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GEOINFORMATION SUPPORT OF THE DECISION-MAKING SUPPORT SYSTEM FOR THE RECONSTRUCTION OF CULTURAL HERITAGE OBJECTS

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Abstract

This article investigates the composition and content of information resources used as sources of geospatial data to support the planning and design of reconstruction and restoration of cultural heritage sites in Ukraine as a result of armed aggression and full-scale war of the Russian Federation on the territory of Ukraine. Therefore, the requirements for geospatial data on cultural heritage sites have been formed following the NSDI.

Keywords*: GIS; SDI; Cultural heritage; INSPIRE; Geospatial database*

Introduction

Modern practices and experience in the restoration and rehabilitation of buildings and structures demonstrate the widespread use of geographic information systems, unmanned aerial vehicles, laser scanners, and other software and hardware tools to build a three-dimensional digital model of a damaged or destroyed object and design it in a geographic information environment (Fig. 1) [1-4].

Geographic information systems (GIS) are the tools for the process of modelling and reconstruction of buildings and structures:

- performing data collection and analysis. GIS can be used to collect and process geographic data about the parcel on which a building is located. This may include data on the geodetic configuration of the area, landscape, soil properties, and other factors that may affect the renovation project.
- reconstruction planning. GIS allows you to decide the optimal location of new buildings or parts in an existing environment. The designer can determine the optimal location of the facilities based on the existing constraints and existing infrastructure in the geographic information environment.
- project visualization. GIS allows you to create visualizations of future buildings and structures, taking into account the environment. This helps to understand what the project will look like after completion and how it will fit into the existing landscape.

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- performing an impact analysis. GIS can be used to assess the impact of a reconstruction project on the natural environment and society. The projector can analyse the environmental, social and infrastructural impacts of the project before its implementation.

Fig. 1. A three-dimensional digital model of the fire station in Zaikivka at 25 Kvitkinska Street, Kharkiv (1886), created by Serhii Revenko as part of the SCAN UA project (https://scanua.com/firedepartment/)

- project resource management. GIS helps manage resources during reconstruction. You can determine the best way to use materials, labour, and equipment, optimize logistics, and reduce unnecessary costs.
- monitoring and controlling the project implementation. Once the reconstruction has begun, GIS can be used to manage the construction process and ensure that the project complies with the requirements. This helps to identify possible problems in time and make adjustments to the project.
- documenting the project results. GIS allows to storage of all information about the reconstruction project in one place. This facilitates the process of data and documentation management and improves communication between project participants.

In general, building renovation uses a variety of geographic information systems and technologies to help collect, analyse, visualize and manage data about a renovation and reconstruction project, such as instrumental GIS and platforms (ArcGIS, QGIS, MapInfo, Mapbox, GeoServer etc.) [5-9], geospatial data collection devices (geodetic instruments, UAVs, remote sensing satellites, etc.) [10-14], three-dimensional modelling [15-19], VR and AR technologies. Depending on the specific needs of the reconstruction project, different GIS tools can be combined to achieve the best and most optimal result.

The article aims to research information resources on cultural heritage sites to form the structure of the geospatial database of the State Register of Immovable Monuments of Ukraine (hereinafter – SRIMU) as an official source of geospatial data on cultural heritage sites to ensure planning and design of reconstruction work on buildings and structures, as well as to determine the requirements for these geospatial data following the current legislation in the field of national spatial data infrastructure (hereinafter – NSDI) and the current level of development of geoinformation systems. The necessary condition for the NSDI development is the use of the geoinformation approach to the creation and updating of geospatial data in all spheres and sectors of the state economy [20-26].

Materials and methods

Following the Resolution [27], the state geographic information system is operating in Ukraine to collect generalised data on damage and destruction caused by the armed aggression of the Russian Federation against Ukraine by region, district, territorial community and settlement, which can be used in the future to determine damage and losses, the number of financial resources required to restore the facilities and to justify the number of funds required.

