greater wear and tear and the inability to use them as intended. The purpose of this research is the analysis of the system of communication routes and the development of the stages of restoration of their operation with the calculation of the estimated need for financing. The article presents the possibility of harmonizing regulatory, legal and organizational aspects of the transport industry of Ukraine with EU countries to meet the needs of the population in transportation and ensure the development of the country's economy by changing approaches to the formation of transport and logistics solutions and the development of modern transport infrastructure. What the stages of recovery involve: short-term (at the stage of martial law); medium term (restoration and restart of systems); modernization (deepening the integration of the national transport network with the EU transport network).

Keywords: Critical infrastructure, railways, highways, multimodal transportation, communication routes, recovery plan, system of interaction of industries of state importance

JEL Classification: R4, P42.

Introduction

The armed aggression of the Russian Federation fundamentally changed the transport system of Ukraine. So, today, due to hostilities on the territory of Ukraine and the introduced martial law, the airspace of Ukraine is closed for civil aviation flights. The blockade of sea ports on the southern coast of Ukraine also began. Warships of the aggressor country block navigation in the Black and Azov Seas for ships heading to and from Ukrainian seaports. Due to the blockade of the sea ports of Ukraine, shippers and carriers are forced to change the logistics of export transportation, directing cargo to the western border crossings. Transporting goods during the war is a difficult task due to the low capacity of border crossings in western Ukraine. Therefore, the most important challenge at the moment is the creation of conditions for maintaining the transport infrastructure in proper functional condition in the territories controlled by Ukraine, maintaining and increasing the throughput capacity of

checkpoints, reorientation of logistics transportation to fulfil the most important functions of the country (Ivakhnik, 2022; Andronik, 2018).

1. Substantive provisions

In order to restore, rebuild, modernize transport infrastructure objects, and gradually integrate the transport network of Ukraine into the EU transport network, it is necessary to take appropriate measures and adopt a number of normative legal acts. The purpose of this plan is to ensure the harmonization of regulatory and legal acts and organizational activities of the transport industry of Ukraine with EU countries to meet the needs of the population in transportation and ensure the development of the country's economy by changing approaches to the formation of transport and logistics solutions and the development of modern transport infrastructure in accordance with EU standards (Figure 1) (Shevchenko et al., 2020).

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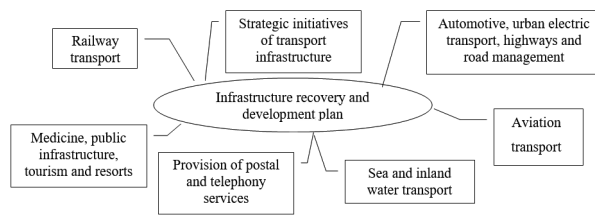


Figure 1. Areas of restoration of the country's infrastructure complex

2. Basic research data and data statistics

The extent of the damage and the long-term effects are difficult to assess, as fighting continues throughout the country. Since the beginning of the Russian Federation's war against Ukraine, there has been considerable damage to the transport infrastructure. So, as of the beginning of December 2022: 8.3 thousand km of the railway network were destroyed or significantly damaged, 67 railway bridges were destroyed, 28 railway stations ceased to function, more than 38 thousand km of highways and 357 highway bridges were destroyed, 4 sea ports were occupied. In connection with the continuation of hostilities in certain territories of our country, it is currently impossible to establish the total final amount of destruction. In general, since the beginning of Russia's military aggression against Ukraine, the total amount of direct documented damage to infrastructure amounted to more than 98 billion dollars (National Bank of Ukraine, 2022).

