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THE CONCEPTUAL MODEL OF THE STRUCTURE AND FUNCTIONAL PURPOSE OF THE GEOINFORMATION SYSTEM FOR ADMINISTRATIVE AND ECONOMIC MANAGEMENT OF A REGIONAL AIRPORT

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Abstract. This article is devoted to the development of a conceptual model of the structure of the geoinformation system (GIS) for the administrative and economic management of regional airports, taking into account the requirements of world and national experience, international and national standards, modern technologies of geospatial data collection. The research is aimed at structuring all the facilities and objects of the airport complex and isolating components by location and function; development of a generalized scheme of directions for the use of administrative and business GIS at airports based on the analysis of world and domestic experience; establishing the need to use international and national standards of the "Geographic Information / Geomatics" series when creating an airport GIS; development of a generic scheme of the composition of the database of the Digital Single Topographic Base of the Airport, basic and profile geoinformation resources for the administrative and economic GIS; development of conceptual model of structure and functional purpose of GIS of administrative and economic management of the airport. The developed conceptual model reflects the main production processes and needs of airports, based on the database of the Digital Numeral Topographic Framework, is a complete and consistent model of the relationship between the administrative and economic needs of airports and the functionality of modern geoinformation systems for the efficient operation of objects, structures and facilities communications, analysis of the current state, monitoring and management decision-making.

Keywords: geospatial data, geoinformation system (GIS), administrative and economic management, regional airport, basic and profile datasets, attribute data.

Introduction

GIS technology is being used in many areas of society for the collection, storage and processing; spatial planning of the territory; inventory management and geospatial data infrastructure; monitoring and forecasting; asset management and management decisions, etc. Also, the technology of Building Information Modeling (BIM) and data integration building models are actively developing in recent years, and Geographic Information Systems (GIS) opens new possibilities for the construction, maintenance, renovation, modernization of major infrastructure projects, including such as airport facilities.

This article explores the problem of developing a geoinformation system for administrative and economic management of an airport, taking into account the requirements of state standards and modern technologies of geospatial data collection. Airports are complex spatial objects with developed infrastructure, the economic complex of which is a set of land, buildings, structures, utilities, passages, runways, aeronautical equipment, lighting, vehicles, etc.

The relevance of the research topic is due to the fact that in many countries of Eastern Europe and the post-Soviet space a number of regional airport development programs have been adopted, in particular, in 2016 the State Targeted Airport Development Program for 2023 was adopted, according to which 17 out of 20 operating airports are subject to reconstruction and modernization (Cabinet of Ministers of Ukraine, 2016). Many of the airports included in the program are in a state of disrepair, there are no up-to-date mapping and topographic-geodetic

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data of the territory, the material and technical base is outdated, the runway and the premises need updating and modernization, there is no effective monitoring and control system using modern technologies.

To implement the program and bring the regional airports to the level of international standards, it is necessary to be considered the accumulated global and domestic experience in implementing GIS for managing the administrative and economic complex at airports, modern methods and technologies of work with geospatial information: collection and updating of geospatial data by modern methods (laser and lidar scanning, use of remote sensing data of the earth – satellite, aerial photography, unmanned aerial vehicles), use of geoinformation (GIS) technologies for spatial planning and decision making, application of information technology technologies design of buildings and structures, etc.

In order to effectively apply the current world experience, it is necessary to carry out a thorough study, analysis, generalization and develop a methodology for the introduction into regional airport complexes, considering their peculiarities and national standards.

1. Analysis of recent research and publications

Since the topic of this research is at the intersection of several scientific interests, the analysis of the available research on this topic – both foreign and domestic, has been carried through several directions:

1) in the field of geoinformatics, creation of geoinformation systems and integration of data between building information models and geoinformation systems;
2) development and implementation of geoinformation systems for administrative and economic management of airports.

Research in the field of geoinformatics is devoted to the articles of many foreign scientists and specialists (Mitchell, 2000; Huang et al., 2019). In particular, recent publications have focused on the integration of data between building information models (BIM) and geoinformation systems (GIS), which opens new opportunities for the design of objects and structures, their construction, reconstruction, operation (Kuehne & Andrews, 2016; Dasgupta, 2018; Andrews, 2019). The experience of using geospatial data to support the activities of airports has outlined in the work of foreign colleagues (Parrish & Nowak, 2009; Chen et al., 2012). The practical experience of using GIS in airports could be found in the materials of the magazine ArcReview, which since 1997 covers the development and implementation of geo-information systems based on software ArcGIS (Vladimirov, 2016; Gokhman & Glebov, 2013). Examples of geoinformation systems for managing the property complex of the airports of Houston, USA, Atlanta, USA (Hartsfield-Jackson Airport Representatives, 2016), Los Angeles, USA (Esri, 2019), Geneva, Switzerland (Peters, 2018), Perth, Australia (Esri and Perth Airport Website, 2016) and others.

