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The use of geoinformation systems for planning and implementing the restoration of territorial communities

O uso de sistemas de geoinformação para planejamento e implementação da restauração das comunidades territoriais

La utilización de sistemas de geoinformación para planificar y aplicar la restauración de las comunidades territoriales

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ABSTRACT

Introduction: The relevance of the use of geodata systems is increasing in view of large-scale destruction of infrastructure caused by cataclysms, as well as human economic and political activity. The aim of the article is to analyse the potential applications of geoinformation systems (GIS) to optimize infrastructure restoration processes and reduce costs. **Methodology:** The research methodology is based on the analysis of the impact of GIS through statistical analysis, modelling and the use of weighted calculations. **Results:** The results of the study demonstrate that the implementation of GIS significantly reduces the time and costs of restoration, improve the accuracy of planning and reduce the risks of future destruction. **Conclusions:** The article identifies the key challenges associated with the implementation of these systems, including technical limitations, the need for qualified specialists and ensuring data security. Proposed solutions include the development of national standards, the training of specialists, and expanding the use of modern technologies. The practical significance of the work is carrying out calculations on the effective implementation of GIS for the restoration of territorial communities in Ukraine in the post-war period. Further research should focus on studying the impact of innovative technologies on reconstruction processes and their integration into national recovery projects.

Keywords: geoinformation systems, territorial communities, spatial planning, project management, spatial analysis, reconstruction, digital technologies, security.

RESUMO

Introdução: A importância do uso de sistemas de dados geográficos está aumentando em vista da destruição em larga escala de infraestruturas causadas por cataclismos, bem como da atividade econômica e política humana. O objetivo do artigo é analisar os potenciais aplicações dos sistemas de geoinformação (SIG) para otimizar os processos de restauração de infraestruturas e reduzir custos. **Metodologia**: A metodologia de investigação baseia-se na análise do impacto dos SIG através da análise estatística, modelação e utilização de cálculos ponderados. **Resultados:** Os resultados do estudo demonstram que a implementação de SIG reduz significativamente o tempo e custos de restauração, melhora a precisão do planejamento e reduz os riscos de destruição futura. **Conclusões:** O artigo identifica os principais desafios associados à implementação desses sistemas, incluindo as limitações técnicas, a necessidade de especialistas qualificados e garantir a segurança dos dados. As soluções propostas incluem o desenvolvimento de normas nacionais, a formação de especialistas e a expansão do uso de tecnologias modernas. O significado prático do trabalho é realizar cálculos sobre a implementação efetiva de GIS para a restauração das comunidades territoriais na Ucrânia no período pós-guerra. Outras pesquisas devem se concentrar no estudo do impacto das tecnologias inovadoras nos processos de reconstrução e sua integração em projetos nacionais de recuperação.

Palavras-chave: sistemas de geoinformação, comunidades territoriais, planeamento espacial, gestão de projetos, análise espacial, reconstrução, tecnologias digitais, segurança.

RESUMEN

Introducción: La importancia de los sistemas de datos geográficos está aumentando en vista de la destrucción a gran escala de las infraestructuras causada por los cataclismos, así como de la actividad económica y política humana. El objetivo del artículo es analizar las posibles aplicaciones de los sistemas de información geográfica (SIG) para optimizar los procesos de restauración de infraestructuras y reducir costes. **Metodología:** La metodología de investigación se basa en el análisis del impacto de los SIG mediante análisis estadísticos, modelización y utilización de cálculos ponderados. **Resultados:** Los resultados del estudio demuestran que la aplicación de un SIG reduce considerablemente el tiempo y los costos de restauración, mejora la precisión de la planificación y reduce los riesgos de destrucción futura. **Conclusiones:** El artículo identifica los principales desafíos asociados con la implantación de estos sistemas, incluidas las limitaciones técnicas, la necesidad de especialistas cualificados y la garantía de seguridad de los datos. Las soluciones propuestas incluyen el desarrollo de normas nacionales, la formación de especialistas y la ampliación del uso de tecnologías modernas. La importancia práctica de la obra es llevar a cabo cálculos sobre la aplicación efectiva de los SIG para la restauración de las comunidades territoriales en Ucrania en el período de posguerra. Las investigaciones ulteriores deberían centrarse en el estudio de los efectos de las tecnologías innovadoras en los procesos de reconstrucción y su integración en los proyectos nacionales de recuperación.