Joint-stock company "Ukrzaliznytsia" entered the war period as the country's largest employer with a staff of 231,000 employees and a profit of 17 million dollars. For 2021, the company provided 82% of cargo and 50% of passenger transportation (Ministry of Environmental Protection and Natural Resources of Ukraine, 2022). In January-April 2022, 65.9 million tons of cargo were transported, which is only 69% of the level of the same period in 2021. At the same time, in January-April 2022, 7.4 million passengers were transported by rail, which is 1.5 million more passengers than in the same period of 2021. The largest increase (64%) occurred in March 2022 due to evacuation transportation. At the same time, such transportation was carried out free of charge. At the same time, after the reduction and gradual cancellation of evacuation trains, passenger traffic decreased significantly, as a result – in April 2022, passengers were transported 19% less than the level of the same period in 2021. Since the first days of the war, JSC "Ukrzaliznytsia" has transported more than 7,000 tons of humanitarian aid from west to east in passenger cars. The cargo direction is also developing – this is more than 1,400 wagons (approximately 70 thousand tons) per month with humanitarian aid, as well as the container direction, which provides transportation from neighboring countries to Kyiv, Kharkiv, Zaporizhzhia and Odessa. JSC "Ukrzaliznytsia" ensures the evacuation of the population: an average of 3 million passengers are transported per month, as well as 40 thousand passengers – to

neighboring countries. Necessary assistance to passengers is provided at all hub passenger stations, as well as the unloading of humanitarian aid and the provision of food (Ministry of Environmental Protection and Natural Resources of Ukraine, 2022).

3. Key challenges in the field of freight and passenger traffic:

- Permanent purposeful destruction of railway, aviation and aeronautical, maritime and inland water, postal, tourist, road, energy, food, housing and communal infrastructure facilities, the need for their restoration and maintenance in good condition;
- Disruption of transport and logistics chains and forced reorientation of cargo and passenger flows caused by blocking of sea ports, closure of aviation space, destruction of transport infrastructure (need to redirect to western road and railway border crossings);
- The need to provide priority free transportation for the state for military and humanitarian purposes (military transportation, evacuation of the population, relocation of enterprises, transportation of humanitarian aid);
- Unfinished reform of the industry in accordance with European directives (and at the same time lack of capacity to implement a significant part of structural transformations and reforms during wartime);
- Reduction of funding sources and the need to ensure its minimum necessary and regulatory level. Increased risks for investments in connection with military operations, decreased interest of private investors in participation in PPP investment projects in Ukraine due to security and financial risks;
- The shortage and increase in the cost of fuel and lubricants, which leads to an increase in the cost and a decrease in the volume of transportation;
- Critical destruction of tourist infrastructure, historical monuments, museums, theatres, etc. Limited tourist information network;
- Low level of inclusivity (accessibility for people with disabilities and other less mobile population groups);
- Insufficient integration of Ukrainian transport networks into the European transport network TEN-T.

4. Key opportunities and limitations in the implementation of the infrastructure reconstruction plan

Based on the situation in the country. Having determined the urgent needs and possibilities of implementing this issue not only as a separate link of the state, but as a part of the entire complex of state infrastructure, which will work as a single whole, and if necessary, as a separate element of state importance. To do this, we will analyze the received data on destruction and damage and consider the possibilities of options for the restoration of communication routes and adjacent components of

this industry in the future (Державні будівельні норми України, 2019).

Namely (Shevchenko & Shevchenko, 2022; Ugnenko et al., 2019):

- Restoration of highways and man-made structures to accelerate the reconstruction of defense, civil and critical infrastructure, ensuring the connection of settlements with each other for the timely delivery of humanitarian aid and other goods;
- Restoration of air transportation and at least the pre-war level of passenger traffic (16.2 million passengers in 2021) and the transit potential of Ukrainian airspace;
- Increasing the carrying capacity, modernization and development of the ports of the Danube region;
- Increasing and renewing the rolling stock to fully meet the needs for the recovery of Ukraine's economy;
- Construction and reconstruction of western border crossings, development of their carrying capacity and improvement of procedures for control and registration of vehicles (in order to establish the logistics of transportation and border crossing for cargo and passenger transport);
- Taking modern standards into account in the infrastructure restoration process (for example, for passenger infrastructure – taking into account the requirements for access by persons with disabilities);
- Improvement of the traffic flow system (including the development and implementation of a traffic management scheme using automated traffic management systems);
- Further digitization of processes;
- Deepening cooperation and improving coordination with EU countries regarding the organization of transportation and development of the TEN-T network.

