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The Mapping Maintenance of Belarusian Aerodromes

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Abstract: The article reads about a Belarusian aerodrome territories mapping maintenance scheme. It consists of exploitation, aeronautical, ecological, ornithological, meteorological and managerial blocks. According to the regional role in the republic's air transport system, aerodromes are divided into four types: international airports, regional aerodromes, local aerodromes and decommissioned aerodromes. Characteristics of electronic terrain and obstacles data creation of Minsk-2 and Homiel aerodromes are considered. The authors proposed directions to improve the existing mapping products on the example of scheming an aerodrome aviation noise sanitary protection zone and the use of the ornithological GIS-model.

Keywords: Aerodrome, aerodrome territory, mapping maintenance, digital terrain model, aerodrome mapping database

1. Introduction

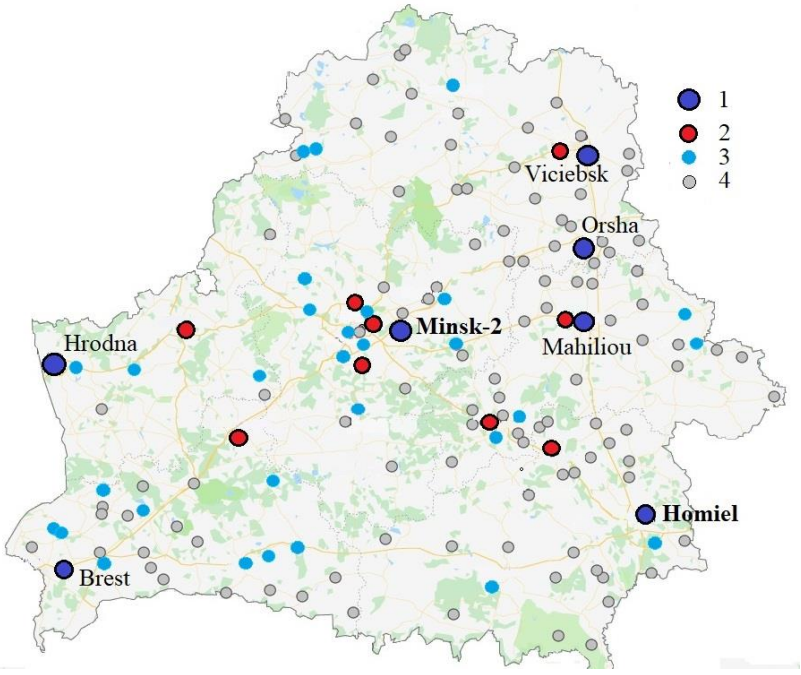
Over recent years, ex-USSR countries' aerodromes have significantly increased the activity on preparation of geospatial and aeronautical information to comply with the standards of the International Civil Aviation Organization (ICAO). According to ICAO terminology and classification, surveyors and cartographers are the originators, i.e. the suppliers of the basic information for the aircraft routing on the ground and in the air. The topical matter of the development of air transport cartography is its territorial belonging, which implies the functioning of the ground infrastructure of state air transport. The use of the term "mapping maintenance" reflects the diversity of mapping works used in this field, including the elements of classical cartography and geoinformation systems. Elements of the aerodrome transportation network require permanent monitoring of the runway's operational suitability, control of the obstacle altitudes and airdrome area environmental conditions. The mapping maintenance scheme of Belarusian aerodrome territories taking into account the entire life cycle of the aerodrome complex from design to disposal is proposed and substantiated for the first time in this research.

2. Belarusian Aerodrome Transportation Network

Belarusian aerodromes are the ground infrastructure of the state and civil aviation. Civil aviation satisfies the needs of citizens and organizations and supports passenger and cargo traffic. State aviation serves the military, border, customs offices, plays a huge role in law enforcement, emergency prevention and response, etc. The aerodromes are also divided into international and local airlines [1].