This geographic information system contains data on the following objects of destruction:

- multi-apartment residential buildings;
- individual (manor) residential buildings;
- dormitories;
- country and garden houses;
- objects of unfinished residential construction;
- public buildings and structures in the field of education, and healthcare;
- objects of improvement;
- objects of cultural institutions;
- housing and utilities facilities (gas, heat, water, electricity supply).

Geospatial data on these objects are provided both in the form of separate documents in electronic form in GeoJSON format for downloading and through an application programming interface (API) following the Regulation [28]. This geographic information system can be used by the projector to obtain official data on damaged or destroyed objects for the restoration and rehabilitation of buildings and structures.

The MCIP as a central executive body ensures the maintenance and publication of the SRIMU, coordinates and controls the certification of immovable cultural heritage objects following the Resolution [29].

Cultural heritage sites, regardless of ownership are subject to registration by entering them in the SRIMU according to their archaeological, aesthetic, ethnological, historical, artistic, scientific or artistic value [30]. This register includes geospatial data, metadata and services, the publication, other activities and access to which are carried out on the Internet [26].

The structure of the geospatial database of documentation in the field of cultural heritage protection was developed for the project on the development and implementation of the electronic system of the SRIMU (supported by USAID/UK aid project, TAPAS) and approved by the order of the MCIP. This geodatabase is defined as part of the package of scientific and project documentation in the field of cultural heritage protection [31].

This geodatabase is transferred in the format of a Geodatabase File (*.gdb) or GeoPackage (*.gpkg). It contains a complete set of geospatial data and documentation metadata following the structure determined by the MCIP.

It should be noted that in urban planning activities, there is a historical and architectural reference plan of a settlement as project documentation as part of the master plan for historical settlements of Ukraine (Fig. 2).

Urban planning documentation at the local level (complex plan for the geospatial development of the territory of the territorial community, master plan of the settlement, detailed plan of the territory, historical and architectural reference plan of the settlement, etc.) also has its structure of the geodatabase, which was approved by the Order of the Ministry of Communities and Territories Development of Ukraine No. 56 dated 22.02.2022. This geodatabase is transmitted in the format of a geodatabase file (*.gdb) or JavaScript Object Notation (GeoJSON) and contains a complete set of geospatial data and documentation metadata following the structure determined by the Ministry of Communities and Territories Development.

