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THE SYSTEM MODEL OF TOPOGRAPHIC MAPPING IN THE NATIONAL SPATIAL DATA INFRASTRUCTURE IN UKRAINE

The article proposes a new development concept of topographic mapping in Ukraine. **The goal.** It is based on the implementation of a new system model that responds to the geoinformation approach to topographic mapping in the development of National Spatial Data Infrastructure (NSDI). The study aims at providing the creation of geospatial data sets in the form of databases and knowledge bases based on existing standards and specifications: series of International Standards ISO 19100 "Geographic information/Geomatics", Open Geospatial Consortium (OGS), INSPIRE, National Standards of Ukraine (DSTU), Complex of Standards Organization of Ukraine (SOU) "Topographic database". **Methods.** The foundation for the research is laid by the analysis of the possibilities of applying the theory of databases and knowledge bases, International Standards and specifications. **Scientific novelty and practical significance.** It provides a high intellectual level of Core Reference and profile geospatial data, which is able to ensure geoinformation analysis and modeling in modern GIS. In addition, the implementation of the infrastructure approach to topographic production and the creation and development of a permanent topographic monitoring system will ensure the publication of geospatial data in real time, almost simultaneously with changes in the terrain. This guarantees the maintenance of the single digital topographic basis and, accordingly, Core Reference Datasets for NSDI.

Key words: National Spatial Data Infrastructure (NSDI), topographic mapping, Core Reference Dataset (CRD), geoinformation system (GIS), topographic database (TDB), geospatial data.

Introduction

The high-level mapping production infrastructure has been created before the proclamation of Independence in Ukraine.

The quality, the accuracy, detail, information and clarity of the topographic maps were so high [Lee, 2003; Sossa, 2014]. There was a rapid development of methods and technologies for collecting geospatial data such as: contact (ground: planimetric and vertical survey; tacheometric survey; global navigation satellite systems (GNSS) survey; ground photogrammetric survey and laser scanning; mobile mapping systems and inertial navigation systems); remote sensing (space, photographic aerial survey and unmanned aerial vehicles (UAVs)); Opensource and crowdsourcing technologies of capturing the geospatial data and their combinations. So, the increasing speed of processing and distribution to meet the modern users` needs, determined the change of the classical meaning of topographic maps as the seamless cartographic composition of multipurpose function. Nowadays worldwide, the topographic map in the classical sense is not the desired end product. They are replaced by topographic databases which are a set of interconnected complex structured geospatial data. [Sarjakoski, 1997; Jakobsson, 2006].

Nowadays in Ukraine digital topographic maps are created by means of modern geoinformation systems such as: ArcGIS, QGIS, GeoMedia etc. Such maps are created for the specific needs of one customer and this customer uses these maps only for his/her own needs. In other words, the map is made once for a specific customer to perform his/her specific tasks. That is why the topographic monitoring of the territory of Ukraine is not working in the mapping production infrastructure. As a result,there is no constant information updating about changes of the topographic features on the territory of the whole country.

Besides that, the cartographic and cadastral activities in Ukraine are carried out with a lack of cooperation between different agencies, as well as competition between different institutions in cadastre matters, and, as a result, without coordination and without a well-defined national concept of cadastre development.

Sectoral cadastres are organized and functionnally separated. The level and forms of financial, regulatory, methodological, information and technological support of sectoral cadastres are very different.

As collecting and processing geospatial data is a very costly process, both financially and temporally, it would be logical to stick to the following rule: "Geospatial data that has been collected once must be used repeatedly and by different users". This multiple-use and unification for the interoperability of the geospatial data can only be achieved under conditions of creation and development of National Spatial Data Infrastructure.

Formulation the problem

The current condition of decision-making on territorial development and spatial planning requires inter-sectoral integration of geospatial data. This causes the transition from the mapping production infrastructure to the development of Spatial Data Infrastructures. As the cost value of territorial management decisions is increasing, the requirements for Core Reference Dataset (CRD) are growing too, because CRD is the only topographic basis for integrating all profile datasets.

Apart from the traditional requirements (relevance, reliability, accuracy, detail, informativeness, clarity), such an increase of the topographic basis value needs additional requirements to increase the intellectual level of the Core Reference Dataset. It would correspond to the modern development level of geoinformation systems and fully provide geospatial analysis and modelling, data interoperability, and the ability to integrate data from different sources. In addition, the development of a permanent system for their monitoring and updating is vital for current requirements for the CRD.

The analysis of the Core Reference Data list shows that it mostly consists of the features of the real world, i.e. the topographic features.This, in turn, increases the importance of topographic mapping in the conditions of the NSDI development.

Analysis of recent research

The ground for the research is the analysis of the possibilities of applying the theory of databases and knowledge bases. They should be created using a series of International Standards ISO 19100 "Geographic Information/Geomatics", Open Geospatial Consortium (OGC) and INSPIRE to solve the problems of improving the intellectual level of Core Reference Datasets of geospatial data.

The research is related to the implementation of the Ukrainian-Japanese project "Creation the National Spatial Data Infrastructure in Ukraine" (2015–2018) and of the Ukrainian-Norwegian project "Maps for good land governance", aimed to create the seamless Topographic Database of the State Topographic Map. The initial data for the Topographic Database will be the updated and unified digital topographic maps of the scale 1: 50 000 for the whole territory of Ukraine. These digital topographic maps will also be the Core Reference Dataset for NSDI .