There are seven international airports in Belarus – Minsk-2, one each for the regional centers (Brest, Viciebsk, Homiel, Hrodna, Mahiliou) and Orsha cargo airport. The National Airport "Minsk" operates as a separate enterprise, the regional airports are part of the state enterprise "Belaeronavigatsia" and are its branches. Joint deployment aerodromes for civil and state aviation are Lipki (Ministry of Emergency Situations and Army, Air Force and Navy Volunteer Society) and Machulishchi (Ministry of Defence and Army, Air Force and Navy Volunteer Society). The total list of landing grounds of state aviation includes more than 50 points. Some of the state aerodromes are ruled by the Army, Air Force and Navy Volunteer Society - Kamenets, Novo-Pashkovo, Minkov, etc. Today the main function of Belarusian local airlines is cargo traffic, firefighting, medical flights, etc. There is no regular local passenger air service as such, with the exception of the seasonal route Minsk-Homiel-Minsk. It should also be noted that there are more than 50 decommissioned aerodromes on the territory of the republic.

The information basis for improving the ground infrastructure of air transport can be typification of aerodromes as outlined in their importance for the republic transport system in general, as well as the specialty of mapping maintenance in particular [2].



Symbols: 1 - international airports, 2 - regional aerodromes, 3 - local aerodromes, 4 - decommissioned aerodromes

Fig. 1 Belarusian aerodromes. Source: authors

The republic aerodromes can be divided into:

1) International airports – twenty-four-hour (Minsk-2, Homiel) and daytime operation (Brest, Viciebsk, Homiel, Hrodna, Mahiliou);

2) Regional aerodromes, which include joint deployment aerodromes (Lipki and Machulishchi), regional bases of the DOSAAF (Borovaya, Peschanka, Novo-Pashkovo, Sichkovo, Minkov), as well as military aerodromes Lida and Baranovichi;

3) Local aerodromes - remaining certified landing grounds;

4) Decommissioned aerodromes.

Like any anthropogenic object, aerodrome has its own life cycle - design, construction, exploitation, reconstruction and utilization [3]. At each of these stages a number of typical mapping and surveying works are carried out. According to the Air lows regulations, the aerodrome area is a limited area, over which aircraft are maneuvered. Dimensions of the airdrome territory are different for civil and state aviation depending on the size and technical characteristics of the runway, the measurement center is the aerodrome control point. The maximum size of the airdrome area is 45 km from the aerodrome control point.

3. Scheme of Belarusian Aerodromes Mapping Maintenance

Aerodromes are one of the aviation transport hotspots in the post-Soviet area, most of them were built in the 70-80s of the last century and worn out. To ensure efficient operation and flight safety, each aerodrome must have a technical passport and the Verification Certificate of Readiness. Aerodrome Mandatory certification is carried out every 5 years, which is the maximum period between documentation updates.

In order to obtain the Verification Certificate of Readiness, each aerodrome must submit a technical feasibility evaluation based on geodetic and aeronautical survey materials, as well as a comprehensive description of obstacles. The results of topographic and geodetic works on obstacle recording and control are presented as a list with obstacles rectangular and polar coordinates and their absolute heights. They are also presented in a graphical form on the plans of the restriction surfaces with the definition of critical obstacles, the altitudes of which exceed the allowable norms. The heights and the plane position of the obstacle limitation surfaces are calculated by the specialists of the air navigation services. The basis for these calculations is the data obtained as a result of topographic and geodetic surveys. For these purposes, the Certification Requirements for Airfields of Belarus provide special areas of obstacle detection. They have a certain plane-high attitude position on the ground and were calculated according to these rules. Each obstacle detection area has its own requirements for the accuracy of the data provided. It should be noted that civil and

state aviation aerodromes have different spatial parameters of the obstacle altitude detection zones, the requirements for the coordinate accuracy also differ.