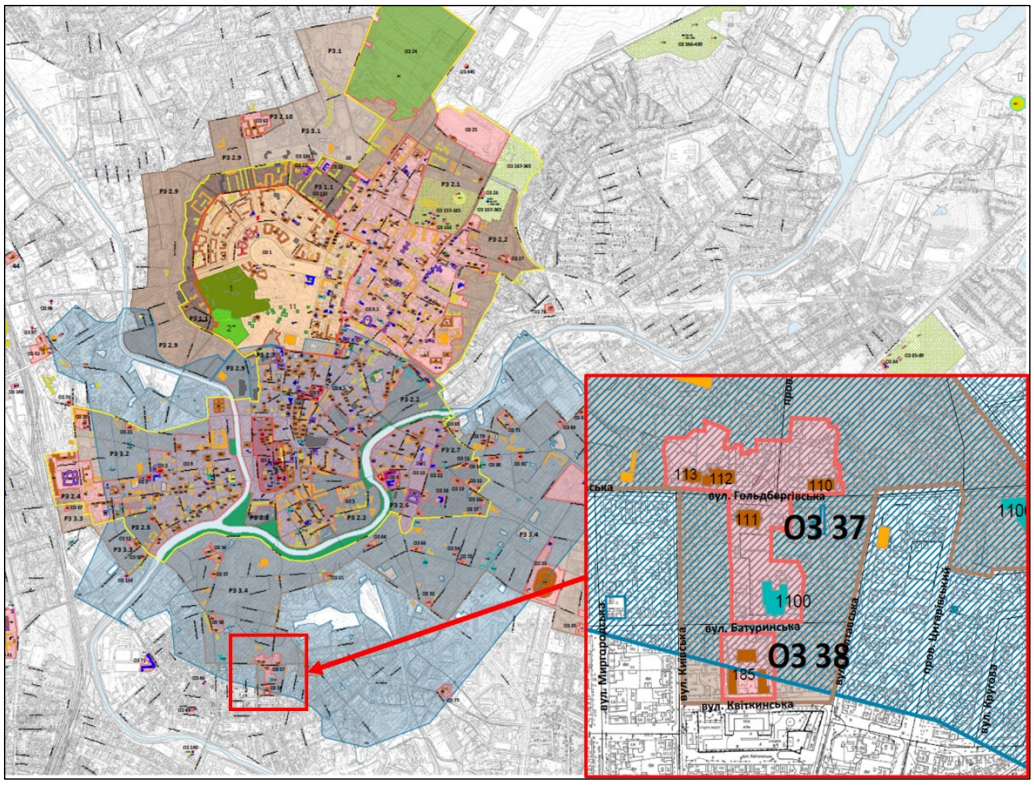

Fig. 2. The fragment of the historical and architectural reference plan of Kharkiv and the complex of buildings of the fire station in Zaikivka at 25 Kvitkinska Street, Kharkiv (No. 185 on the map, registration number 483). (https://v.gd/72OR86)

Thus, today, geospatial data on cultural heritage sites can be maintained in such information resources:

- GIS for monitoring of damage and destruction by regions of Ukraine as a result of the armed aggression of the Russian Federation.
- State Register of Immovable Monuments of Ukraine.
- Geodatabase of documentation in the field of cultural heritage protection.
- Geodatabase of urban planning documentation at the local level.

It should be noted that the mentioned GIS does not contain complete information on damaged and/or destroyed cultural heritage sites, but only on cultural facilities. The SRIMU will contain, among other things, information from the geodatabase of documentation in the field of cultural heritage protection. Therefore, the article will further analyse the latter two resources in terms of their composition and content, taking into account the NSDI.

Results and Discussions

The list of feature classes was formed and the correspondence between them was established for a detailed analysis of the structures of the geodatabase of documentation in the field of cultural heritage protection and the geodatabase of local-level urban planning documentation (Table 1).

A green fill colour means that full compliance has been identified. A yellow fill colour means that a partial match has been identified with an additional comment. A red fill colour means that no compliance has been identified.

Table 1. The list of feature classes of the geospatial database documentation in the field of cultural heritage protection and geospatial database of local-level urban planning documentation

No	Feature class in the GDB of documentation in the field of cultural heritage protection	Feature class in the GDB of	Type of geometry	Comment
1	Protection zones	Protection zones for cultural heritage sites	Polygon	
2	Building regulation zone			
3	Protected landscape zone			
4	Protection zone of the archaeological cultural layer			
5	Sub-zones of the protected landscape zone	None	Polygon	
6	Subzones of the development control zone	None	Polygon	
7	Subzones of the archaeological cultural layer protection zone	None	Polygon	
8	Subzones of security zones	None	Polygon	
9	A buffer zone of the World Heritage site	Buffer zones of World Heritage sites	Polygon	
10	Sub-zones of the buffer zone of the World Heritage site	None	Polygon	
11	Historical and cultural reserve	Historical and cultural reserves	Polygon	In the GDB of local-level urban planning documentation does not fully preserve important information about monuments and restrictions
12	Historical and cultural protected areas	Historical and cultural protected areas	Polygon	
13	Protected archaeological areas	Protected archaeological areas	Polygon	The GDB of local-level urban planning documentation does not provide for the possibility of entering information about the maritime memorial
14	Historical areas of settlements	Historical areas of settlements	Polygon	
15	Subzones of the historic areas of settlements	None	Polygon	
16	Protection zone (regulatory)	None	Polygon	
17	World heritage sites	Natural UNESCO World Heritage Sites	-/Point	These feature classes are defined partly through a classifier that is not correct. There is a separate “Natural UNESCO World Heritage Sites”, but natural ones do not include other UNESCO monuments, such as architectural ones, etc.
18	The territory of the World Heritage site	Territories of natural UNESCO World Heritage Sites	Polygon	
19	None	Historical districts of the settlement	Polygon	
20	None	Historical buildings	Polygon	
21	Construction (work of art)	Monuments of cultural heritage	Polygon/Point	
22	Places of interest			
23	Complex (ensemble)	None	Polygon	
24	Information about the type of cultural heritage	None	–	The GDB of local-level urban planning documentation has the opportunity to