Currently, there are 13 types of state cadastres in Ukraine such as: land, urban, water, forest, mineral deposits and manifestations, natural healing resources, territories and objects of nature reserve fund, natural territories of resorts, cadastres of wildlife and flora, radioactive waste repositories, aquatic bioresources and fisheries water bodies and a national inventory of anthropogenic emissions and greenhouse gas absorption.

All of them require up-to-date and high-quality Core Reference Datasets in the form of topographic maps and plans.

In 2018, topographic, geodetic and geoinformation works were analysed, using tender materials to determine the demand for topographic and geodetic works, as well as cartographic products in Ukraine.

Public procurement information obtained from tender platforms was used as an indicator of demand for topographic and geodetic works and mapping products. It also allowed identifying their areas of application.

The 64 tenders for the period 2016–2018 were considered. The division of tenders into official categories was determined in percentage terms (Fig. 1): scientific and technical services in the engineering field make up 28 %; architectural, engineering and surveying services – 14 %; software related services – 11 %; information systems – 6 %; such categories as complex engineering services, data processing services, digital mapping make 5 % each; and other services account for 26 %.

The distribution by purpose was determined, according to the categories of tenders. Most orders were for creation (updating) of topographic plans of territories of cities and settlements – 24, software for work with geospatial data of urban planning cadastre – 8, creation of topographic basis for urban planning documentation – 6, software providing for work with other profile geospatial data, etc. (Fig. 2). In addition, topographic plans of the scale 1: 2000 and the smallest 1: 5000 were found to be in greatest demand. Besides that, 3 tenders concerned the creation of topographic maps of the scale 1: 10000, 1: 25000, 1: 100000 for the territory of cities and southern regions of Ukraine for military purposes (Fig. 3) [Karpinskyi, & Lazorenko-Hevel, 2018)].

The purpose of the article is to research whether digital topographic maps can be a Core Reference Dataset for the creation and development of the National Spatial Data Infrastructure; to substantiate the basic principles of topographic mapping in the context of the NSDI development in Ukraine and the new system model that describes the geoinformation approach to topographic mapping in the NSDI and takes into account the importance of creating and development of topographic monitoring of the terrain, and also solves the issues of multiple use of geospatial databases.

Since 2019, a nationwide project has been launched in Ukraine – the Ukrainian-Norwegian project "Maps for good land governance". The Ukrainian-Norwegian project consists of three components such as: creation (updating) digital topographic maps of the scale 1:50 000 for the whole territory of Ukraine; creation seamless Topographic Database and geoportal of the Main State Topographic Map. The purpose of the creation (updating) of the digital topographic maps of the scale 1:50 000 for the whole territory of Ukraine is the creation of the Main State Topographic Map as a set of interconnected structured geospatial data in the Topographic Database and arrangement it on the Geoportal of the Main State Topographic Map. It aims at ensuring the relevance of a single digital topographic basis, by conducting topographic monitoring of the terrain, and at developing National Spatial Data Infrastructure in Ukraine.