As a rule, the main part of projects on geodetic support of airfields in Belarus is carried out by two large state enterprises - Belgeodesy and Belgiprodor. Also, these types of works were partially carried out by large Russian organizations. Here it is necessary to mention the project "Geodetic maintenance of aviation of the Republic of Belarus", which have been carried out in 2007-2008 by research and production company "Geodinamika". Also, a number of surveys and works on design were carried out by specialists of Russian enterprise "Lenairproject". Since monitoring of obstacles is carried out by different organizations, the survey data is often not comparable and contains errors. At present, Belaeronavigatsia is trying to unify these processes and create an obstacle database to the republic territory in accordance to the requirements of the Aviation rules, but so far it has not been put in practice.

In order to consider all the aerodrome's needs, the mapping information should connect the type of the aerodrome with its life-cycle period. On the basis of information analysis on the aerodrome exploitation and the intensity of landing operations in Belarus, the authors proposed a scheme of Belarusian aerodromes mapping maintenance in accordance with Table 1:

Table 1 Blocks of Belarusian aerodromes mapping maintenance. Source: authors

Exploitation	Geodetic surveys
	Land-use plan
	Urban development plan
Aeronautical	Aeronautical maps
	eTOD and AMDB
	Common state obstacle database
	Constraints map for drone aircraft
Ecological	Enviroment impact assessment such as GIS-geochemical mapping
	Ecological passport
	Sanitary protection zone such as noisy map chart
Ornithological	Aviation rules charts
	Ornithological GIS-model
Managerial	GIS of airport
	Automated information data system of Technical Passport

*Colors: black - existing blocks; green - implemented by the authors; red - proposed for creation.

1) Exploitation - the most extensive and practice-oriented block of the entire complex, aimed at obtaining accurate geospatial information to maintain the permanent air transport ground functioning, as well as to regulate the legal aspects of the aerodrome territory usage by land users. It includes the complex of plans and large-scale maps prepared by geodesists for aerodrome requirements as an operator, land use and urban planning, as well as constraints map for drone aircraft.

2) Aeronautical block contains mapping data used by the Aeronautical Information Service and describing the conditions for the aircrafts landing on the territory of an aerodrome. It also includes electronic terrain and obstacle data (eTOD) with a digital terrain model (DEM) of the aerodrome area and an aerodrome map database (AMDB).

3.1 Electronic Terrain and Obstacle Data

Electronic terrain and obstacle data (eTOD) is a geospatial dataset that corresponds ICAO requirements for on-board application and desktop safety software. eTOD is notable for different requirements for horizontal and vertical data accuracy for each geospatial zone of aerodrome territory. The procedure of eTOD creation is not regulated, so the mapping data executant should be guided by the National legislation and aerodrome certification requirements. At present, the eTOD creation is recommended for all international airports, and these works have been carried out for two aerodromes - Minsk-2 and Homiel (2015-2019) for the first time in Belarus.

The specialty of the Belarusian eTOD version is the tender procedure for data creation executant: the State Enterprise "Belaeronavigatsia" chooses executant on a competitive tender basis and winner carries out data creation under the Customer and the Interstate Aviation Committee expert control. The most rational ways to create the Belarusian version of this product were the use of ground-based instrumental geodetic surveying in combination with the creation of DEM from archive satellite data and ultimate commercial digital terrain models [4].

Digital mapping datasets include:

- Digital aerodrome area terrain model;
- Aerodrome mapping database (AMDB) with navigation elements and obstacle altitudes;
- Location and terrain data converted to AIXM 5.1 aeronautical data exchange model format.

For digital terrain model creation the aerodrome area is conditionally divided into three zones with certain way data collection processes:

- Aerodrome zone (includes areas 4, 3, 2a according to ICAO classification);
- Aerodrome area within a radius of 10 km from control aerodrome point (includes ICAO areas 4, 3, 2a, 2b, 2c);

- Aerodrome area between circles within a radius of 45 km and 10 km from control aerodrome point (includes ICAO area 2d).

The World Geodetic System 1984 (WGS84) was adopted as a horizontal reference frame for the ITRF2014 implementation, which made it possible to take into account the tectonic plate movement impact for the Earth's crust. The vertical reference frame is the mean sea level (MSL) expressed through the Earth's Gravity Model 2008 (EGM2008).