No	Feature class in the GDB of documentation in the field of cultural heritage protection	Feature class in the GDB of	Type of geometry	Comment
	object			make only one type of cultural heritage object
25	Territory of the cultural heritage site	None	Polygon	
26	Sights	Sights - monuments of cultural heritage	Polygon	
27	None	Urban planning dominants (landmark buildings)	Point	
28	None	Disharmonious (dissonant) buildings and structures	Point	
29	None	Significant lost facilities	Point	
30	None	Planning and compositional axes	Polyline	
31	None	Planning and compositional nodes	Point	
32	None	Characteristic types of urban spaces	Point	
33	None	Zones of inspection of architectural monuments	Polygon	
34	None	Characteristic distances (qualitative thresholds) of the view of architectural monuments	Polyline	
35	None	Viewpoints	Point	
36	None	Review axes	Polyline	
37	None	Review fronts	Polyline	
38	None	Zones of Species Formation	Polygon	

If the feature class of the GDB of documentation in the field of cultural heritage protection is not present in the GDB of urban planning documentation at the local level, it is because the structure of the first GDB has been expanded following the legislation in the field of cultural heritage protection.

If the feature class of the local level GDB of urban planning documentation is not included in the GDB of documentation in the field of cultural heritage protection, it means that the structure of the GDB of urban planning documentation should take into account, first of all, the provisions of the Law of Ukraine "On Protection of Cultural Heritage", for example, according to Article 14, it is not provided for the geodatabase to store separate information on the territory of monuments, their boundaries and modes of use. In some cases, this may also mean that feature classes of the GDB of documentation in the field of cultural heritage protection are not needed in urban planning activities.

The geodatabase of documentation in the field of cultural heritage protection and the geospatial database of the State Register of Immovable Monuments of Ukraine belong to the geospatial data set "World Heritage Sites, their territories and buffer zones, cultural heritage sites", which is defined in the Annex [26] and Annex 2 [32].

It is necessary to provide for the implementation and support of the mentioned geospatial data set by the MCIP, which is harmonized with the INSPIRE theme "Protected Sites" for European integration, following the Annex [26].

Therefore, the geospatial database of the SRIMU must necessarily take into account the provisions of the INSPIRE data specification "Protected Sites" and the application scheme D2.8.I.9.

The conceptual model of the data set contains an "enumeration" named "ProtectionClassificationValue" that contains the unique value "cultural" according to the INSPIRE theme "Protected sites" description and application diagram. Description of this value: "The Protected Site is protected for the maintenance of cultural heritage". Also, this specification contains a reference to the classifier "UNESCOWorldHeritageDesignationValue", which is recommended to be provided in the relevant geospatial database.

The mentioned geospatial database following the Technical Requirements [33] shall be provided with:

- a feature classes catalogue with attributes of features and domains of their values in XML format of an electronic document according to the requirements of national standards DSTU 8774:2018 and DSTU ISO 19110:2017;
- metadata following the specified technical requirements;
- geospatial data specification developed following the national standard DSTU ISO 19131:2019 and harmonized Commission Regulation (EU) No. 1089/2010 [34].