In Ukraine, many scientists are engaged in research in the field of geoinformatics, development and implementation of geoinformation systems, among which it could be noted the following works (Karpinsky et al., 2016; Lyashchenko & Cherin, 2011; Palekha et al., 2012; Palekha, 2013; Stadnikov, 2016), which pays great attention to the theoretical bases for the development and implementation of GIS technologies, GIS urban planning cadastre, GIS for the management of territories of the united territorial communities (UTC), for spatial planning the territories and development the general plans of settlements, creation of National Geospatial Data Infrastructure, GIS for environmental monitoring, etc. By the Technical Committee TC-103 "Geographic information / Geomatics", which was established for the development, review and approval of international (regional) and national standards in the field of geoinformatics have been developed and adopted national standards that comply with international standards ISO 19100 "Geographic information / Geomatics" (Research Institute of Geodesy and Cartography, n.d.).

There are many examples of successful implementation of geoinformation technologies both in Eastern Europe and in Ukraine, which have been implemented for major airports through the collaboration of scientists and practitioners: systems of urban cadastre of settlements, geoportals (political and administrative system, regulatory monetary valuation of agricultural land, settlements, nature reserve fund, water fund, etc.), geoinformation systems of different levels and purpose (transportational GIS, GIS for the united territorial communities, GIS for housing and communal services, conception of GIS for regional development, etc.), a pilot project has been implemented on the creation of a National Geospatial Data Infrastructure, etc.

Despite the active introduction of geoinformation technologies in various spheres in the post-Soviet countries, the development of GIS for the administrative and economic complex of regional airports has received little attention and publication on this topic is practically absent. In the article (Lyashchenko & Cherin, 2011) was examined the architecture of modern GIS based on geospatial data bases, namely conceptual and technological tasks for the implementation of database management system based on object-oriented architecture, which were worked out during the development of the GIS project on the example of the largest airport of Ukraine "Boryspil International Airport". In the paper (Grunenfelder, 2006) was devoted to the consideration of geographic information technology and base map data in the management of airports and analyzed the structure of the airport map database and the possibility of working with it. In 2008–2010 the Research Institute of Geodesy and Cartography of Ukraine developed a draft concept of creation and development of GIS "Boryspil International Airport", which was aimed at meeting the airports needs in all types of geographical information, improving the use of geospatial data and geoinformation technologies in the management support

systems of management and services of the enterprise, but it concept was not implemented. At the XXI International Conference of Esri Users in Ukraine "GIS in Territorial Development Management", Kyiv, 2018, representatives of the State Airport "Boryspil International Airport" presented a report on the "Prototype of the geographical information system of SA "Boryspil", which considered the proposed requirements for GIS functionality, its architecture and structure, technical requirements and specifications (ECOMM Co, 2018).

Thus, analyzing the available scientific and practical materials, we can conclude that the problem of introduction of geoinformation technologies to manage the administrative and economic complex of regional airports in Ukraine and in the countries of the post-Soviet space is still not sufficiently studied, it is practically not realized and needs additional research taking into account the current world and national experience, the possibilities of modern technologies of collecting and processing geospatial data, implemented international and national standards.

The development of the GIS conceptual model for airports, both large and regional, and methods for the introduction of complex geoinformation technologies will enable effective management and development of regional airports.

The *purpose* of this study is to develop the concept of the airport geoinformation system structure for administrative and economic management and to define the sets of geospatial data of objects and their attribute characteristics, which constitute a single digital topographic basis of the airport, considering the national and international standards.

The objective of this study is the following:

1) investigate the general structure of the airport and its management system;
2) analyze the world and domestic experience in the development and use of administrative and business GIS at airports;
3) research the international and national standards using for the Geographic Information / Geomatics series to create the GIS;
4) identification the elements of a single digital topographic base of the airport;
5) development the GIS concept of administrative and economic management of the airport.