But currently there are key limitations in the implementation of this plan (Державні будівельні норми України, 2018b): Russia's ongoing large-scale military aggression against Ukraine, the actual functioning of the industry under martial law for an indefinite period; lack of objective information on the extent of destruction

of transport infrastructure; significant difficulties in carrying out development, modernization, and reconstruction of damaged infrastructure facilities (funding deficit, security risks, the need to demine relevant facilities and determine their actual technical condition); incompatibility of railway infrastructure of Ukraine and EU countries; closure of the airspace of Ukraine in connection with the introduction of martial law; limited number of ports in operation compared to the pre-war situation; lack of sustainable funding for restoration/construction/modernization of transport and logistics (multimodal) terminals in accordance with the requirements of a radical change in cargo flows; the regulatory framework that regulates the activities of the transport industry (and in particular the control procedures when crossing the state border) is different from that of the EU countries; insufficient development of information systems and electronic registers. But there are still many accompanying questions (Державні будівельні норми України, 2022).

The main problems that must be solved within the framework of the Plan for the restoration of roads and adjacent infrastructure (Державні будівельні норми України, n.d.).

As of the beginning of 2022, most of the railway, road, and air infrastructure facilities required repair and modernization. During the restoration of the infrastructure, it is advisable to take into account modern standards (for example, for passenger infrastructure – taking into account the requirements for the access of persons with disabilities); diversification of export transportation logistics by developing the capacity of western border crossings; increasing the coordination of the transportation process with EU countries; improvement of technological processes (Estimated norms of Ukraine, 2021).

As a result of the highlighted information and conducting research, we present the plans for the implementation of projects for the restoration of the country's critical infrastructure with justification and calculation of the estimated amount of implementation (Table 1), this information is calculated in current prices for December 2022 for the implementation period of 5–6 years and inflation of 27% (Estimated norms of Ukraine, 2021).

Table 1. Plans of critical infrastructure restoration projects of Ukraine

Description of the project	Justification	Criteria / performance indicators of the offer (quantitative or qualitative)	Estimated need for financing (million hryvnias, without value added tax)
1	2	3	4
Railway infrastructure			
Restoration of destroyed or damaged railway infrastructure	Due to the military aggression of the Russian Federation, the railway infrastructure is damaged and destroyed every day, which can lead to an unstable process of cargo and passenger transportation. In order to ensure a smooth transportation process, it is necessary to carry out restoration work on the railway infrastructure in a timely manner.	Overhaul of: CSB devices; traction substations; transformer substations; contact networks; engineering structures Overhaul of 293 km of track; 95 sets of turn signals (Shevchenko et al., 2018)	5812

Continued Table 1

1	2	3	4
Modernization of the infrastructure directly adjacent to the western junctions with European countries	The implementation of these projects will allow to expand the capacity, increase the volume of cargo transportation and the number of passengers from the EU. For this, it is necessary to carry out the reconstruction of the 1435 mm Eurotrack, the construction of the 1435 mm track, the reconstruction of the 1520 mm track, the repair of the 750 mm track, the construction and reconstruction of traction substations at the sections: Mostyska II – State Border, Rava Ruska – State Border (Grebenne), Kovel Izov State Border, Hayvoron – Rudnytsia, Berehovo – Vynogradovo, Antohivka – Zarichna	Laying of 88 km of track 1435 mm: Rava-Ruska – State Border, 7 km Mostyska II – State Border, 81 km Reconstruction of 94 km of track 1520 mm in the section Kovel-Izov State Border (construction of 2 traction substations; reconstruction of transformer substations) Repair of track 750 mm. Laying of 125.8 km of 1435 mm track: Kovel – Yagodin – Polish border, 65 km; Chop – Uzhgorod, 22 km, State Border – Starzhava – Khyriv – Nizhankovichi – State Border, 38.8 km; Reconstruction of 192 km of 1520 mm track: Odesa – Izmail, 116 km, (construction of 22 bridges, 102 switches), Izmail – Reni, 55 km, Berezyne – Basarabyaska, 21 km (construction of 14 bridges, 3 railway crossings, modernization of SCB) Laying of 35 km of railway track ArtsyzDzinylor-Kiliya 1520 mm	45 350
Ensuring the continuity of passenger transportation during military operations (Webstore International Electrotechnical Commission, n.d.)	In order to ensure the continuity of passenger transportation, to carry out the effective evacuation of the population from the territory where active military operations are conducted, it is necessary to carry out capital repairs to the existing fleet of passenger cars and purchase new units of passenger cars.	Purchase – 80 wagons; Capital repairs of 15 sections of the MVRS; 370 units of major repairs of wagons; 740 units of depot repairs of wagons	5364
City Express project (Wang, 2018)	Further development of suburban rail connections in the main urban conglomerates (Kyiv, Lviv, Kharkiv, Dnipro-Zaporizhia, Odesa).	Comprehensive reconstruction of key railway stations and adjacent areas with the construction of multimodal passenger hubs that will connect the railway with various types of urban transport with convenient schedules and transfers, as well as provide connections between cities and suburbs with modern suburban trains	58 568
High-speed railway (HSR) construction project connecting Kyiv-Warsaw	The implementation of the mentioned project will reduce the travel time on this route from 17–19 hours to 5–6 hours, due to the achievement of an average speed of 180 km/h.	Reconstruction, modernization with electrification of 585 km of tracks (Kyiv-Yagodin State Border), artificial structures, stations – the Ukrainian part of the project. Overhaul of 23 units of equipment for moving wagons from 1520 mm trolleys to 1435 mm trolleys	39 568
Other expenses	Due to the military aggression of the Russian Federation, locomotive depots were damaged. In order to ensure the fulfilment of locomotive repair schedules, it is necessary to carry out work on the restoration of damaged depots. Due to the increase in export and import with the countries of Europe through the western junctions, there is a need for capital repairs of freight wagons, for the transportation of the required amount and types of cargo	Overhaul of 5,766 wagons. Restoration of 3 locomotive depots. Modernization of 28 locomotives; Overhaul of 160 locomotives. Compensation % of the rate under rolling stock leasing contracts (up to 100 wagons per company) – for a volume of up to 3,000 wagons per year.	7354