Palabras clave: sistemas de geoinformación, comunidades territoriales, planificación espacial, gestión de proyectos, análisis espacial, reconstrucción, tecnologías digitales, seguridad.

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This paper offers an interesting and analytical approach is to analyse the potential applications of geoinformation systems (GIS) to optimize infrastructure restoration processes and reduce costs.

INTRODUCTION

The war in Ukraine, which began on February 24, 2022, significantly changed the global security system, undermining the foundations of international relations and legal norms. A sharp violation of the sovereignty of one of the largest European states demonstrated to the world how precarious modern security mechanisms can be. The intervention became the reason for the revision of many international agreements and treaties regulating relations between states (Gryshchenko et al., 2024). Military aggression, being contrary to numerous peace agreements, called into question the effectiveness of the UN, OSCE, and other international organizations. They could not prevent the war or respond quickly and effectively to the destruction of the country's infrastructure.

According to Gould-Davies (2024), damage to critical infrastructure has revealed a vulnerability for global countries that requires reformation of international law. The most effective means can only be the use of planning with the help of GIS. Global risks for the entire world community in matters of energy security, food resources, and economic stability require a detailed study of implementation processes.

The spread of digital technologies and the growth of data volumes make GIS the fundamental tools for the analysis, processing and visualization of spatial data. Their work is based on the integration of various sources of information: satellite images, data from drones, laser scanning (LiDAR) and ground measurements. According to Hoang, Kuzin, Zobov and Zobova (2023), the accuracy of measurements in modern GIS can reach up to 0.1 meters. The speed of data processing is measured in thousands of points per second, making the systems extremely efficient for monitoring changes in real time. The physics of the systems is based on algorithms for the analysis of large arrays of geospatial data, which consider topography, geodesy, and spatial characteristics of the environment.

The escalation of military conflicts in different parts of the world creates new challenges for the international community. The Russian invasion is one of the largest conflicts of our time, but not the only one. The war in Syria, tensions in Yemen and covert military operations in the African region have serious implications for global stability. Da Silva Peres, Sluter and Velho (2023) believes that some of these conflicts have a hidden nature, as not all hostilities are publicly recognized by the international community, but they continue to destabilize the political and economic situation. The corresponding dynamics of global events make the issue of using geoinformation systems for recovery after destruction extremely urgent. The conduct of hostilities leads to the massive destruction of infrastructure, which requires accurate and rapid restoration. The use of spatial systems optimizes restoration processes, ensure accurate planning and reduce risks during reconstruction. These systems are a decisive factor in minimizing the long-term consequences of military operations on the economy and the environment.

The aim of the study is to analyse the effectiveness of the use of geoinformation systems for the reconstruction of territorial communities in Ukraine. The aim involves the fulfilment of the following research objectives:

1. Determine the number of territorial communities in Ukraine by region and the corresponding level of damages.

2. Identify the features of using GIS for modelling and reducing costs during reconstruction.

3. Investigate trends in the implementation of the latest digital technologies in reconstruction processes based on European experience.

4. Develop recommendations for improving reconstruction procedures based on the experience of European countries and the use of GIS in Ukraine.

