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GIS-MONITORING OF THE ENVIRONMENT IN AIRPORT VICINITY

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In the paper the synthesis and comparison of the available information on GIS monitoring of environmental factors in the vicinity of the airports is presented. The use of GIS methods for exposure modelling and monitoring has a relatively recent history. Outside inventory and monitoring, the emphasis has mainly been on inventory analysis and dispersion modelling, and on a range of so-called second-generation models have been developed (eg, PolEmiCa, IsoBella, 3PRisk) to support environment protection management in airport vecinity. Designed national models are compared with similar tools designed worldwide. The differences between the tools' calculated results for noise and emission are within the 10%, which are appropriate value taking in mind the differences between the used approaches for modelling. The results of the development can be incorporated into the operation of aviation vehicles in intelligent transport systems.
Keywords: airports, GIS, monitoring, noise, safety, local air quality, electro-magnetic fields.

Introduction. Airports serve a key role in transportation of people and goods and in regional, national, and international commerce. Airports are inherently spatial. From planning to maintenance and security, airport managers need to know where events are taking place. Significant growth in traffic has left many airport properties severely constrained for space. Airport managers must carefully manage competing needs for revenue-generating facilities and effectively readjust facilities for the ever-changing needs of their tenants. Geographical Information System (GIS) can be integrated with property management applications, improving accuracy and timeliness in responding to property information requests.

The needs to develop a new GIS-based airport monitoring method can be reflected from several facts. First, previous studies on using GIS for emissions and noise estimation frequently applied basic capabilities of GIS, such as data processing and mapping; however, recent advances of GIS technology have rarely been found in the applications of modeling mobile (for example, aircraft, airport ground vehicles, etc.) source emissions. Second, the growing attention to reducing mobile source emissions requires that emissions estimation models should not only be limited to obtaining emissions totals for the transportation conformity analysis purpose but also need to serve for identifying effective emissions reduction measures as well as air quality modeling. Third, GIS should play a more important role in modeling vehicular emissions not only due to the natural spatial dependence of emissions modeling but also because the two ends of emissions modeling (travel forecasting and air quality modeling) are often GIS based. The enhanced requirements need emissions inventory models to further improve their accuracy and resolution. Integrating GIS in emissions estimation could fulfill these requirements by offering added value to present data sources, such as local vehicle population data, land uses, and detailed travel activities.

GIS is used in environmental protection (EP) applications are generally developed according to the specific requirements needed to meet the objectives of the airports, airlines and flight control organizations [1]. GIS-based airport monitoring method can be defined as the regulation of the amount, location and time of pollutant emissions to achieve some clearly defined set of ambient air quality standards or goals. It includes the evaluation of various set of emission control schedule to determine consequences to air quality. It also includes the formulation of alternative emission control schedules to meet air quality goals subject to some other constraint, *e.g.*, technological feasibility or minimum cost. GIS-based airport monitoring method is basically a strategy to overcome the problems of air pollution and is most effective towards continuous improvements of air quality, particularly when targeting regional problems.

Analysis of the latest investigations. The conceptual approach of GIS not only provides the capability of querying the spatial data but also, with its inbuilt analytical tools, translates the existing spatial patterns into measurable objectives. GIS facilitates the integration of various field-specific applications into its interface and allows integrated ways to conduct research and develop new analytical approaches to relate their information to the terrestrial activities. These abilities (providing fully functional data processing environment) distinguish GIS from other information systems as it results in enhancing the applications with productive findings that are broadened and deepened in a geographic location.

Commercial airlines, airports and air traffic control regulators use GIS for airspace planning and routing applications as well as for facilities management applications. Recent enhancements to three-dimensional GIS allow more advanced airspace modelling applications to be combined with geographic information from local communities such as parcels, land use, building heights, new construction, and modified terrain around the airport. Management of airport properties was the most popular application, but management of infrastructure, noise programs and storm water programs also received very strong support.