Data collection of on the aerodrome zone terrain should be carried out by an instrumental methods (GPS/GLONASS geodetic satellite receivers), and identification of obstacle altitudes should be carried out using satellite stereo images with spatial resolution not worse than 0.5 m/pixel and not more than half a year from the product receipt date for eTOD creation works. A geodetic survey of navigation elements to form AMDB was performed using GNNS definitions.

Obstacle altitudes geodetic survey of 2A, 3 and 4 areas was carried out by RTK-GPS observation method with receiving corrections from the base receiver installed at the points of the aerodrome geodetic reference network. Control over the coordinate determination of aerodrome navigation elements in the WGS-84 coordinate system was carried out as a result of repeated GNSS observations in relation to the points of the aerodrome geodetic reference network. Control over the coordinate determination of aerodrome radio-navigation facilities in WGS-84 coordinate system was carried out as a result of repeated linear and angular measurements by an electronic tachymeter installed at the points of survey justification determined by the GNSS observation method in relation to the reference geodetic network points. Information was encoded using cyclic redundant CRC-32 code to ensure its integrity after data import from surveying equipment.

Vectorization included point generation, linear and area obstacles using survey points. Geometry generation of area obstacle objects represented by forests was made by the forest boundary contours digitization of using actual orthophotoplans with a spatial resolution of at least 0.7 m/pixel. AMDB final product was formed in compliance with the requirements of topological correctness of geometric elements describing the aerodrome objects presented in RTCA-272C. AMDB vectorization was performed with the displaying of all information about of aerodrome navigational element altitudes to form a three-dimensional representation of all information of aerodrome elements.

A different set of semantic data was assigned for each AMDB object classes in accordance with the RTCA-291C requirements. AMDB converting was performed in the following universal formats:

- format Arcinfo *. shp;
- AMXM format of aeronautical information exchange;
- A set of AMDB tables in CSV and XLS formats;

- Transitional MIF/MID format for mapping information export to AIXM 5.1 air navigation information exchange format.

Table 2 Technological chain of electronic terrain and obstacles mapping data

Stage 1. Preparation
1.1 Creation and organization of systematized data storage for field measurement and transitional data
1.2 Development of the work program and methodology in accordance with ICAO documents
Stage 2: Geodetic aerodrome work in 4, 3, 2a Areas
2.1 Select of remote sensing data
2.2 Aerodrome geodetic reference network inspection
2.3 Aerodrome navigation element coordinates and altitudes surveys
2.4 Aerodrome radio-navigation aids coordinates and altitudes surveys
2.5 Obstacle identification, surveys and determination in 4, 3, 2a Areas
2.6 Coordinates and altitudes round control points determination for photogrammetric works
2.7 Control measurements
2.8 Obstacle data converting into AIXM 5.1 format.
Stage 3: Geodetic and photogrammetric works in aerodrome areas
3.1 Space images processing photogrammetric works
3.2 DEM creation of 4, 3, 2 Areas
3.3 Obstacles coordinate and altitude identify in 2b, 2c, 2d Areas
3.4 AMDB creation in AIXM 5.1. and AMXM formats
3.5 AMDB and obstacle data converting into AIXM 5.1 format

Quality control of AMDB digital product in AMXM format was performed using "amxm.xsd" XML-chart from the official website http://amxm.aero/ using Altova XMLSpy and Luciad AIXM5 Viewer software products.

The Pilot Program and methodology of Belarusian aerodrome eTOD creation was developed by the expedition of the Aerodrome Design Division of the State Enterprise "Belgiprodor" in 2015-2016. Later, eTOD data was renewed for the Minsk-2 aerodrome because the second runway was brought into service in 2019. In the future, the eTOD data will be changing for all international airports in Belarus within the ICAO Roadmap framework as a stage of the overpass from the Aeronautical Information Service to the Aeronautical Information Management.

3) The ecological block of mapping maintenance contains the results of aerodrome territory environmental impact assessment: both the impact of aircraft and the consequences of the

aerodrome operation. Its specificity in count environmental requirements of ICAO and Belarusian legislation (procedure of environmental impact assessment, design of sanitary protection zones and Environmental passport preparation) [5].