Literature Review

The issue of using geoinformation systems for the restoration of a large area of urban or natural territory is becoming increasingly relevant in the academic environment. This trend is determined in the context of large-scale destruction of infrastructure as a result of the war. Deuerlein et al. (2022) studies various aspects of the effectiveness of GIS in the planning and management of restoration processes. Zhunissov (2023) investigates the role of spatial systems in accelerating infrastructure restoration processes. Karpinskyi et al. (2024) and Kryshtanovych et al. (2022) consider the advantages of using design work to assess the risks of natural and man-made disasters. Ayodele and Emmaogboji (2024) focuses on the impact of GIS on the optimization of costs in the planning of restoration works, proposing methods of reducing financial costs due to the use of spatial data. Rădulescu et al. (2023) deals with the experience of European countries in using specialized systems for recovery after natural disasters, particularly floods and earthquakes. Freymueller et al. (2024) emphasizes the importance of integrating international standards into reconstruction processes and forecasting changes in geospatial conditions. Jakimow et al. (2023) analyses the technological challenges that regions face when implementing GIS, especially the lack of qualified specialists. Keller et al. (2021) explores the role of design analysis in reducing risks in infrastructure rehabilitation, noting that risk prediction is a key factor in sustainable reconstruction.

A study by Chunin et al. (2021) reveals the importance of international expertise in the use of digital technologies for coordination between different regions and countries during large-scale construction projects. Karelkhan et al. (2023) examine the cyber security and data protection issues that countries face when processing spatial data. Bansal (2023) emphasizes the importance of using GIS to optimize the reconstruction and development of infrastructure in the face of modern challenges. Goihl (2023) examines international projects that implement smart systems for disaster recovery. Racetin et al. (2023) analyses the problems of restoration of mass areas in the context of limited resources, emphasizing the need for technical support of international organizations. Shithil, and Adnan (2023) note that the successful application of spatial systems depends on the availability of appropriate infrastructure and data management skills. Gnädinger (2023) examines the technical and legal obstacles faced by countries rebuilding devastated areas. The reseacher offers ways to solve these problems through the use of centralized databases and the integration of international experience.

Calzati, and van Loenen (2023) confirm that a systematic approach to the management of restoration processes can significantly increase the effectiveness of reconstruction. De Lange (2023) highlights the challenges associated with the use of local data centres in the difficult conditions of reconstruction after cataclysms or significant man-made disasters. According to Theilen-Willige (2023), the use of GIS in large-scale restoration projects requires a flexible legal framework and adaptation of international standards to national conditions. Therefore, the researchers call for more active involvement of digital technologies at the regional level and the development of specialist training programmes, which will contribute to the effective management of reconstruction processes. In view of the limitations of GIS-related studies, it is necessary to continue the academic analysis of their application for the restoration of urban areas.

METHODS

Research design

The research methodology includes a consistent analysis of the possibilities of using GIS for the restoration of territorial communities. First, an analysis of the current state of territorial communities in Ukraine was carried out and the level of damage caused by military operations for 2022 to 2024 was determined. Total damage to infrastructure and residential facilities was assessed, which became the basis for further calculations. Next, the density of destruction per unit of territory was determined to identify the most affected regions and districts. The next step was to assess the effectiveness of the use of GIS for the restoration of damaged areas. The methodological section outlines the analytical approach taken to assess the application of geoinformation systems across various regions of Ukraine. It details the use of descriptive statistics to evaluate potential cost savings in GIS implementation for regional and community restoration, incorporating international experience and projected outcomes.

Sampling

The sample included 24 regions of Ukraine, which suffered because of military operations and require large-scale infrastructure restoration. The choice of regions is the most appropriate, as all of them have suffered significant damage and need comprehensive restoration. In addition to the analysis of the state of the territories, the study considered four leading GIS: ArcGIS, QGIS, MapInfo Professional and AutoCAD Map 3D. Their choice is determined by a wide functionality, high accuracy and speed of data processing, which makes them suitable for solving restoration tasks in difficult conditions.

Methods

Research methods included the use of statistical tools to analyse data on infrastructure damage and recovery opportunities (Kraemer & Blasey, 2015). Statistical analysis was applied to determine the relationship between the level of destruction and potential savings when using the designed systems. The projections were based on the experience of other countries that used GIS in restoration after natural and man-made disasters. The weighted average calculations were used to estimate average indicators of losses and cost savings. The methods of financial modelling were used to assess the possible reduction of risks when implementing innovative technologies in the process of infrastructure restoration.