The quality of environment is a very important factor in projecting or representing the status of environment and health of any region. Local air quality (LAQ), electro-magnetic fields (EMF), third party risk (TPR) and noise studies that analyze the quality of environment provide strategic information to the decision making process and play a significant role in the implementation of the policies that influence the environmental quality of a region around the airport in particular [2]. Most of the environmental quality models, in their pollutant and noise levels distribution simulations, consider their physical characteristics such as wind direction, speed, temperature etc., in determining the moving sources of air pollution and noise trajectory. Integrating these models with GIS presents a geographic dimension to the environmental quality information by relating the actual pollution concentrations, noise or/and EMF levels, TPR to the human life in that location. With its numerous analyst tools, GIS can demonstrate the relationship of poor quality of the environment and occurrences of deficient human and environmental health. GIS can portray the spatial correspondence between the environmental quality and the disease (mortality) statistics in the area that is potentially impacted. Examining the relationships between high factor impact across various demographic thematic layers helps in identifying hotspots that are in need of special investigation or monitoring. Having this information makes it easier for planning and implementation groups to expedite projects in accordance with ICAO priorities.

Formulating the task. A growth of an airport can be controlled by setting up flight safety, operational, economic and environmental limits (Fig. 1) [3]. In addition to the increasing traffic demand, new constraints on the traffic flows have been imposed and limited the capacity and efficiency of air transportation. In many cases, the responsibilities imposed on airport operators and EP responders continue to rise, while access to, and timeliness of critical information remains as it always has been. GIS has been traditionally used to support planning, infrastructure development and management activities, for example associated with EP functions. In particular environmental protection consists of prevention, preparation, response, mitigation, and recovery and at airports it usually involves different agencies.

Main purpose of GIS «Airport-EP», which is under the development currently, is to protect public health, safety, and welfare by ensuring the orderly expansion of airports and the adoption of land use measures that minimize the public's exposure to excessive noise, air pollution, EMF and safety hazards within areas around public airports to the extent that these areas are not already devoted to incompatible uses [1, 2]. For this purpose complex tool ALFA – Airport Local Factors Assessment, including PolEmiCa (LAQ), IsoBella (Noise), EMISource (EMF) and 3PRisk (Third Party Risk), was designed to calculate any possible operational scenario in airport under consideration. Specific module ModIST quantifies the technical and economic interactions between mitigation measures for the considered factors and fuel burn (plus greenhouse gases – GHG, if necessary). It assesses the simultaneous multi-factor impacts reductions on local environment as well as for selected metrics of GHG (e.g., the global warming potentials) with further economical evaluations. In addition, ModIST includes an optimization approach that allows the search for least-cost combination of mitigation measures for all the environmental factors and FB/GHG that meet user-specified constraints (policy targets) for each possible of the environmental endpoints. The optimisation capability of ModIST is applied in MaxEnt and enables the development of multi-factor and multi-effect impact control strategies. MaxEnt tool is currently under development for all environmental factors and it was validated for operational scenarios at the busiest Ukraine's airports with and shown increase of noise airport capacity up to 10% and 15% for day and night time accordingly; and the implementation of NAPs – 20-25%. Thereby, ModIST can identify mitigation strategies that achieve related targets simultaneously at least cost.