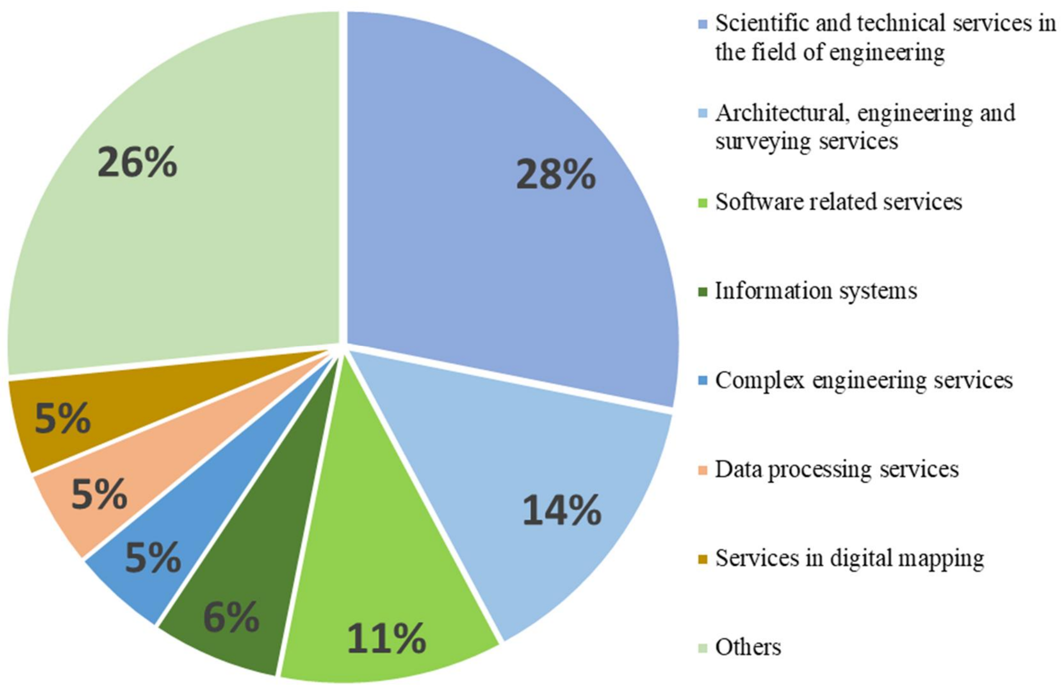

Fig. 1. Distribution of tenders by official categories, %

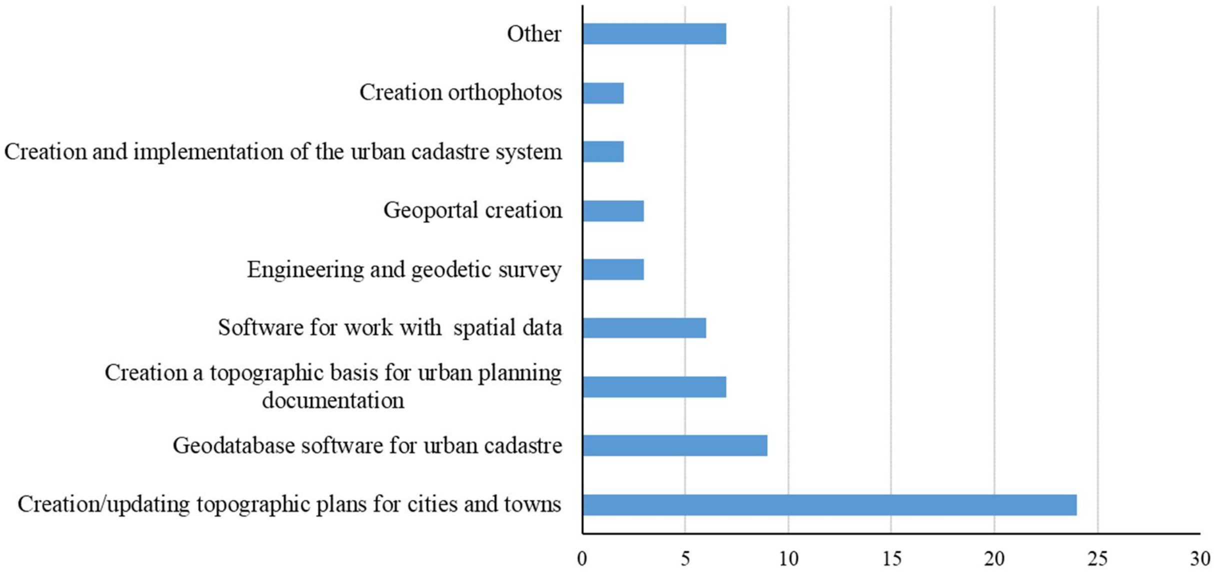

Fig. 2. Distribution of tenders by purpose

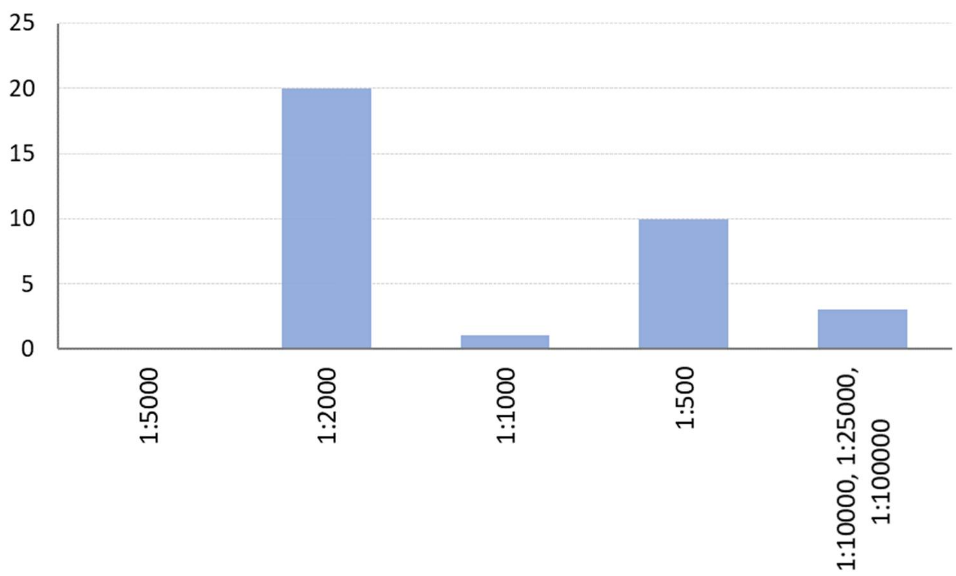

Fig. 3. Ranking of tenders by scale of topographic plans and maps

Results

The topographic mapping K_m in the mapping production infrastructure. The cartographic approach to the production of digital topographic maps and plans can be described as a system model. This model is the interaction of the three following systems: the terrain T contains a set of mapped features; the set of topographic information I obtained as a result of topographic survey f_{TI},, and the digital topographic map M formed as a result of the processing of topographic information in the environment of geographic information systems f_{IM} (Fig. 4) [Lisitskyi, 1984]:

$$K_m = \{T, I, M, F\}$$

where K_m – topographic mapping in the mapping production infrastructure; T – the feature set that is mapped while performing a series of topographic survey work f_{TI}; I – the set of topographic information f_{TI}: $T \rightarrow I, f_{TI} \in F$; f_{IM} – the digital map creation in the geographic information systems environment, using the mapping methods f_{IM}: $I \rightarrow M$, $f_{IM} \in F$; M – digital map.