2. Methodology and theoretical basis

The methodological basis of this research is following: analysis of the airport economic complex structure and the general management system; an analysis of the master plans of open access airports; analysis of geoinformation systems implemented at airports in the world, their functions and capabilities (Boyko, 2018); analysis of the GIS Development Concept of the Boryspil Airport of the 2010, developed by the Research Institute of Geodesy and Cartography; Report of the representatives of the Boryspil International Airport at the XXI International Esri User Conference in Ukraine "GIS in Territorial Development Management", Kyiv, 2018, on the topic "Prototype of the geographical information system of SE MA Borispol"; regulatory documents on the creation of a single digital topographic base; international and national standards of the Geographic Information / Geomatics series (Cherin, 2019); research on integrating BIM/GIS-technologies (Boyko et al., 2019).

As software to create a geoinformation system are considered ArcGis software from Esri (USA), a world-leading company in the development of geographic information system development tools that meets the essential requirements of international standards.

To form digital topographic bases are used to form geospatial data: "Complex of standards Topographic database "Rules for encoding and digitally describing vector data" (National Standard of Ukraine, 2010), Topographic Instruction in Scale 1:500 (Order of the Headquarters of Geodesy, Cartography and Cadastre (Verhovnaja Rada Ukrainy, 1998)), topographic symbols in scales 1:500 – 1:5000 (Topographical-Geodetic and Cartographic Activity: Legislative and Regulatory Acts, 2002), substantive provisions of planning and development of territories (State Building Codes of Ukraine, 2019), ICAO requirements, (International Civil Aviation Organization [ICAO], 2019) due to design and operation of aerodromes.

3. Investigation of airport structure and management system

According to the State Aviation Service of Ukraine, as of 2019, there are twenty operating airports in Ukraine (Geoportal of the State Aviation Service of Ukraine, 2020). To solve the issue of modernization and reconstruction of regional airports, bringing its infrastructure to the requirements of the International Civil Aviation Organization (ICAO) and to modern safety requirements and passenger services at the state level designed and implemented program will be done in the 17 regional airports to take a prominent place in transport infrastructure.

The structure of the airport is quite complex and includes a large number of different elements that make up a single, clear and well-functioning complex. All airport buildings and facilities of the complex can be divided into three groups by location and functionality (Figure 1):

- airport (terminal) – (one or more);
- an airfield that includes runway, taxiways, platforms, airplane parking areas, end and side safety lanes, overburden, deviation pad, engine launch pad, etc.;
- service and technical territory, including hangars, repair shops, fuel and lubricant stores, post and cargo terminals, on-board power supply, transformer substation, compressor station, emergency rescue building, motor vehicle transport storage facility, vehicle transport bases, radio navigation and communica-

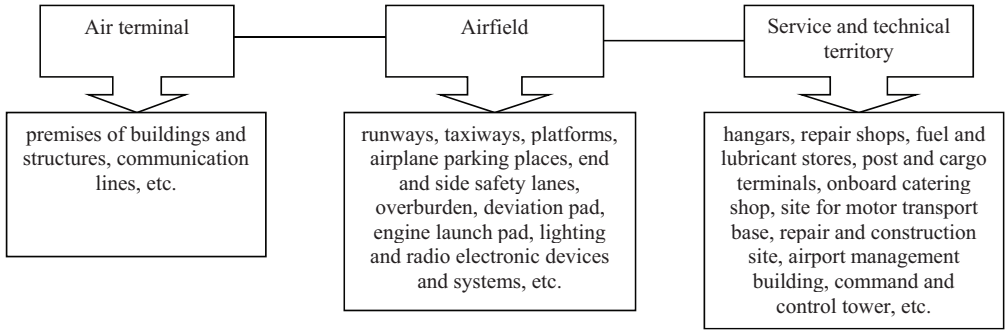

Figure 1. The constituent structures of the airport complex by location and function

tion services, boiler room with reserve fuel warehouse, main mechanic's workshop building, airfield service base, car access and road repair and construction section, warehouse logistics property, service dining room, building control airport training and technical unit, command and dispatch tower station square plot refueling and so on.

Also in the infrastructure of the airport are lighting and electronic devices and systems necessary to ensure the safety of aircraft operations, communication lines, water supply, sewage, etc.

The organizational structure and management system of airport complexes at different airports differ, depending on the area of the territory, available economic assets, passenger traffic, etc. But it is mandatory to have:

1) the engineering and technical services providing maintenance of buildings and structures;
2) the airfield service responsible for the maintenance of the airfield and airfield area (runways, taxiways, carriageways, etc.);
3) the services responsible for managing the facilities of the airport and the terminal area;
4) air navigation and flight safety services;
5) airport security service and others.