Continued Table 1

1	2	3	4
Automotive, urban electric transport, highways and road management			
Ensuring uninterrupted functioning of the road network in 2023	Conducting a survey and determining the minimum necessary amount of work on new construction, reconstruction, current repair and current average repair and maintenance on highways (including areas that have been destroyed as a result of hostilities) in order to ensure the uninterrupted functioning of the road network in 2022, including preparation for winter maintenance of the road network Determination of the required amount of work on new construction, reconstruction, current repair and current average repair and maintenance on road roads (including areas that were destroyed as a result of hostilities)	Execution of works on new construction, reconstruction and current repair and current average repair of public highways for 2 thousand km and 50 bridges (Shevchenko et al., 2022)	78 543
Analysis and development of building regulations and normative documents	Analysis and development of building codes and regulatory documents for compliance with internationally recognized principles of regulation in the construction of public highways, as well as modern technologies and requirements for materials during construction and operational maintenance, and based on the results, to provide proposals to the lists for their revision or development of new ones	Construction standards correspond to internationally recognized principles of standardization in the construction of public highways (Міністерство інфраструктури України, 2012)	0.58
Implementation of the system of collecting fees for the use of public roads by motor vehicles with a gross weight of 12 tons and more	Implementation of Directive 1999/62/EC dated 17.06.1999 on charges from vehicles for the transportation of heavy goods for the use of certain infrastructures (Державні будівельні норми України, 2015).	System on roads of state importance (Ugnenko et al., 2020)	1.356
Carrying out restoration work on highways (including areas destroyed as a result of hostilities) for the implementation of the medium-term work plan for 2023–2032	Determining the required amount of work on new construction, reconstruction, current repair and current average repair and maintenance on highways (including in areas that were destroyed as a result of hostilities)	Execution of works on new construction, reconstruction and current repair and current average repair of public highways for 22.9 thousand km and 1.7 thousand bridges (Shevchenko & Shevchenko, 2022)	3 154 000
Direction of strategic initiatives of transport infrastructure			
Modernization of existing and opening of automobile checkpoints (Bugaec et al., 2019)	Ensuring the continuity of cargo traffic by road transport across the state border is key to ensuring the functioning of the economy, ensuring the transportation of export cargo, as well as the import of humanitarian and defense cargo. Construction of terminals (waiting areas) for the storage of cargo vehicles). Ensuring the construction and arrangement of multimodal terminals at the borders with EU countries with the possibility of overloading automobile transport units, in particular on railway platforms for transportation on tracks with a width of 1520 mm and 1435 mm	Modernization of checkpoints: Jagodin, Ustilug, Luzhanka, Uzhhorod, Chop, Plug, Calling, Dyakove, Cosino, Chopped, Dyakivtsi, Krasnoilsk Construction/opening of new checkpoints: - Bila Cherkva; - Deyda; - Russian (Shevchenko et al., 2022)	4531.66