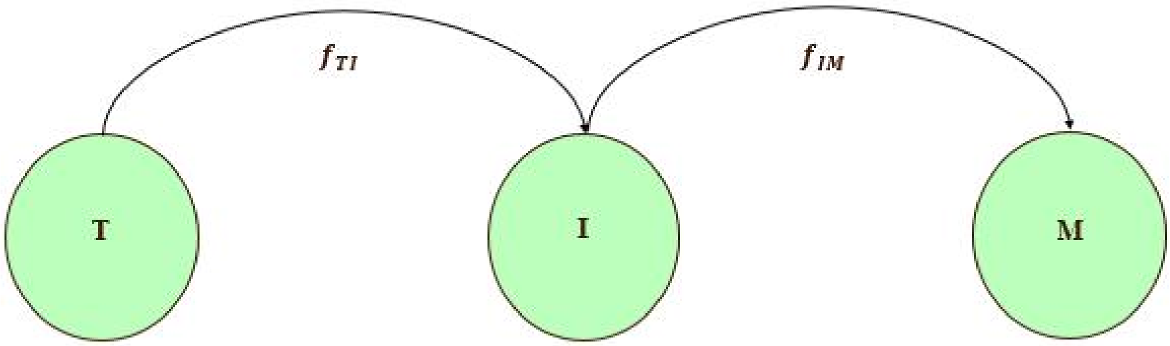

Fig. 4. The system model of the cartographic approach to the production of digital topographic maps and plans

Currently, the main trends in the development of topographic-geodetic and mapping activities are dependent on the development of information technologies. They incorporateGNSS location of features, aerospace high-resolution systems to capture information about the Earth, the creation of high-performance facilities of capturing spatial information about the Earth in real time based on optical-electronic terrain scanning systems, satellite radar, laser scanning, digital aerial photography. The latter include drones, non-metric cameras, pictographic capture to creation of realistic terrain models, digital imaging and geospatial information, the widespread use of geoinformation systems and telecommunication technologies as a primary facility of providing access to geospatial data and information etc. The lifecycle of creation (updating) digital topographic maps has been reduced to 3–6 months. The digital topographic maps are created in the modern GIS for a specific customer and he/she uses them only for his/her own needs [Lee, 2003].

This approach allows compiling the digital topographic map as the "cut of the terrain" for a certain time. It does not take into account changes in the terrain. In addition, during topographic surveys, as a rule, only topographic characteristics of geospatial features are collected and data from different sources are not integrated. The production of a digital topographic map occurs in the context of a specific GIS that does not provide the interoperability of geospatial data collected in other GIS. This causes problems in creating, updating, exchanging, sharing and distributing such data between different producers and users.

Data converters are used for the exchange of geoinformation models between GIS of different producers. It is easy to identify the main disadvantages of corporate GIS with such an architecture. Besides, the process of converting large amounts of data becomes a time-consuming process. The converted data, as a rule, do not fully reflect the original structure of the source geoinformation model. This, in turn, requires the additional cost of adjusting the result model conversion, and in general there is duplication of information in different GIS formats. Practically,the integrity and adequacy of data models is not exactly ensured, and data management becomes difficult.

So, there is an answer to the question, whether digital topographic maps in the file structures form can be a Core Reference Data for the creation and development of National Spatial Data Infrastructure. This answer is obvious: No, they cannot, because the main condition for the creation and development of NSDI is the interoperability of geospatial data for creation, integration from different sources, updating, sharing, distribution between different producers and users.

Topographic mapping K_D in the National Spatial Data Infrastructure. The study proposes a new system model that describes the geoinformation approach to topographic mapping in the National Spatial Data Infrastructure.

This dynamic model consists of four systems: T – terrain with numerous simulated geospatial features; I – set of topographic information obtained as a result of topographic and geodetic and cartographic works using methods of geospatial data collection

f_{TI} ; *D* – a bank of topographic data that forms the basis of topographic data f_{ID} and *M* – sets of digital topographic maps that are formed during the queries executions f_{DM} to the bank of topographic data. In addition, the model takes into account changes in the terrain – f_{TT}. These changes are made during updating the set of topographic information – f_{II}. Thereafter, the process of updating the bank of topographic data – f_{DD} takes place and accordingly there is an opportunity to update the set of digital maps – f_{MM} (Fig. 5).

$$K_D = \{T, I, D, M, F\}$$

where:

K_D – topographic mapping in the National Spatial Data Infrastructure;

I – set of topographic information: $F : T \rightarrow M$, $F = \{f_{TT}, f_{TI}, f_{II}, f_{ID}, f_{DD}, f_{DM}, f_{MM}\}$

D – topographic data bank;

M – topographic maps;

f_{TT} – the process of changing the terrain: $f_{TT}: T \rightarrow T, f_{TT} \in F$;

f_{TI} – the complex of works on topographic surveying: $f_{TI}: T \rightarrow T, f_{TI} \in I$;

f_{II} – updating the set of topographic information: $f_{II}: I \rightarrow I, f_{II} \in F$;

f_{ID} – creation of the topographic data base – Clearing House: $f_{ID}: I \rightarrow D, f_{ID} \in F$;

f_{DD} – updating of the topographic data base: $f_{DD}: D \rightarrow D, f_{DD} \in F$;

f_{DM} – creation the set of digital topographic maps: $f_{DM}: D \rightarrow M, f_{DM} \in F$;

f_{MM} – updating the set of digital topographic maps: $f_{MM}: M \rightarrow M, f_{MM} \in F$;