4. Research the world and domestic experience

Using the design concepts of the GIS development of Boryspil Airport, scientific and practical articles of ArcReview, the research of architecture, methods of gathering geospatial information and functionality of geoinformation systems was performed for administrative and economic management of airports: Boryspil (Ukraine), Houston (USA), Atlanta (USA) Los Angeles (USA), Geneva (Switzerland), Perth (Australia).

On the example of work (Hartsfield-Jackson Airport Representatives, 2016) it presents a window of GIS airport Atlanta (USA), a viewer for a maintenance team that provides access to all the data necessary for its efficient operation. (Figure 2). GIS is implemented on the ArcGIS platform based on a common centralized Web GIS, the system supports both daily and local data updates in the cloud environment to ensure business continuity. And a number of applications for ArcGIS, including Collector for ArcGIS, Operations Dashboard, Explorer for ArcGIS, ArcGIS Pro and others, created with the help of the Web AppBuilder constructor allow to expand the possibilities of interaction with the system of any employee in the organization at any time, anywhere and at any device.

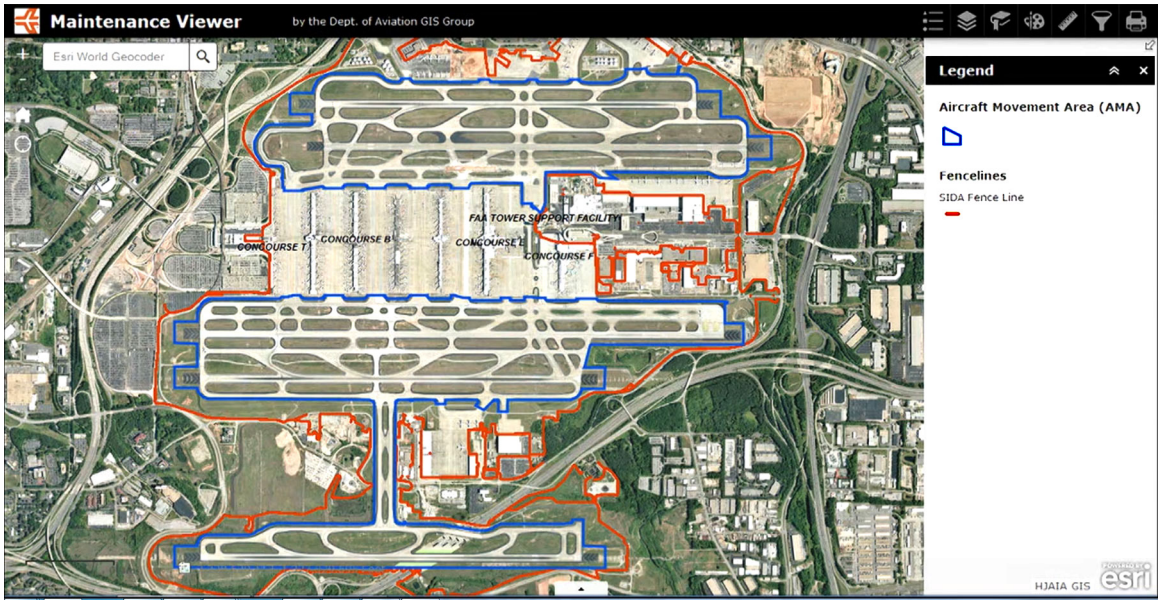

Figure 2. The viewer for a maintenance team that provides access to all the data necessary for its efficient operation (Hartsfield-Jackson Airport Representatives)