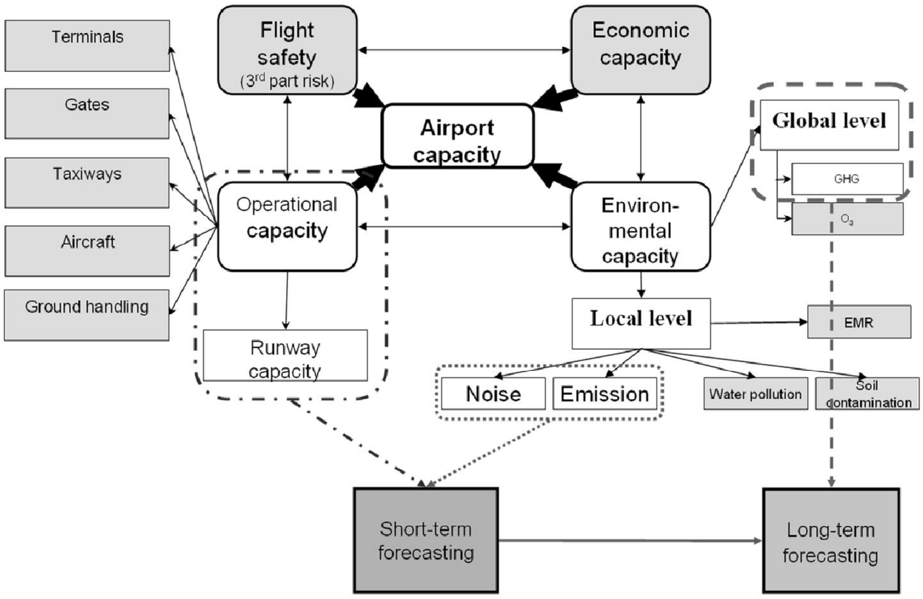


Figure 1 – Airport capacity concept

A combination of air pollution and noise measurements and stochastic for pollution (and TPR) and deterministic for noise (and EMF) modelling procedures is usually used to assess long term average exposure to traffic related environmental factors and described in detail elsewhere. GIS data on population density and traffic intensity specified for certain buffer zones were used in regression models to predict annual average air pollution concentrations and noise levels at the monitoring sites. As a rule the regression models explain 56–85% of the variability of the annual average concentrations depending on study area and specific pollutants.

GIS «Airport-EP» must provide: to promote compatibility between the airport and surrounding uses; to establish land use measures, restrictions and standards to be adopted by local jurisdictions; to «rely» upon the guidance provided in the ICAO Airport Land Use Planning Manual; to establish the planning boundary (i.e., airport influence area) only after hearing and consultation with the involved agencies (Ministry of Health Protection, Ministry of Environment Protection, State Emergency Service of Ukraine, etc.); be based upon an adopted Airport Master Plan (AMP) or Airport Layout Plan (ALP); to have a time horizon of at least 20 years.

Main results. GIS organizes geographic data so that a person reading a map can select data necessary for a specific project or task. A thematic map has a table of contents that allows the reader to add layers of information to a basemap of real-world locations. For EP purpose it is mostly important to organize the data for Airport Influence Area (AIA), which usually encompasses the geographic extent of, at least, six types of compatibility concerns: Overflight – Locations where aircraft overflights can be intrusive and annoying to many people; Airspace Protection –Places where height and certain other land use characteristics, particularly uses that attract birds, need to be restricted in order to protect the airspace required for operation of aircraft to and from the airport; Noise – Locations exposed to potentially disruptive levels of aircraft noise; LAQ – Locations exposed to potentially disruptive concentrations of air pollution; EMF – Locations exposed to potentially disruptive levels of electro-magnetic fields; Safety –

Areas where the risk of an aircraft accident poses heightened safety concerns for people and property on the ground – their individual risks (TPR) to be damaged.

Main data for impact factors inside and outside the airports are the results of calculation modeling with usage of calculation tools designed for these purposes (tab. 1).

Table 1 – Calculation tools for the factor in module ALFA

Factor	***Tool***	***Description***	***Input***	***Output***
LAQ	PolEmica	Emission inventory calculator (both for certification LTO or real LTO, defined by performance model); dispersion calculation (Euler approach) for airport-related pollutant sources	Aircraft fleet/ flight schedule; airport and flight routes layout; non- aircraft sources; meteorology; topography	Emissions inventory results; concentration fields: maximum instantaneous concentrations, short time (20 min) and long time (daily) means, for each pollutant
Noise	IsoBella	Noise level indices at specific points and/or noise contours calculation for airport flight scenarios	Airport and flight routes layout; aircraft flight schedule; ANP database	Noise level indices at specific points and/or noise contours
EMF	EMISource	EMF intension at specific points and/or its contours calculation for airport layout	Airport layout with navigation facilities; flight navigation facilities database	EMF intension at specific points and/or its contours
Safety	3PRisk	Individual risk at specific points and/or risk contours (10^{-4}, 10^{-5}, 10^{-6}) calculation for airport flight scenarios	Airport and flight routes layout; aircraft flight schedule; accident rates data for groups/types of aircraft	Individual risk at specific points and/or risk contours (10^{-4}, 10^{-5}, 10^{-6})

The main performances of the calculation modeling tools are described as following.