It is the whole set of processes *F*: f_{TT}, f_{TI}, f_{II}, f_{ID}, f_{DD}, f_{DM}, f_{MM}, – that actually make up topographic monitoring of the terrain:

$$F = \{f_{TT}, f_{TI}, f_{II}, f_{ID}, f_{DD}, f_{DM}, f_{MM}\}.$$

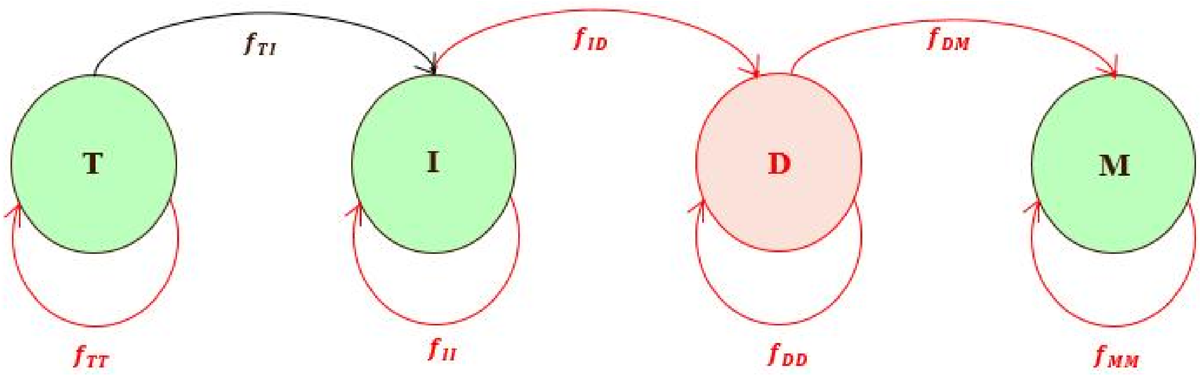

Fig. 5. The system model of the geoinformation approach to topographic mapping in the National Spatial Data Infrastructure

The architecture of the Main State Topographic Map (Fig. 6), which corresponds to the geo-information approach to topographic mapping under the conditions of development of the National Spatial Data Infrastructure, can be described as follows:

1. We have a terrain (*T*) with a constantly changing and time-varying geospatial features – f_{TT};

2. Multitude of topographic information obtained as a result of topographic, geodetic and mapping works using geospatial data collection methods f_{TI}. These methods include the following: contact (ground), remote, mapping, Opensource and crowdsourcing-technologies, and combined ones [Karpinskyi, & Lazorenko-Hevel, 2018]. Terrain changes are made when the set of topographic information is updating – f_{II}.

3. The topographic data bank *D*, which is formed by topographic data bases – f_{ID}, DBMS and GIS tools. UML models help organize topographic data bases. They are developed on the basis of International and National Standards and specifications in the field of Geographic Information/Geomatics. The information about the terrain changes is updated in TDB in real-time.

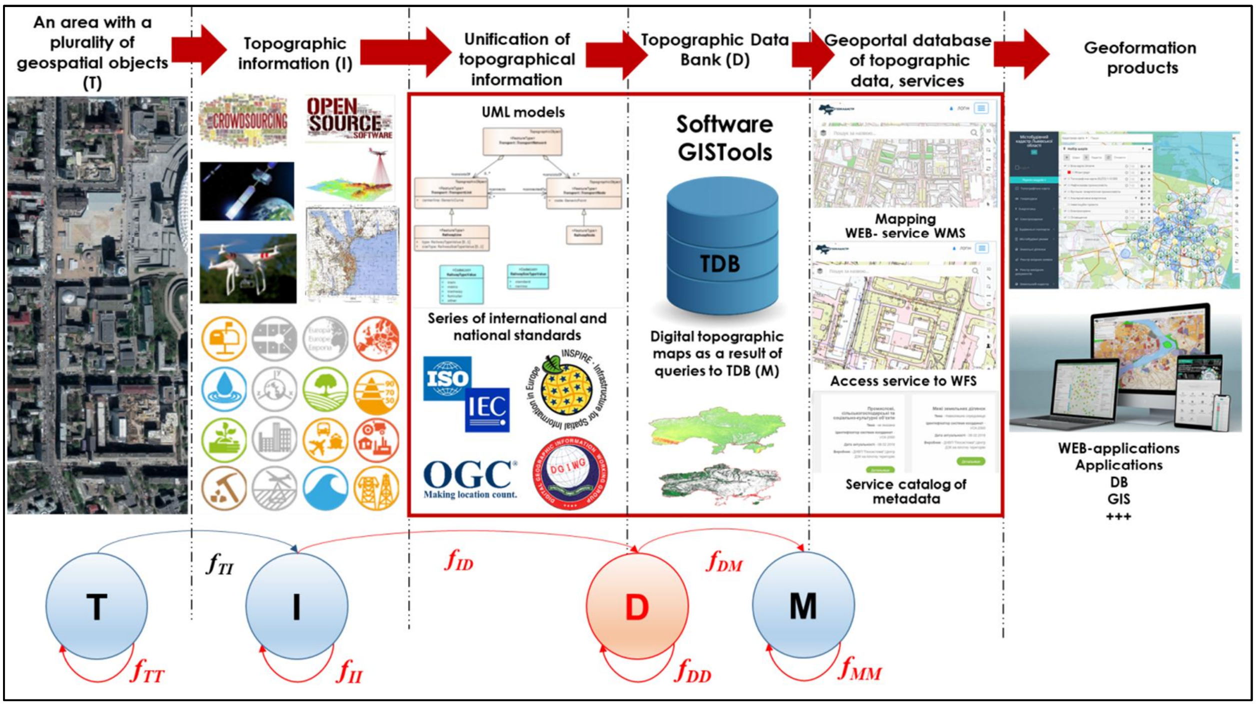

Fig. 6. The architecture of topographic mapping in NSDI

4. Digital topographic maps M are formed as a result of queries to the topographic data bank – f_{DM}. The constant updating of information in the bank of topographic data provides updating of a set of digital topographic maps – f_{MM} and conducting of topographic monitoring of the terrain.