Also, the developed structure of the geospatial database of the SRIMU should be part of the specification of the said geospatial data set by the MCIP following clause 13 of the Technical Requirements [33].

The structure of the geospatial database of the SRIMU must specify the coordinate system in which its geospatial data will be maintained and stored. Following clause 6 of the Resolution [30], geospatial data are produced, updated, processed, stored and delivered in the State Geodetic Reference System of Coordinates USC-2000 and the Baltic Height System of 1977, and from January 1, 2026 – in the EVRS.

The structure of the UCS-2000 includes [5, 6] (Fig. 3):

- the XYZ spatial Cartesian coordinate system;
- the BLH geodetic (ellipsoidal) coordinate system;
- the Gauss-Krueger Cartesian coordinate system in 6- and 3-degree zones;
- 27 local coordinate systems.

The structure of the State Geodetic Reference Coordinate System UCS-2000 is in Figure 3.

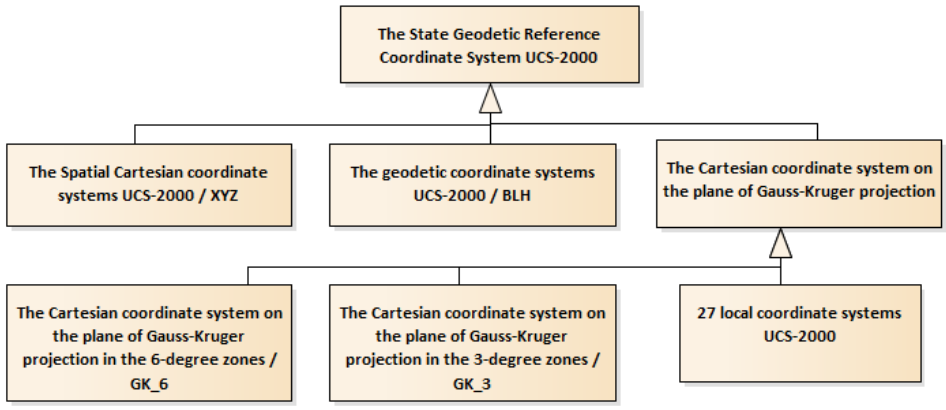

Fig. 3. UML – diagram of the structure of the State Geodetic Reference Coordinate System UCS-2000

The XYZ spatial coordinate system and the BLH geodetic (ellipsoidal) coordinate system extend to the entire territory of Ukraine. The Cartesian coordinate systems in 6- and 3-degree zones in the Gauss-Krueger projection with the corresponding standard central

meridians cover the entire territory of Ukraine. The local coordinate systems are used to provide large-scale topographic and cadastral surveying.

The State Enterprise "Research Institute of Geodesy and Cartography" created a description of the coordinate systems UCS-2000 in terms of ArcGIS for the territory of Ukraine in the format *.prj. The input cartographic data and project materials must be transformed into the current coordinate system of UCS-2000. Determination of cartometric properties of geospatial objects should be performed on the reference ellipsoid [35].

Conclusions

It is necessary to use official and reliable geospatial data maintained by the relevant executive authorities to ensure the planning and design of the reconstruction and restoration of cultural heritage sites. Given the current level of development of geographic information systems, these geospatial data must be highly intelligent and interoperable to meet the needs of designers, so their quality must be ensured by their respective holders.

Authors have formed problematic issues that need to be agreed upon by their developers having established the correspondence between the structures of the geodatabase of urban planning documentation at the local level and the geodatabase of documentation in the field of cultural heritage protection.

The requirements for the geospatial database of the State Register of Immovable Monuments of Ukraine were also formed, taking into account the NSDI. One of the main tasks to be performed by its holder is to ensure interoperability, unification and quality of geospatial data that is stored and maintained in a state geographic information system, the methods of which are described in [20]. This will make it possible to share up-to-date and reliable official data with users who will be able to implement new projects and start-ups.

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