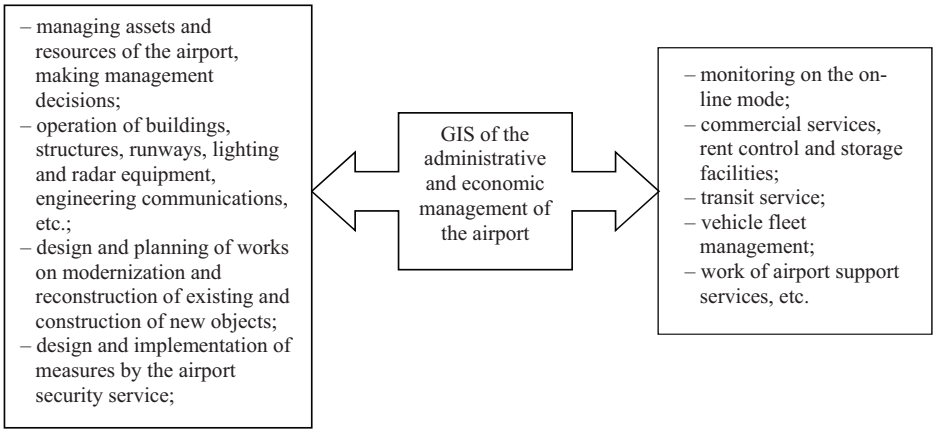

Figure 3. Generalized scheme of directions of application of GIS at airports

Experience shows that taking advantage of the ArcGIS platform helps to support the successful operation of the airport and achieve its top priorities: efficiency, high quality of service and safety.

By analyzing the global experience of using GIS at airports for administrative and economic management, it could be distinguished different groups of users served by GIS: operators, planners, mobile flight crews, repairers and technical personnel for engineering communications and facilities, decision makers, airport security, contractors, inspectors, passengers, customers and the public. Spatial planning and efficient management of airport infrastructure require detailed information on the location and condition of their sites, regular collection and accounting of accurate spatial data, and the ability to analyze them.

On the basis of GIS analysis of administrative and economic complexes of airports of the world, it could be formed a generalized scheme of directions of GIS application at airports: property management and rent control; warehouse management; capacity estimation and planning and passenger flow calculation; vehicle fleet management (equipment monitoring, cost accounting and fuel spill); terminal management; setting boundaries and checkpoints; reconstruction of the airfield complex; business services and service; ensuring the safety of the aerodrome complex; transit service, etc. (Figure 3).

The main areas of use of GIS can be distinguished:

– general management of the airport complex, management of assets and resources of the airport, operation, monitoring, spatial planning, reconstruction and construction;
– management of the airfield as a component in the structure of the airport complex;
– management of business infrastructure that includes real estate and engineering communications.

5. Research on international and national standards

Geoinformation systems provide the ability to collect, process, analyze and provide the necessary data from a common array of geospatial data, which forms a single information space that operates on the basis of common principles and general rules. The use of uniform requirements and standards ensures the interaction of all subjects of the management system, as well as meeting its needs; promotes topological, communication and interoperability and interoperability of information systems and registers at the airport; eliminates duplication of work on the formation and support of information resources and cost savings.

The development of the airport geo-information system concept should be implemented in accordance with international and national standards, as well as the European geospatial data infrastructure (INSPIRE), which aims at creating a European Union spatial data infrastructure for the purposes of EU environmental policy.

According to the INSPIRE Directive, regulations should be implemented by the INSPIRE Implementing Rules in the following areas: metadata, data specification, interoperability of data and services, network services, monitoring and reporting. Integration of information about objects collected from different sources is ensured by the use of unified object catalogs and classifiers, unified object identifiers, unified address links using unified registers, a single digital topographic basis of the territory (Cherin, 2019).

Compliance with international standards ISO 19100 "Geographic information / Geomatics" provides data usage through international projects, access to open data, services and applications that can be easily integrated without need for refinement and based on common standards and concepts of modern information technology.

Compliance with Ukrainian Standards "Geographic Information. Reference Model", "Geospatial Data Modeling Rules", standards system "Topographic Database" provides the creation, integration and accumulation of data across different units and organizations, allows to use the accumulated data and integrate it into a single information array; provides information and interoperability of system components within the National Geospatial Data Infrastructure on

the basis of a unified structure, unified system for classification and coding of topographic objects and their attributes, rules for digital description of vector data and digital terrain models, metadata for topographic objects and topographic data sets, export / import formats of topographic data in the process of information components interaction in the system environment and with other systems.

6. Identification the elements of a single digital topographic basis

The basis of the geoinformation system of the administrative and economic management of the airport is the Unified digital topographic basis of the territory and adjacent areas, which is formed as a geodatabase and includes basic and thematic datasets of spatial objects with attribute information, search, filtering, sorting, scaling and viewing geospatial data tools.

Today, there is a wide range of geospatial data collection technologies using modern technologies: GNNS observations, tacheometric shooting, according to aerial photography, laser and lidar scanning, georadar shooting, etc. When choosing the technology for collecting location data, it is necessary to take into account the area of the territory, the intensity of the airport, traffic levels of the runways (Boyko et al., 2019).