It is necessary to mark the problem area for further research and management decisions, as the interests of ICAO and national legislation are different in environmental issues. Ecological mapping data according to the Law of the Republic of Belarus "About the state ecological expertise" and Technical code of common practice "Estimation rules of an environmental impact assessment (EIA) and preparation of the ecological report" should contain alternative variants of object planning, nature protection and planning restrictions (especially natural protected areas, wild animals habitats and growth of red-listed species plants, water protection zones, etc.), places of sampling and potential zones of possible influence on the environment.

According to existing ICAO's aviation ecology approaches, the most common environmental impacts from operational changes are noise, air quality, fuel consumption and greenhouse gas emissions, although other areas of impact may be considered at the national or local regulatory level. The international regulation priority directions are pollution inventory and emission compensation systems development for international aviation in terms of pollutants, such as CORSIA for carbon emissions [6]. Thus, national environmental legislation is primarily interested in assessing the spatial pollution distribution in the aerodrome area, and international legislation is interested in assessing the total amount of pollution.

4) The ornithological block includes both mapping charts with attractive objects for birds and directions of their seasonal migration, provided for the aviation rules creation. It may include geospatial analysis products;

5) The managerial block runs about airport geoinformation system (AGIS) creation, the purpose of which is to optimize the airport functioning and create Automated Information Systems for low-intensity aerodromes.

4. Proposed improvements for Belarusian Aerodromes Mapping Maintenance

4.1 Aircraft Noise GIS-mapping for Clarifing Sanitary Protection Zones at Low-intensity Aerodromes

The flights intensity at the republic aerodromes and landing sites is predominantly low, despite the fact that National Airport "Minsk" is among the 100 largest airports in Europe in terms of daily flights served number. The takeoff and landing operations number does not allow to perform a sufficient number of field measurements of aviation noise level to ensure confidence level according to State All-Union standard 22283-2014. However, airdrome area spatial noise zoning

should be carried out during the renewal of the sanitary protection zone boundaries, EIA procedures and the development of an aerodrome Ecological passport [7].

The solution to this problem may be GIS-mapping with the "Natural neighborhood" method interpolation on the basis of field measurements of the maximum aircraft noise level in accordance with Figure 2. The results of graphical modeling of noise values predicted can be attached. It should be 2 certified instruments performed for at least 10 measurements during most noisy aircraft landing operations. The main task of instrumental measurements and interpolation is the daily boundaries determination of the noise zones and the sanitary break line determination using the value of La max = 70 dBA. This approach was tested by the author on the fieldworks data for Homiel aerodrome in the summer of 2017-2018 and has established as the most rational for low intensity aerodromes with the landing operations number less than 2000 per year (is specified for all Belarusian aerodromes, except Minsk-2) [8].

GIS soil and geochemical mapping of Zyabrovka aerodrome located in the Homiel suburban area, the territory of which is currently considered as a perspective for urban planning, was performed.