5. Increasing the level of access to the Main State Topographic Map is provided by its Geoportal and the following services:

- the search services that provide the detection of geospatial data and geospatial data services in information networks;
- the services for viewing geospatial data, information on characteristics of geospatial features and content of metadata;
- the access services providing direct access to geospatial data or obtaining their copies;
- the coordinate operations services that provide the transformation and turning coordinates of geospatial data from one coordinate system or map projection into another one.

6. The producers create their geographic information products on the basis of the information obtained from the geoportal of the Main State Topographic Map. These products include WEB applications, GIS applications, profile geospatial datasets and GIS.

Scientific novelty and practical significance

The geoinformation approach to topographic mapping in the National Spatial Data Infrastructure is based on the following principles:

1. The topographic monitoring of the terrain must develop;
2. The topographic database is the core of topographic mapping. The topographic database does not depend on GIS software;
3. Formation of digital topographic maps and other maps as a result of queries to the Topographic Database;
4. Increasing the intellectual level of geospatial data creation;
5. Integration of Core Reference and profile data.

The topographic monitoring of the terrain. All topographic data are updated in the Topographic database as a result of topographic monitoring according to the following rules:

- any artefact feature can be put into operation only after the executive topographic survey had been done with placing it in the topographic database;

- while using Big Data [Lu, et al., 2016] and crowdsources technologies for detecting changes of topographic features on the terrain, such changes can be fixed and put into operation only after the executive topographic survey had been done with placing in the topographic database;
- data on natural topographic features are updated at least once every 3–5 years.

It is obvious that the organization of such a system of topographic monitoring is possible only under the conditions of the development of the National Spatial Data Infrastructure, which requires effective interaction between its participants.

The topographic database is the core of topographic mapping. The topographic database is independent of GIS software. There is the principle in the National Spatial Data Infrastructure: "that once created data in one place is used repeatedly" by various users in the environment of various geoinformation systems.

In the architecture of modern GIS, which belongs to the third generation GIS by the evolution of geoinformation systems, they are fully integrated with universal DBMS. They also have access to the global information space through the Internet. In such GIS, both components of the geographic feature model (attribute and spatial) are stored in a single database environment, and the SQL language allows you to describe many spatial predicates to perform spatial analysis [Hampe, et al., 2004; Jakobsson, 2006].

An effective method to stick to this principle is to use independent databases of any GIS. The undeniable advantages of using databases are:

1. Minimizinge redundancy. The database applications minimize the excess data inherent in file systems. It is the reduction and elimination of duplication of data that ensures their efficient operation and improved reliability. The avoidance of duplication of data and minimization of their redundancy is ensured by the interconnectedness of the data, while maintaining various linkages between the data.

2. The unification of data organization tools is achieved through the use of application schemas developed on the basis of International Standards and National Standards of Ukraine in the field of Geographic information/Geomatics. Currently, Ukraine adopted 14 national standards harmonized with the series of International Standards of the ISO 19100 Geographic Information/Geomatics. They were submitted by the Research Institute of Geodesy and Cartography, which functions as the secretariat of the Technical Committee for Standardization TC 103 "Geographic information/ Geomatics", National standardization body – State Enterprise "Ukrainian Research and Training Center of Standardization, Certification and Quality" (SE "UkrNDNC") by Decree No. 226 of August 14, 2017. In addition in accordance with Order No. 158 of June 11, 2018, UkrNDNC, the National Standard of Ukraine DSTU 8774: 2018 "Geographic Information. Rules for modelling geospatial data" [National standard] came into operation. The use of these National Standards in the field of topographic-geodetic and cartographic activity is one of the basic conditions for the creation and development of a unified state topographic basis and National Spatial Data Infrastructure in Ukraine.

3. Synchronous data support (synchronous replication). In the case of synchronous replication, the following rule is applied: if the replica is updated, all other replicas of the same piece of data must be updated in the same transaction. Logically, this means that there is only one version of the data. In most products, synchronous replication is implemented using trigger procedures. The disadvantage of synchronous replication is that it creates additional load when performing transactions that replicate replicas.

4. Integrity and protection against unauthorized access, which determines the corresponddence of the database information to its internal structure and set rules. Each rule imposes a certain limit on the possible state of the database – integrity constraint. Database integrity refers to consistency and compliance with the stored data requirements. Since databases are targeted at a wide range of applications, protection measures against unauthorized access are needed .

5. The independence of the data structures from software programs. The use of databases provides a high degree of independence of data from programs, which means the ability to change the data structure without changing the software that uses them. For the sake of power, these databases will ensure the decentralization of the development of information systems. This property

of databases ensures the decentralized development of information systems. Changes to data structures do not require the involvement of software developers, which provides considerable flexibility to modernize field information systems.

6. Software independence from data structures. The use of databases provides a high degree of independence of programs on changes in the data structure, which means the ability to change the software without changing the data structure. This property of databases provides software development to ensure compatibility with existing data structures.

A distributed geospatial database (DGDB) is located on a set of remote nodes. A distributed database management system is software that is designed to manage DGDBs and may contain different DGDBs. In fact, this is the advantage of using a distributed geospatial database for creation (updating) Core Reference Datasets for integrating all profile datasets in the conditions of development of National Spatial Data Infrastructure in Ukraine. Information is exchanged through a communication network. All distributed geospatial database users are equal, regardless of distance.

Besides it should be borne in mind that the profile and attribute geospatial data can be generated and maintained by a variety of holding organizations that monitor them. Therefore, the use of distributed geospatial databases is an effective tool to ensure their integration and data synchronization [Frank, 1988].