The base set of geospatial data forms the core of geographic information resources through which spatially and thematically united all other geospatial data – attribute, profile, case. Base kits should be stored in an integrated repository that collects, updates, and provides general-purpose geospatial information.

Basic data sets of the geospatial data of the airport include information resources of the Uniform Digital Topographic Basis: mathematical and geodetic foundations; digital topographic base ground and underground parts of the airport (digital raster and vector models of topographic plans of the territory in scale 1:2000 and 1:500); digital orthophotomaps; aerial and satellite imagery, lidar data capture; digital relief model (DRM) and digital terrain model (DTM); terrestrial laser scanning data.

Geospatial thematic datasets include all types of geographic data that are created using basic datasets and meet the requirements of standards for geographical information and metadata hosted in an information environment in compliance with the principles and rules of access and use of geo-information resources. Thematic geospatial data sets of the airport include land boundaries with cadastral numbers, owners and functional data; geospatial data of all engineering networks and structures with characteristics; registers of artificial coverings; register of buildings and structures with characteristics; geospatial models of all thematic zones at the airport territory; register of high-altitude objects and obstacles; geospatial object models of all registries, created and maintained by major GIS core entities with attributes of identification, address binding, purpose and functional use.

Geospatial profile sets could also be generated by extending the attributes of the underlying set objects while maintaining coordinate-spatial and topological compatibility. Figure 4 presents the generalized scheme of the database composition of the Unified digital topographic airport base, basic and profile geoinformation resources, that developed as a result of the research.

Spatial binding of individual objects could also be performed using the following source materials: the master plan of the airport; digital base plan of the airport; land inventory materials; materials of land plots allotment of the past years; executive shoot materials. During registering the spatial location of new objects and its spatial referencing using a digital topographic plan it is necessary to monitor the spatial and topological consistency, with the geometry of the objects contained on the Uniform Digital Topographic Base.

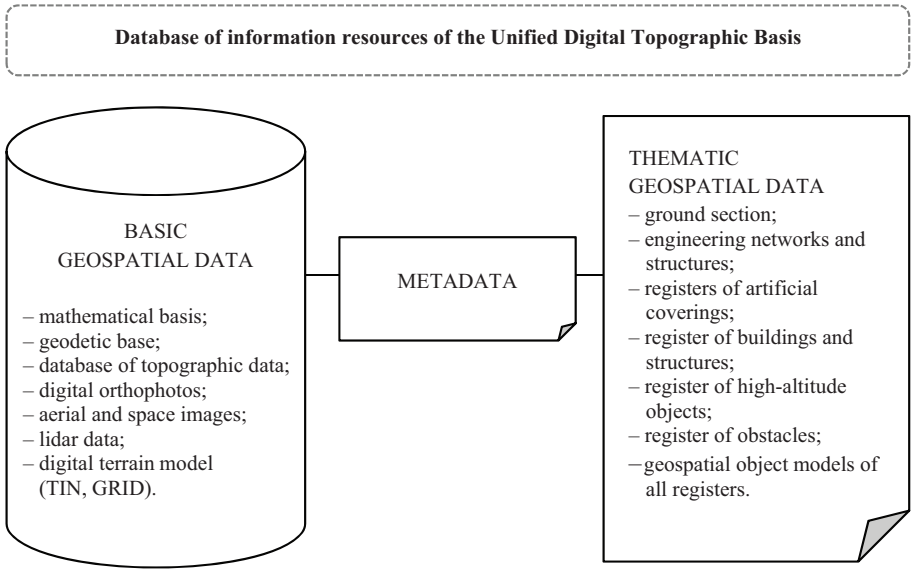

Figure 4. Database schema of the Unified digital topographic airport base

7. Conceptual model of the geoinformation system structure for administrative and economic management of regional airports

Based on the analysis of the organizational structure, geospatial data used by the airport units, international and domestic experience in geoinformation systems creating, including airports GIS, national and international standards for the creation and display of geospatial information, the structure has been defined and a conceptual model of the general type of geoinformation system for airports administrative and economic management has been developed.

The conceptual model of structure and functional purpose of GIS of administrative-economic management of the airport has been developed, and it reflects the main production processes and needs of airports, based on the database of the Unified Digital Topographic Basis, is a coherent and consistent model of the relationship between the administrative and economic needs of airports and the functionality of modern geoinformation systems for the efficient operation of facilities, structures and engineering communications, analysis of the existing state, monitoring and management decision-making (Figure 5).