End of Table 1

1	2	3	4
Extension until 2025 of the State Targeted Economic Program for the Development of Public Highways of State Importance for 2018–2023, approved by Resolution No. 382 of the Cabinet of Ministers of Ukraine of March 21, 2018	Only in recent years has a planned and systematic restoration of the state of public highways begun, but given the catastrophic state of the network, which was before the start of large-scale works, a large number of highways are in an unsatisfactory condition. During 2019–2021, about 10,000 km of public highways of state importance were repaired. According to the road development plans, in the period 2022–2024, it was planned to repair about 20 thousand km of state highways, for which preparatory work was carried out at an active pace	Organizational and financial conditions have been created for carrying out repair and construction works of public highways of state importance (Державні будівельні норми України, 2014)	4 568 256
Development of sections of railway, road and inland waterways included in indicative maps of the TEN-T network	Integration into the Trans-European transport network TEN-T	Increasing competitiveness and transport corridors, improving the quality of infrastructure, increasing the volume of transportation (Державні будівельні норми України, 2018a)	256 845

At all stages of the implementation of projects for the restoration of infrastructure facilities, the principles of integrity, transparency and accountability must be observed and other necessary measures aimed at minimizing corruption risks must be taken. In addition, it is mandatory to observe environmental and sanitary safety during demolition of rubble and reconstruction of buildings and engineering structures. The main priority tasks for ensuring the effective operation of transport in wartime are related to overcoming the challenges of changing logistics routes due to the aggressor blocking the seaports of Ukraine, and the need to increase the capacity of the western border crossings, primarily related to the need to change the track width. It should also be noted that this work should be coordinated with Western partners, in particular, with Poland, Hungary, Romania, and Slovakia regarding the modernization and increase of the capacity of the railway tracks of the respective countries to ensure the possibility of accepting all cargoes offered by Ukraine. To this end, on 2022, May 12, the Verkhovna Rada of Ukraine adopted the Law of Ukraine “On Amendments to Certain Legislative Acts of Ukraine Regarding the Peculiarities of Regulating Land Relations in Martial Law”, which provides, in particular, for simplifying the allocation of land plots for the construction of multimodal terminals and industrial transshipment complexes under martial law. This will create favourable conditions for the development of transport and logistics infrastructure on the western borders of Ukraine (Національний стандарт України, 2019).

Increasing the logistics potential and developing a step-by-step plan for the full transition to paperless technologies for supporting rail freight transportation, including customs and border control procedures, including with EU countries; analysis of the potential for increasing the interoperability of transportation, using the infrastructure capabilities of European-style 1435 mm tracks located on the territory of Ukraine and 1520 mm tracks located on the territory of neighbouring EU countries; analysis of the possibility of construction and use of innovative wagons and specialized containers on the railways of Ukraine. Acquiring the status of a candidate for membership in the EU to carry out a review of the plan of measures for reforming railway transport, approved by the order of the CMU dated 30.12.2019 No. 1411, taking into account the new realities of the war and post-war times. At the same time, it is expedient to “reasonably” postpone the introduction of new principles of railway transport market functioning (at least 2 years after the end of martial law), since the implementation of any structural transformations and basic reforms of the railway transport market in wartime is impractical. Taking into account the systematic and purposeful destruction of the transport infrastructure by the aggressor, the main task of the post-war period will be:

- restoration of critical infrastructure;
- adjustment and restoration of the full operation of the transport system.

Restoration of the destroyed transport infrastructure should take into account possible changes in the location

of large industrial enterprises, and, accordingly, the places where freight flows originate. It can be assumed that the location of mining and agriculture enterprises will not be changed, but the question remains open regarding the enterprises that were destroyed, as well as enterprises that used the relocation mechanism and accordingly moved their production facilities to the western regions of Ukraine. In addition, the scale of infrastructure restoration will depend on the amount of destruction, which is increasing every day. It is already possible to speak with confidence, for example, about the urgent need to rebuild the destroyed traction substations in order to restore the electrification of railway tracks (Національний стандарт України, 2022).