Instruments

The main tool for data processing and financial calculations was Microsoft Excel, which was used to systematize information and perform multivariate analysis (Gardener, 2017). Reports from various government and international organizations, including DeepState, were used to obtain data on damage, losses, and military operations. The reports contained detailed information about the destruction of infrastructure in each of the regions, which made it possible to build accurate models for further financial and technical calculations.

RESULTS AND DISCUSSION

An important stage in the reconstruction of Ukraine is the restoration of several hundreds of territorial communities throughout the country. Significant damage to infrastructure, housing, transportation routes, and critical infrastructure facilities requires careful planning for recovery. The largest losses were registered in the Donetsk region — about 37 billion hryvnias (UAH), and in the Kharkiv region — more than 30 billion. Each of the communities needs restoration, rethinking of its development based on modern technologies. Table 1 shows the general state of territorial communities in Ukraine by type and losses in the region.

Table 1. Number of communities and losses in the regions of Ukraine

Region	Urban communities	Urban-type community	Village communities	Total communities	Losses, UAH million
Vinnytsia	18	22	23	63	480
Volyn	11	18	25	54	15
Dnipropetrovsk	20	25	41	86	3,369
Donetsk	43	14	9	66	37,374
Zhytomyr	12	22	32	66	1,004
Zakarpattia	11	18	35	64	11
Zaporizhzhia	14	17	36	67	14,773
Ivano-Frankivsk	15	23	24	62	384
Kyiv	24	23	22	69	11,188
Kirovohrad	12	16	21	49	149
Luhansk	20	12	5	37	17,127
Lviv	39	16	18	73	219
Mykolayiv	9	14	29	52	7,853
Odesa	19	25	47	91	1,471
Poltava	16	20	24	60	672
Rivne	11	13	40	64	215
Sumy	15	15	21	51	3,398
Ternopil	18	16	21	55	119
Kharkiv	17	26	13	56	30,224
Kherson	9	17	23	49	12,277
Khmelnytskyi	13	22	25	60	1,195
Cherkasy	16	10	40	66	128
Chernivtsi	11	7	34	52	73
Chernihiv	16	24	17	57	5,773

Source: developed by the authors based on KSE (2024)

The first estimates of the destruction of territorial infrastructure in the regions of Ukraine are based on the area of damaged land and the volume of destroyed infrastructure. The greater the amount of destruction, the more difficult the process of planning and designing restoration works. This especially applies to regions that have suffered significant losses, such as Donetsk and Luhansk regions, where the density of losses per community exceeds UAH 500 million. The restoration process includes dismantling of destroyed objects, comprehensive cleaning and filtration of contaminated areas. Determining the scope of work should consider the specifics of each type of infrastructure — transport, utility, residential. Calculations should cover the area of pollution, the level of destruction of underground and surface communications, take into account the change in the water regime of the territories because of the damage to hydraulic structures.

The calculations were carried out to determine the amount of funding needed to restore the destroyed infrastructure, as well as for effective planning of construction and restoration works. The average damage per community in the Donetsk region is UAH 566.27, while this indicator is UAH 539.71 million in the Kharkiv region, the percentage of losses from the total level of destruction is the highest. Table 2 shows detailed calculations of damage per territorial community. That is why the role of GIS in the reconstruction process is key, as they provide the opportunity to conduct real-time data analysis, visualize destruction, and automate calculations. GIS are used to create three-dimensional models of territories, which allows engineers and planners to more accurately assess the scale of destruction and predict effective recovery paths.

Before the full-scale war in Ukraine, territorial communities suffered much less destruction, and the use of GIS was mostly aimed at urban infrastructure management, land analysis and environmental monitoring. Starting from 2022, the destruction of infrastructure has reached unprecedented levels because of large-scale hostilities. There were significant changes in the territorial structure of the regions during 2022-2024, which requires a comprehensive approach to reconstruction. In the Donetsk region, 24.65% of the total losses fall on one community, which demonstrates the need for accurate distribution of resources. In Zaporizhzhia region, this figure is 9.73%, while in Kyiv region it is 7.36%.