In the conceptual model for effective management of the airport complex is proposed to create three geographic information subsystem on the Unified Digital Topographic Basis:

- management of economic infrastructure, which includes thematic data on land resources (land boundaries, their area, purpose and functional use, distribution by users, property rights, restricted zones and encumbrances, etc.), and real estate data (contours of buildings and structures with quality characteristics, areas, passport data and functional use); this subsystem aims at maintaining land cadastre, controlling land use, leasing premises, developing a master plan, planning for modernization and reconstruction, etc.;
- management of engineering communications, which includes thematic data on engineering networks (water supply, household, pressure, drainage and drainage sewerage, gas pipeline, cable sewage of telecommunication and communication lines, video

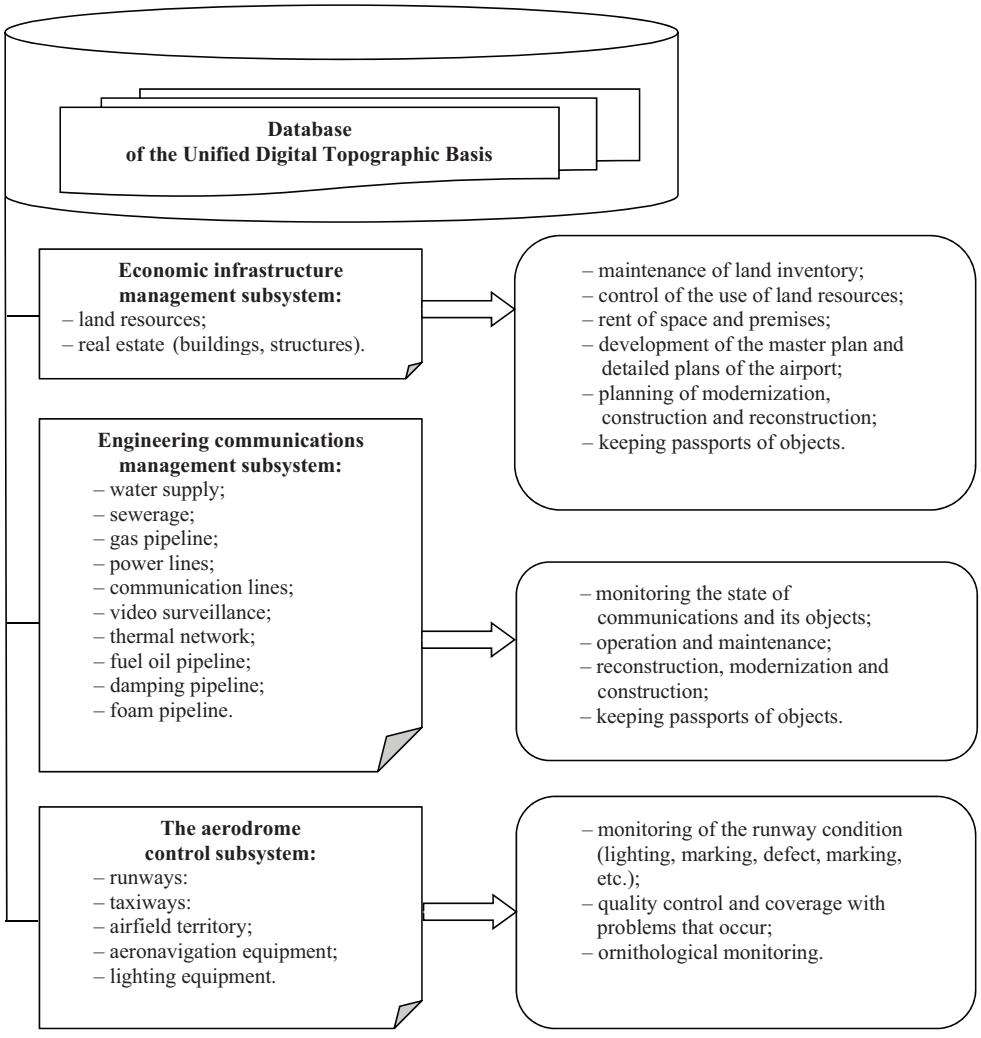

Figure 5. Conceptual model of structure and functional purpose of geoinformation system for administrative and economic management of the airport

surveillance system, thermal network, electrical network, fuel oil, gas pipeline, foam); this subsystem aims at monitoring, operation and reconstruction of utility networks;
– aerodrome management, which includes thematic data about runways and taxiways, its cover and state, lighting and air navigation equipment, etc.; this subsystem aims to monitor the state of the aerodrome and runway (lighting, marking, defect, marking, etc.), quality control of the cover with fixing problems that occur, etc.