Among the infrastructure projects for the medium-term period, it should be noted: reconstruction of the destroyed infrastructure (with electrification) in the direction of sea ports using the latest technologies, increasing the capacity of the railway with EU countries through the development and modernization of complexes for rearranging wagons from a 1520 mm to 1435 mm track and transshipment capacities (logistics centers) within or outside the border crossing points at the border crossings with the EU, taking into account the requirements of interoperability and efficient use of the railway infrastructure of the 1435 mm and 1520 mm systems, the development of railway infrastructure in the direction of the ports of Reni and Izmail (in particular, the construction of the second tracks, electrification (development in the direction of the EU Rhine-Danube railway corridor), modernization of existing and construction of new logistics multimodal terminals in the western and southern regions of Ukraine with the functions of integrated transport and logistics centers, implementation of customs services negotiation and application of modern digital logistics management solutions (TMS, YMS, WMS), creation of modern standardized multimodal station centers on the basis of railway stations in small cities of Ukraine (first of all, in those that suffered during the war) that will provide city residents with a comfortable and a convenient transfer to other modes of transport, recreational and shopping areas and an integrated public safety system (a network of bomb shelters). Comprehensive reconstruction of key railway stations and adjacent areas with the construction of multimodal passenger hubs in the main urban conglomerates (Kyiv, Lviv, Kharkiv, Dnipro-Zaporizhia, Odesa), which will connect the railway with various types of urban transport with convenient schedules and transfers, as well as ensure the connection of cities with the suburbs by modern suburban trains (City Express projects); provision of high-speed and comfortable connections by modern Intercity trains for residents of the main regional centers, which involves the purchase of new trains, modernization of the railway infrastructure to increase the speed to 160 km/h (200 km/h in the future), electrification of sections; implementation of the plan for full transition

to paperless support for railway freight transportation; creation of a joint logistics enterprise with Poland and, in the future, with Lithuania, Latvia and Estonia, to increase the volume of railway transportation of Ukrainian exports to the EU and to world markets through Europe. The establishment and restoration of passenger rail service should take place immediately after the restoration of control over the territories. The restoration of freight railway traffic to the level of 2019 (before the war and before the coronavirus disease pandemic) will depend primarily on the scale and pace of recovery of Ukraine's industry. At the same time, large-scale works related to the reconstruction of Ukrainian cities will require coordinated work of all types of transport, including railway transport, in order to deliver construction materials.

Conclusions

The restoration of the state after the war can take place in several stages:

Immediate Relief Phase: In this phase, it is important to provide immediate relief to the people affected by the war. This can mean providing humanitarian aid (food, water, medical supplies), ensuring safety and security, and evacuating people from danger zones. This process began at the beginning of the full-scale invasion and continues now not only on the territory of Ukraine, but also in other states that have sheltered refugees and provide macro-aid.

Infrastructure Recovery Phase: After immediate relief has been provided, it is time to rebuild the infrastructure. This can mean the rehabilitation of roads, bridges, buildings, electrical networks, water pipes and other necessary infrastructure systems. As a result of an in-depth study covering all important systems of human and social life. This is ensured by plans for the restoration of the most important areas and artificial structures in a short period of time. Restoration of electrical networks and support of consumers and other systems are presented in Table 1 of this study.

Stage of economic recovery: After infrastructure recovery, it is necessary to start the recovery of the country's economy. This may include reviving businesses, attracting investment, providing jobs, supporting small businesses, and more.

Stage of social rehabilitation: At the last stage, it is necessary to ensure social rehabilitation of people who suffered as a result of the war. This may include supporting veterans, reparations, providing psychological and medical care, and restoring education and cultural life.

Each war and each country have its own unique challenges that need to be addressed during the recovery process. However, the overall approach includes immediate relief, infrastructure restoration, economic recovery, political stabilization and social rehabilitation. The authors of this work and the workers who helped in the calculations have faith and hope for a faster end to the

war and the reconstruction of the country according to modern standards for life, values and health of mankind.

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