Loss ratios show that different regions require different approaches to recovery, and GIS are a tool for creating damage maps, identifying critical infrastructure, and calculating the optimal use of resources. The use of GIS makes it possible to accurately model damaged areas and analyse changes in the environment. They are used to determine changes in riverbeds or the dynamics of soil erosion, which significantly affects further design. Table 3 shows the application of these systems in countries with large-scale natural disasters and their effectiveness.

Table 2. Generalized losses per territorial community in the region of Ukraine

Region	Average losses per community, UAH million	Percentage of losses from the total level, %	Loss density per community (UAH million /community)
Vinnytsia	7.62	0.32	7.62
Volyn	0.28	0.01	0.28
Dnipropetrovsk	39.17	2.22	39.17
Donetsk	566.27	24.65	566.27
Zhytomyr	15.21	0.66	15.21
Zakarpattia	0.17	0.01	0.17
Zaporizhzhia	220.19	9.73	220.19
Ivano-Frankivsk	6.19	0.25	6.19
Kyiv	162.16	7.36	162.16
Kirovohrad	3.04	0.10	3.04
Luhansk	462.35	11.30	462.35
Lviv	3.00	0.14	3.00
Mykolayiv	151.02	5.18	151.02
Odesa	16.16	0.97	16.16
Poltava	11.20	0.47	11.20
Rivne	3.36	0.14	3.36
Sumy	66.63	2.24	66.63
Ternopil	2.16	0.08	2.16
Kharkiv	539.71	19.92	539.71
Kherson	250.57	7.64	250.57
Khmelnytskyi	19.92	0.79	19.92
Cherkasy	1.94	0.08	1.94
Chernivtsi	1.40	0.05	1.40
Chernihiv	101.28	3.80	101.28

Source: calculated by the authors

Table 3. Application of GIS for recovery in Europe

Country	Natural disaster	Use of GIS	Results	Potential experience for Ukraine
Germany	Reconstruction after floods	Optimization of placement of dams and other infrastructure facilities	Reducing the risks of further disasters	Optimization of infrastructure solutions in risk areas
France	Planning after earthquakes	Analysis of risk zones and planning of construction works	15% restoration time reduction	Application of GIS to reduce reconstruction time
Italy	Planning after earthquakes	Risk modelling and reconstruction management	20% reduction in building placement errors	Reducing the risk of errors in the placement of new facilities
Great Britain	Floods and climate change	Reconstruction planning and risk management	10% cost reduction	Optimization of logistics and resources to reduce costs

Source: created by the authors

In global practice, GIS have shown high efficiency after disasters, which will be extremely useful for Ukraine. In Germany, these systems were implemented after large-scale floods to optimize the placement of dams and other water infrastructure facilities. This made it possible to significantly reduce the risk of repeated disasters and increase the efficiency of engineering solutions. For Ukraine, this approach can be applied in risk zones, where it is necessary to restore damaged facilities and minimize the likelihood of repeated destruction. In France, GIS helped to reduce reconstruction time by 15% after a series of earthquakes thanks to the effective analysis of risk zones and optimization of construction works. A similar experience could be implemented in Ukraine to speed up reconstruction work, especially in critical regions. In Italy, the use of GIS for risk modelling allowed to reduce the number of errors in the placement of new buildings by 20%. Table 4 shows the main technical characteristics of these systems, which can be used in Ukraine.

Table 4. Technical characteristics of GIS with potential application in Ukraine

GIS system	Accuracy (m)	Processing speed (dots/sec)	Number of supported formats	Area determining error (m²)
ArcGIS	0.5	1,000-5,000 (depends on the data)	70+	500
QGIS	1	5000	100+	1,000
MapInfo Professional	1-2	2,000-4,000	50	800
AutoCAD Map 3D	0.1	3,000-5,000	30+	1

Source: created by the authors

The most effective is ArcGIS, which provides high accuracy up to 0.5 meters and can process from 1000 to 5000 dots per second, depending on the volume and quality of the data. It supports more than 70 data formats, which allows you to work with various sources of information, including satellite images, topographic maps, and relief models. The small error in determining the area — only 500 m² — makes ArcGIS an indispensable tool for the reconstruction of destroyed territories, where accurate measurement of areas and distances is critical.