PolEmiCa. PolEmiCa is a combined emissions/dispersion model for assessing pollution at civilian airports and heliports due to the methods [4-6]. This model produces an emission inventory of airport sources and calculates concentrations produced by these sources at specified receptors. The system stores emission factors for fixed sources such as fuel storage tanks and incinerators and also for mobile sources such as automobiles or aircraft. PolEmiCa incorporates an emissions model to calculate an emission inventory for each airport source and a dispersion model to calculate pollutant concentrations produced by these sources at specified receptors. PolEmiCa is appropriate for the following applications: cumulative effect of changes in aircraft operations, point source and mobile source emissions at airports; simple terrain; transport distances less than 30 kilometres; and, 20-minutes and 1-hour to annual averaging times.

Main purpose of the PolEmiCa is to calculate the inventory and dispersion parameters of the aircraft engine emission during the landing-takeoff cycle of the aircraft in airport area [4-6]. Emissions Inventory for any airport is calculated by PolEmiCa for the following emission sources: aircraft during landing-take off (LTO) cycle; start-up procedures; ground support equipment (GSE); aircraft and ground power units (APU/GPU); power plants; fuel farms. Fuel flow and EI values are used for relative thrust (percentage of rated thrust) of the engine at character power settings due to ICAO LTO definition [4-6].

Aircraft engine EI for CO, HC and NO_x are defined from ICAO emission databank. EI for SO_x is equal to 0,005 in accordance with [5]. EI for PM is defined for appropriate values of SN by simple algorithm from ICAO Doc 9889 [4]. The emissions for the single LTO cycle (single flight case – aircraft at departure or at arrival) are then a summa of the individual stages of the cycle. Start-up emissions calculation for the starting sequence there is only HC emissions required for consideration (article 6.53 in Doc 9889 [4]).

GSE, APU and GPU emissions inventory are doing in PolEmiCa for CO, HC and NOx in accordance with ICAO Doc 9889 [4]. Computation for stationary sources is executed in accordance with [8] for the power plant emissions and [9] for fuel farm emissions. Road Vehicle Traffic is realized in PolEmiCa in accordance with National rules [10]. Total inventory results for additional sources are shown in tab. 2 below. PolEmiCa tool demonstrated good accordance of emission inventory for all emission sources with other LAQ models (tools), which were exeminated at CAEP/8 and CAEP/9 [7], tab. 3.

Table 2 – Summary of airport emission source groups (in kilograms)