For developing the concept, the main functions and capabilities of GIS have been identified, which should be implemented for the administrative and economic management of the airport: management of large data sets and different types of information about objects that are subordinate to different services on the Unified digital topographic basis; solving tasks related to forecasting, planning and modeling; solving complex problems related to spatial planning, reconstruction, construction, operation of objects and structures; centralized storage and administration of data.

Applied tasks that are solved by the administrative and economic GIS of the airports are as follows:

providing up-to-date information to the structural units of the airport regarding the location and condition of the engineering systems, areas of structures and other objects;
– monitoring of land use and protection;
– operation of buildings, structures, utilities and communications;
– visualization of all assets in 2D and 3D;
– integration of information modeling of buildings and structures for further operation and reconstruction.

The main software for the creation of the geoinformation system of the airport is considered the line of ArcGis software by Esri Company (USA), that is world's leading company for the development of tools for the creation of geographical information system, which meets the basic requirements of international standards. The ArcGis software enables interoperability with other airport and state geographic information systems within the National Geospatial Data Infrastructure.

8. Discussion and interpretation the results obtained

This investigation has been limited to the conceptual foundations development of the regional airport geoinformation system structure for administrative and economic management and generalization its functions. The performed research is the basis for further development of the logical and physical model of airport GIS. The conducted research is also an integral part of the introduction of modern high-precision methods of collecting and processing geospatial data of the airport territory to create the Unified digital topographic base, integration of BIM / GIS models of airports buildings and structures, development of logical, physical and technological models of GIS-system and its subsystems, determination of the list of attribute data for each object, use of GIS-system for operation and reconstruction of the airport (Prusov, 2009, 2012).

The research have a practical direction, focused on the introduction of geoinformation technologies for managing the economic complex of the airport, improving the method of engineering and geodetic surveys and the collection of geospatial data.

Conclusions

The main results of the performed researches are correlate to the tasks set, including formation the structures and objects of the airport complex as well as components by location and function have been selected; to develop a generalized scheme of directions of administrative-economic GIS application at airports; to establish the necessity of using international and national standards during creation the airport GIS; to develop the database composition scheme of the Unified digital topographic airport basis; and as a result to create the conceptual model of structure and functional purpose of GIS for administrative and economic airport management.

As a result of the performed researches, it has been established the following:
– all structures and objects of the airport complex have been structured, thematic blocks have been identified and components have been allocated by location and functional purpose for the development of the conceptual model of GIS administrative and economic complex: business infrastructure block, utility network and communications block, airfield control unit;
– application tasks and a set of functions for GIS of administrative and economic management of the airport have been established, a generalized scheme of directions of application of GIS in airports has been developed;
– the list of standards, as requirements to be considered in the development of GIS for the administrative and economic airport management has been identified, as well as the necessity of using international and national standards of the series "Geographic Information / Geomatics" in creating the GIS of the airport has been established;
– the list of basic and profile sets of geospatial data of the digital topographic basis of the airport has been formed, and a generic scheme for the composition of the database of the Unified Digital Topographic Base of the Airport has been developed;
– the conceptual model of structure and functional purpose of GIS for administrative and economic airport management has been suggested and developed.

The application of the proposed conceptual model is the scientific basis for the development and implementation of GIS for the management of the regional airports economic

complex, that have modernized its infrastructure and management system at Eastern Europe countries in recent years. World experience shows that the implementation of such geo-information systems increases the efficiency of available assets and resources using, provides control over the operation of airport infrastructure facilities, flight safety by monitoring the runway, etc.

The developed conceptual model would allow to optimize and increase the efficiency of the airport and its services, would allow to shorten the terms of design and operational works, while improving the quality of data collection, processing and systematization.

Implementation of the developed scientific and methodological conceptual model of structure and functional purpose would provide opportunities for monitoring of all property assets – from buildings, structures, utilities, to the runway conditions, would expand opportunities for access to geospatial data and its analysis for representatives of all interested airport services, and would provide opportunities for improving the property management efficiency, would promote the development of air transportation, accounting and forecasting of passenger flows, that would have a positive economic effect on the development of regional airports, as well as aimed at supporting and providing the system of designing and planning the development of regional infrastructure with the development of new regulations for solving the urgent tasks.

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