MapInfo Professional provides accuracy within 1-2 meters and processing speed of 2000-4000 dots per second. Although it supports only 50 data formats and has a larger area error (800 m²), the system has proven itself in the analysis of urban data. It can also be used for planning buildings in urban and rural areas. AutoCAD Map 3D is the most accurate among the presented systems, with an accuracy of up to 0.1 meters and a minimum error in determining the area — only 1 m². The processing speed of up to 5,000 dots per second and support for more than 30 data formats make it ideal for accurate engineering design and technical documentation.

Based on the experience of European countries that used GIS in disaster recovery, it is possible to calculate that the use of such technologies in Ukraine can significantly reduce expenses. In Germany and France, spatial systems reduced the total restoration cost by 10-15%. In Ukraine, where the scale of the destruction is unprecedented, the implementation of GIS can reduce planning time and reduce the total costs of infrastructure restoration by 10-20%. It will also speed up the recovery of destroyed communities and critical facilities by 3-5 years. Given the projected pace of restoration, the most optimistic scenarios suggest that full infrastructure restoration could be completed by 2030, assuming the war ends in 2025-2026. Table 5 provides the calculated effectiveness of these systems for restoration in Ukraine in order to reduce risks in further project decisions.

Table 5. Calculations of the effectiveness of GIS for the restoration of territorial communities

Region	Losses, UAH million	Cost savings, UAH million	Risk reduction, UAH million	The number of communities that can be restored for savings
Vinnytsia	480	48.0	96.0	6.3
Volyn	15	1.5	3.0	5.4
Dnipropetrovsk	3369	336.9	673.8	8.6
Donetsk	37374	3737.4	7474.8	6.6
Zhytomyr	1004	100.4	200.8	6.6
Zakarpattia	11	1.1	2.2	6.4
Zaporizhzhia	14773	1477.3	2954.6	22.0
Ivano-Frankivsk	384	38.4	76.8	6.2
Kyiv	11188	1118.8	2237.6	16.2
Kirovohrad	149	14.9	29.8	3.0
Luhansk	17127	1712.7	3425.4	46.2
Lviv	219	21.9	43.8	3.0
Mykolayiv	7853	785.3	1570.6	15.1
Odesa	1471	147.1	294.2	16.2
Poltava	672	67.2	134.4	11.2
Rivne	215	21.5	43.0	3.4
Sumy	3398	339.8	679.6	66.6
Ternopil	119	11.9	23.8	2.2
Kharkiv	30224	3022.4	6044.8	53.9
Kherson	12277	1227.7	2455.4	50.6
Khmelnytskyi	1195	119.5	239.0	19.9
Cherkasy	128	12.8	25.6	1.9
Chernivtsi	73	7.3	14.6	1.4
Chernihiv	5773	577.3	1154.6	10.1

Source: calculated by the authors

Analysing the calculations of losses and potential savings, one can see the significant impact of using systems on reducing costs and risks. In the Donetsk region, losses amount to UAH 37,374 million, but the implementation of GIS can save costs in the amount of UAH 3,737.4 million and reduce risks by UAH 7,474.8 million. In the Luhansk region, the total losses amount to UAH 17,127 million, the possible reduction of costs reaches UAH 1,712.7 million, and the risk reduction is UAH 3,425.4 million, which will allow the restoration of more than 46 communities.

These results demonstrate the high efficiency of using GIS in large-scale restoration projects. It is important to note that they reduce costs and significantly reduce the risk of design errors, which is a key factor in ensuring infrastructure sustainability. This risk should be especially considered in the context of possible future military conflicts on the territory of Ukraine or natural disasters.