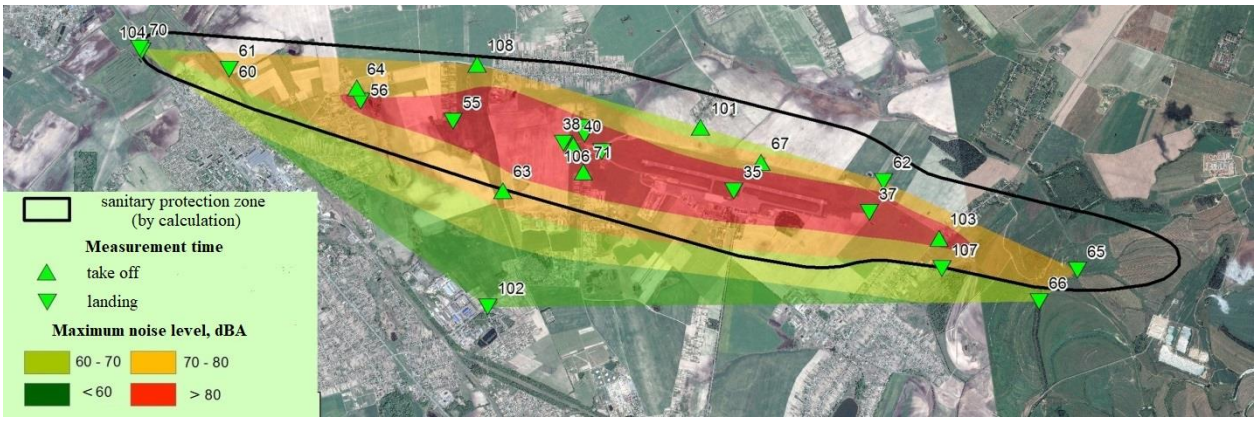


Fig. 2 Interpolation results for aviation noise instrumentally measured values on the basis of LA max indicator at Homiel aerodrome territory. Source: authors

Twenty samples of forest and grassland soils were taken at different distances from the runway edge, including aircraft parking areas, technical maintenance areas and etc. as shown in Figure 3. A sampling of mixed soil samples was carried out by envelope method from the depth of 0-0.2 m in accordance with State All-Union standard. Displaying the results of soil and geochemical survey by mono element maps compiling allows to perform data spatial analysis with satellite data as a base layer and DEM. Maps are being built according to the sampling points network data with the Inverse Distance Weighting (IDW) interpolation method. Soil and geochemical testing did not reveal any exceedances of maximum permissible concentrations for Cu, Pb, Mn, Ni, Sn, Ti and Cr, as well as exceedances of these elements background concentrations. Minor increases in lead concentrations were observed only in the administrative and storage areas. The aerodrome was

decommissioned since more than 20 years have elapsed and mapping results may indicate a local soils high self-cleanability and the removal of the analyzed compound into the groundwater and aeration zone. Geochemical GIS-mapping is recommended by the article author as a mandatory component of the EIA for the aerodrome utilization [9, 10].