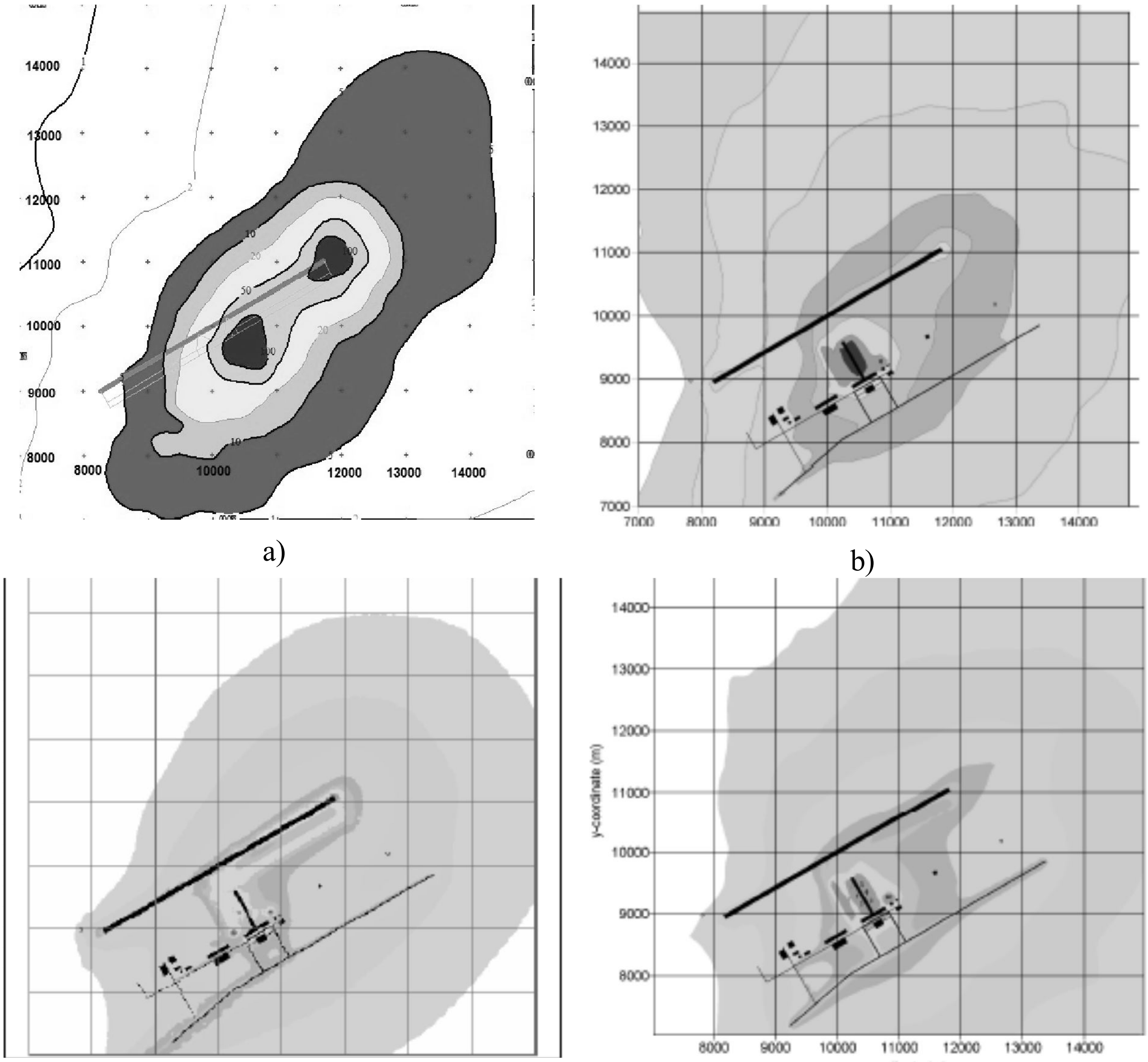
Substance	***Gate Sources***	***Roadways and Parking***	***Stationary Sources***	***Grand Total***	***Aircraft***
CO	20634,7	55911,5	5846	311159,2	228767,0
HC	7539,1	24555,6	491,4	74373,1	41786,9
NOx	39926,8	12088,7	8012,9	393772,6	333744,3
SOx	0	747,3	8255,5	124011,6	115008,8
PM10	2379,1	25,6	68,3	4998,8	*2525,9*
PM2.5	0	0	1377,4	1377,4	0
Fuel	846243,5	1758710,9	N/A	25606674,4	23001720

Table 3 – Comparison between the airport emission inventory results defined by ICAO calculation tools (aircraft only, in kilograms)

Substance	***Calculation tools***					
	LASPORT	**EDMS**	**ALAQS**	**ADMS**	**PEGAS**	**PolEmiCa**
CO	232685	256163	208850	300359	302395	228767
HC	50529	91541	54575	35789	51815	41787
NOx	307083	238866	301880	279453	309382	333744
SOx	19514	27058	20729	16351	96103	115009
PM10	1928	2827	1961	4243	2340	2529
Fuel	24394000	19895750	20783565	20438419	19220622	23001720