This provides complete freedom for producers and users of geospatial data and products to use different software (Fig. 7). Interoperability is ensured through the use of application schemes created on the basis of a series of International and National Standards of Ukraine in the field of "Geographic Information/Geomatics".

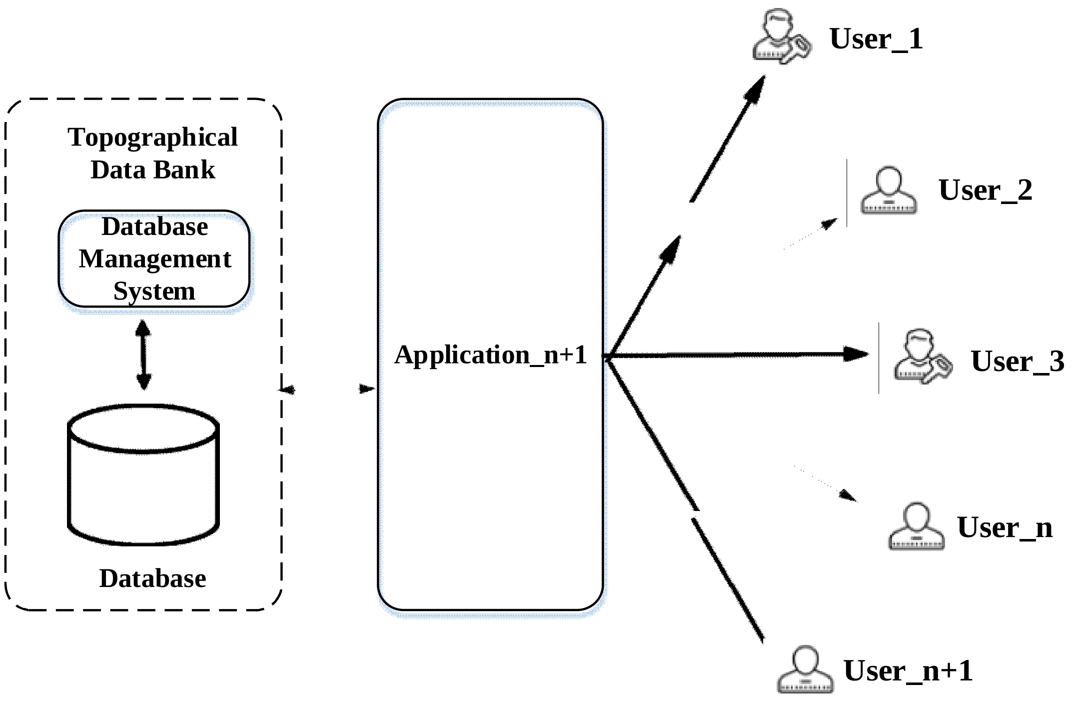

Fig. 7. Usage of geospatial databases for creation, updating, exchange and distribution of digital topographic maps and plans created by different producers in different GIS environments

The creation of digital topographic maps. All digital maps are compiled as a result of the query to the topographic data base. Typically, such queries for the creation of digital maps are made in the format GML, which is also independent of specific GIS.

Increasing the intellectual level of geospatial data creation. This is provided by the application spatial schemas, the description of the internal construction of models and rules for the digital description of geospatial features, the unification of the catalogue of features and their attributes, topological consistency of geometry in accordance with standards and specifications: series of National Standards of Ukraine DSTU ISO 19100 “Geographic information/Geomatics”, accepted by the cover method of the International Standards this series and DSTU 8774:2018 “Geographic information. Geospatial data modeling rules”, the complex of Standards of the Organization of Ukraine (SOU) “Topographic database”. The usage of the above marked standards will provide the unification of the structure and composition of digital terrain models in topographic databases, and will improve the quality and compatibility of topographic data supplied by different producers.

Integration of Core Reference data and profile data. The attribute characteristics of topographic features are collected as a result of topographic surveys with the existing mapping paradigm. As a rule, these attribute characteristics do not contain full profile information about these features. At the same time, the holders of the profile data of these geospatial features usually operate these features and, by potency of their activities, collect and update the information necessary for the effective management of these features. A geographical identifier is allocated to integrate (connect) the Core Reference and the profile geospatial data. It is present in both datasets and carries out connections of the relational relationships (Fig. 8).

A	B	C
a_1	b_1	c_1
a_2	b_2	c_2
a_3	b_3	c_3
…	…	…
a_n	b_n	c_n

JOIN

C	D	E	F	G	H	…	Z
c_1	d_1	e_1	f_1	g_1	h_1	…	z_1
c_2	d_2	e_2	f_2	g_2	h_2	…	z_2
c_3	d_3	e_3	f_3	g_3	h_3	…	z_3
…	…	…	…	…	…	…	…
c_n	d_n	e_n	f_n	g_n	h_n	…	z_n

A	B	C	D	E	F	G	H	…	Z
a_1	b_1	c_1	d_1	e_1	f_1	g_1	h_1	…	z_1
a_2	b_2	c_2	d_2	e_2	f_2	g_2	h_2	…	z_2
a_3	b_3	c_3	d_3	e_3	f_3	g_3	h_3	…	z_3
…	…	…	…	…	…	…	…	…	…
a_n	b_n	c_n	d_n	e_n	f_n	g_n	h_n	…	z_n

Fig. 8. The example of integrating Core Reference and profile geospatial data in the object-relational geospatial database

This integration is ensured by the use of the Union operation of relational algebra (Join) of heterogeneous Core Reference and profile geospatial data sets supported by different geospatial data producers in environments of different database management systems based on established geographical identifiers in accordance with DSTU ISO 19112:2017 (ISO 19112:2003, IDT). Geographic information. Spatial referencing by geographical identifiers [Karpinskyi, et al., 2020].