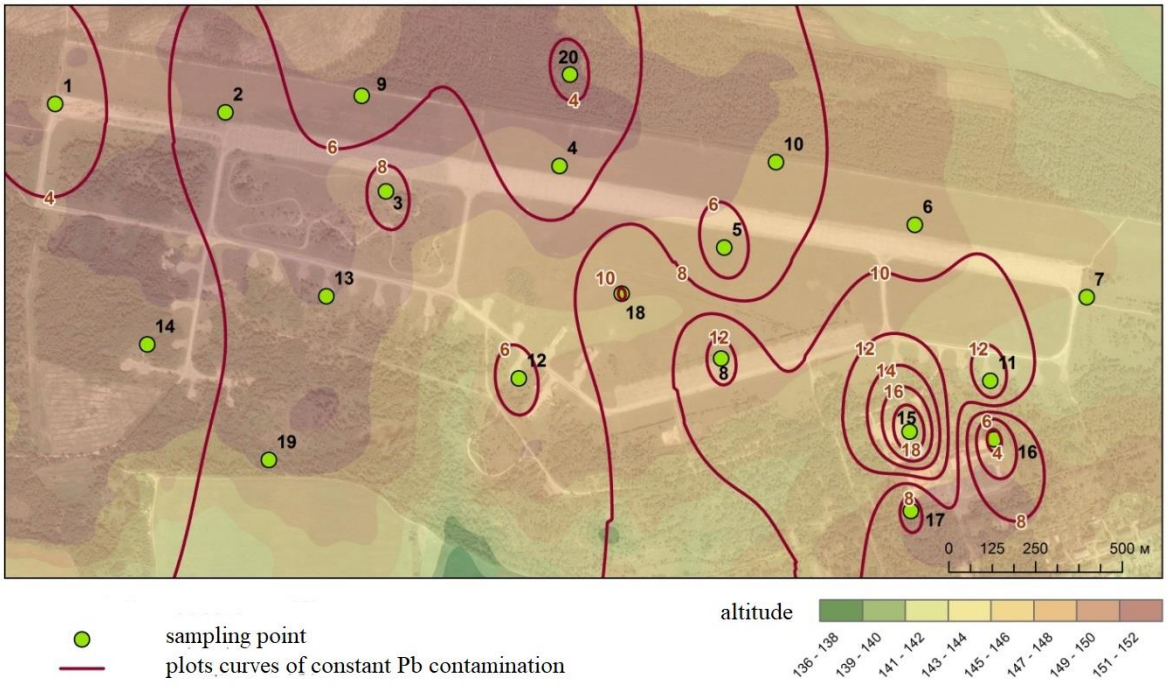


Fig. 3 Lead Pb isolines soil map of Zyabrovka aerodrome, mg/kg**.** Source: authors

4.2 Spatial-temporal Ornithological GIS-model.

Using GIS to estimate the birds number and aerodrome areas distribution is common practice in the world. But similar work involves a lengthy field data collection and therefore it's difficult in conditions of Belarus because regular ornithologists are present only at the National Airport. Spatial-temporalOrnithological aerodrome territory GIS-model is offered as an affordable alternative to paper maps. It is implemented by the authors as a Python programming language script. The model has two main components:

a) GIS - contains vector coordinate-tied points data with birds concentration places (nesting, feeding, etc.) and polygonal data with aircraft landing routes in accordance with aircraft type. Both desktop GIS and web-mapping services (ArcGIS Online, GeoMixer, etc.) with mobile applications for creating, storing and visualizing spatial layer data can be used;

B) Common bird species dictionary with their migration periods and aircraft altitude characteristics.

Predictive map with the danger zones of possible collision of a certain birds species with aircraft and a text report indicating season and possible collision height at the script results can be

obtained. The model advantage is the possibility of its continuous filling with web services data and mobile applications through their field collection from volunteers. Application of the above described model will allow improving ornithological aerodrome support, determining bird-dangerous conditions of aircraft landing, distributing bird- deterring means, studying the ecological situation and determining more precisely the factors of bird concentration at airdrome territory.

4.3 Aerodrome Technical Passport Automated Information System for the Regional and Local Aerodrome Management.

The creation of a full-fledged aerodrome GIS (AGIS) is expedient only for the National Airport "Minsk" in Belarus due to the significant material costs of its creation. An aerodrome technical passport is a document containing the technical characteristics of the aerodrome and reflecting the availability and condition of the complex of structures, equipment and facilities required for flight support, and is an integral part of the aerodrome manual. This is the main document when ensuring its operation, and it is important to provide convenient and prompt access to its contents to the aerodrome service staff and all interested agencies. The concept Aerodrome technical passport automated information system (ATP AIS) may become an alternative to a full-fledged AGIS. The main principles of ATP AIS implementation include:

A) The vector basis in the shp-file format is represented by the contour part of the aerodrome elements and service-technical territory, visualized on a raster base layer from satellite data;

B) The project serves as a kind of visualized database, where each layer attribute table contains hyperlinks to CAD drawings and text documents ("hot links");

B) The project layers are supplemented by a digital terrain model in the .tin format;

D) All data used for sharing is stored on the organization's cloud service server or in the Internet.

5. Conclusion

Belarusians aerodromes are divided into four types: international airports, large regional aerodromes, local and decommissioned aerodromes. It’s necessary to specify that mostly republic aerodromes have low-intensity landing operations. Aerodrome mapping maintenance products are united into exploitation, aeronautical, ecological, ornithological, meteorological and managerial blocks. Characteristics of electronic terrain and obstacles data creation of Minsk-2 and Homiel aerodromes are considered. New mapping products are proposed to improve existing approaches to Belarusian aerodrome mapping maintenance. These include aircraft noise maximum level GIS mapping, an ornithological GIS model, aerodrome technical passport automated information system and mandatory soil geochemical GIS mapping for decommissioned aerodromes.

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