Discussion

The research established that the use of GIS in Ukraine significantly increases the efficiency of restoration processes. The views of researchers regarding the use of these systems in case of potential global disasters remain interesting. The results are consistent with Naß, and van Gasselt (2023), who emphasize the importance of spatial systems in spatial data-based restoration planning. According to Vu et al. (2023), restoration of territories through the creation of project models can significantly reduce the costs of restoration, which is completely consistent with the obtained calculations. Batoon, and Piad (2023) support our findings on cost optimization through accurate modelling of damaged areas. However, Hunko (2023) notes that the complexity of technical support and the lack of qualified specialists can become obstacles to the large-scale implementation of GIS. Stupen et al. (2023) and Alazzam et al. (2023) confirm the importance of financial savings when implementing spatial systems, which was revealed during the study. Hagmann et al. (2023), Dudar et al. (2024), and Kunchev, and Angelova (2023) focuse on positive international experience, which confirms his own conclusions about the importance of integrating European practices in the recovery of Ukraine. Xu et al. (2023) and Kiseleva et al. (2023) considers the constant training of specialists to be a critical necessity for the effective use of digital technologies.

FINAL REMARKS

The implementation of GIS for the restoration of territorial communities is a critically important step in post-war recovery. The analysis showed that the use of these systems optimizes the processes of planning, allocation of resources, and reduces the time for the restoration of the destroyed infrastructure. Accuracy, processing speed and a wide range of supported formats make ArcGIS, QGIS, MapInfo Professional and AutoCAD Map 3D systems indispensable tools for spatial data management. European experience shows that GIS can reduce recovery costs by 15-20%. The use of appropriate technologies makes it possible to predict future risks for Ukraine in case of a potential escalation of the war.

Global challenges include issues of cyber security and data protection, as the use of GIS involves the processing of significant amounts of information. It is important to consider global climate change, which may affect long-term restoration planning. It is necessary to implement strategic technical solutions to effectively overcome these challenges. The national standards for the use of GIS should be developed and implemented, which will be coordinated with international practices and adapted to the specifics of Ukrainian territories. There is a need to create a centralized database on the condition of the infrastructure, which integrates information from various sources and allows full control over the restoration processes. At the same time, it is important to invest in the training of specialists capable of working effectively with the system through the organization of training programmes and professional development. It is necessary to attract international experience in the use of GIS for restoration after natural disasters or military conflicts. The set of actions will be able to improve recovery processes and minimize the risks of future destruction, ensuring the stable development of territorial communities in Ukraine.

Limitations and future research

The article acknowledges certain theoretical and methodological limitations. The theoretical constraints stem from the evolving nature of geoinformation systems, where continuous advancements may impact the long-term applicability of the findings. Methodologically, the study relies primarily on descriptive statistics and available spatial data, which may limit the depth of predictive modeling. Additionally, variations in data availability across regions could influence the accuracy of cost-saving projections and feasibility assessments.

Future research should focus on expanding the practical applications of geoinformation systems (GIS) in the restoration of territorial communities by developing adaptive models that consider regional socio-economic and environmental factors. Further studies should explore the integration of artificial intelligence and machine learning with GIS to enhance predictive analytics for urban planning and disaster recovery. Additionally, research should address the challenges of data accessibility, interoperability, and security in GIS-based restoration projects, ensuring more effective cross-sectoral collaboration. Comparative analyses of GIS implementation in different countries can also provide valuable insights into best practices and policy recommendations for Ukraine’s regional development.

Recommendations

The conducted research gives grounds to propose the following measures to ensure the effective restoration of territorial communities in Ukraine.

1. Develop and implement national standards for the use of GIS, which will consider the specifics of each region.

2. Create a centralized database of analysis of spatial information about the state of infrastructure and facilities to be restored.

3. Deliver training and advanced training programmes for specialists who will work with GIS.

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	A1	A2	A3	A4	A5
A. theoretical and conceptual foundations and problematization:	20%	20%	20%	20%	20%
B. data research and statistical analysis:	30%	10%	30%	10%	20%
C. elaboration of figures and tables:	20%	30%	10%	30%	10%
D. drafting, reviewing and writing of the text:	10%	30%	20%	10%	30%
E. selection of bibliographical references	30%	10%	30%	10%	20%
F. program development	20%	20%	20%	20%	20%

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