This Join minimizes the attribute set for the Core Reference dataset and mandatory persistent storage for each feature. This includes class code, unique class identifier and feature name, and as well as mandatory identifiers (codes) of feature, according to the official national systems of classification (codification) of features in the relevant branch registers:

1) the COATUU for the features of the administrative and territorial structure of Ukraine;

2) the codes of high voltage power grids – according to the registers of the Ministry of Energy of Ukraine;

3) the cadastral numbers of parcels – according to the register of the State Service of Ukraine for Geodesy, Cartography and Cadastre;

4) the codes of rivers, reservoirs and drains – according to the State Water Cadastre Classifier;

5) the forests and vegetation – according to the register of the State Forest Cadastre;

6) the buildings and structures – according to the registers of real estate, the registers of the Bureau of Technical Inventory (BTI) and Urban Cadastre;

7) the highways, bridges, crossings, features of railway according to the registers of the Ministry of Infrastructure of Ukraine, Ukrzaliznytsia, State Agency of Highways of Ukraine (Ukravtodor) and others.

Conclusions

The article explores two approaches to the production of digital topographic maps and plans: mapping and geoinformation.

It has been found that the mapping approach to the creation (updating) of digital topographic maps no longer satisfies the modern industries and society. In this approach, the digital map is a "slice of the terrain" for a certain period of time and does not take into account the changes of the terrain. Moreover, it does not allow for data integration, collected from different sources for map updating. Digital map production occurs in a specific GIS environment, which does not ensure the interoperability of geospatial data collected in other GIS, causing problems with creating, updating, exchange and sharing information between producers and users.

It has also been found that digital topographic maps in the form of file structures cannot be the Core Reference Dataset. However, it may be possible,in the case of creating (updating) them as datasets within the topographic database.

Complete integration with universal DBMS is observed in the architecture of modern GIS, which by the evolution of geoinformation systems belong to the third generation GIS. They also have access to the global information space via the Internet.

In such GIS, both components of the geographic feature model (attribute and spatial) are stored in a single database environment, and the extended SQL language allows you to describe many spatial predicates to perform spatial analysis.

Therefore, a new system model is proposed. It corresponds to the geoinformation approach to topographic mapping in the context of development of National Spatial Data Infrastructure and provides for the creation of geospatial data sets in the form of databases and knowledge bases.

Applying an infrastructure approach to topographic production and the creation and development of a permanent topographic monitoring system, will ensure the publication of geospatial data in real time, almost simultaneously with changes in the terrain. This guarantees the maintenance of a single topographic base and, accordingly, Core Reference Dataset for NSDI.

The creation of Such databases should be created in accordance with standards and specifications: series of International Standards ISO 19100 "Geographic Information/Geomatics", Open Geospatial Consortium (OGS), INSPIRE, National Standards of Ukraine (DSTU), Complex of Standards of Organization of Ukraine (SOU) "Topographic Database". This will ensure a high intellectual level capable of providing geoinformation analysis and modeling in modern GIS.

Geospatial databases can integrate data from different relational models based on Join operation.

Also, the use of a distributed geospatial database will ensure the independence of geospatial data from any GIS that restrict the use and exchange of data between different producers and users of geospatial data.

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СИСТЕМНА МОДЕЛЬ ТОПОГРАФІЧНОГО КАРТОГРАФУВАННЯ В НАЦІОНАЛЬНІЙ ІНФРАСТРУКТУРІ ГЕОПРОСТОРОВИХ ДАНИХ В УКРАЇНІ

В статті пропонується нова концепція розвитку топографічного картографування в Україні. **Мета.** Вона ґрунтується на впровадженні нової системної моделі, яка відповідає геоінформаційному підходу до топографічного картографування в умовах розвитку Національної Інфраструктури Геопросторових Даних (НІГД) та передбачає формування наборів геопросторових даних у вигляді баз даних та баз знань на основі існуючих стандартів і специфікацій: серії міжнародних стандартів ISO 19100 “Географічна інформація/Геоматика”, Відкритого геопросторового консорціуму (Open Geospatial

Consortium – OGS), INSPIRE, національних стандартів України (ДСТУ), комплексу стандартів організації України (СОУ) “База топографічних даних”. **Методи.** Основою дослідження є аналіз можливостей застосування теорії баз даних і баз знань, міжнародних стандартів і специфікацій. **Наукова новизна і практичне значення.** Це забезпечує високий інтелектуальний рівень базових і тематичних геопросторових даних, який здатний забезпечувати геоінформаційний аналіз і моделювання в сучасних ГІС. Крім того впровадження інфраструктурного підходу в топографічне виробництво та створення і розвиток постійно діючої системи топографічного моніторингу забезпечить публікацію геопросторових даних в режимі реального часу практично одночасно зі змінами на місцевості, що гарантує підтримання в актуальному стані єдиної цифрової топографічної основи і відповідно наборів базових геопросторових даних для НІГД.

Ключові слова: Національна Інфраструктура Геопросторових Даних (НІГД), топографічне картографування, набір базових геопросторових даних (Core Reference Dataset – CRD), геоінформаційна система (ГІС), База Топографічних Даних (БТД), геопросторові дані.

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