PolEmiCa calculates the concentration fields in airport area taking into account intensity of flights of airplanes of different types, a loading factor of different taxiways and runways, and there are a lot of other operational circumstances [1]. Usual practice for the FSU countries that the air pollution must be calculated, first of all, for the stationary sources using the methods of OND-86 and just these data must be taken into account in procedures of zoning around the polluters, in that number around the airports. For this reason the stationary sources in PolEmiCa are calculated by algorithm of the OND-86. For the purposes of evaluation and comparison between the ICAO calculation tools the 20-minutes averaging data (results of OND-86) transformed to 1-hour averaging data. PolEmiCa dispersion modelling results are compared with results of other verified by CAEP tools (fig. 2). Maximum concentrations for CAEPort scenario were calculated inside the airport area at locations of stands and of runway end [7].

IsoBella. IsoBella model has been designed in NAU for calculation of noise levels at specific points and/or noise contours (few types of level indices are calculated) for airport flight scenarios under consideration [1,3,11]. The noise model is usually consists of two components, the *noise engine* and an *aircraft database*. Traffic is broken down into aircraft types or categories with different noise and performance characteristics which have to be stored in the aircraft database. The noise engine is the core processor that models the physical processes of sound emission and propagation. The Aircraft Noise and Performance (ANP) database includes 10 data tables. The contents of the tables are fully described in [11]. ANP database of version 2.0 is prepared for distribution, it includes bigger list of aircraft types and improved data for engine thrust coefficients. Analyzing trends including the 2006 and 2026 scenarios for airport under consideration the model may predict that the 65dB(A) contour will double its area (consistent with the doubling of the number of movements), fig. 3.



a) b) c) d)

Figure 2 – Comparison between the airport dispersion results defined by ICAO calculation tools for CAEPort scenario: a) IsoBella; b) EDMS; c) ADMS; d) LASPORT

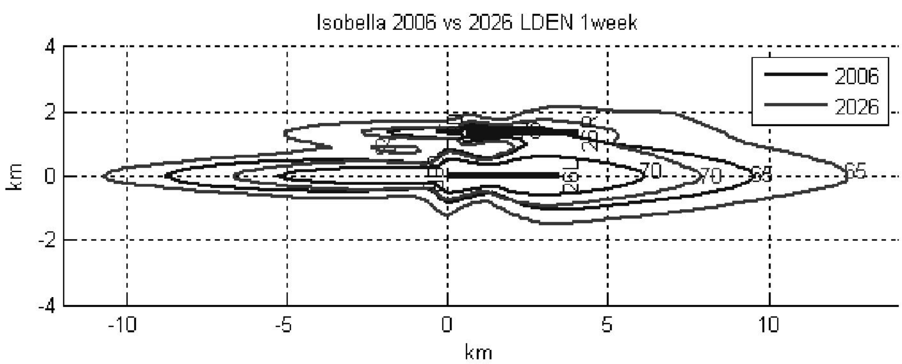


Figure 3 – Contours for aircraft noise outside the airport for 2006 and 2026 flight scenarios

3PRisk. For the population living in the vicinity of an airport the involuntary exposure to the risk of aircraft accidents exists and requires for its control. A method to assess third party risk around airports has been developed and recommended by CAEP for usage in grounding of Public Safety Zones around specific runways or airports as a whole [12]. A policy for Public Safety Zones (PSZ) is under development (in UK, The Netherlands, Germany, USA, Ukraine) to replace land use restrictions that have been in place for a number of years.

Methods for estimating crash risk contours could be used to define a better shape for the PSZs than at present, as the PSZ could then be the area inside a particular crash risk contour representing the desired proportion of crashes. This would enable the PSZ area to be defined more ‘efficiently’ than at present, as it would then correspond to the minimum area needed to contain the required proportion of crashes. The fig. 4 provide the result of the calculations with 3PRisk model. It should be noted that the contour areas are relatively small and any difference will thus be «exaggerated» when considering them via %.

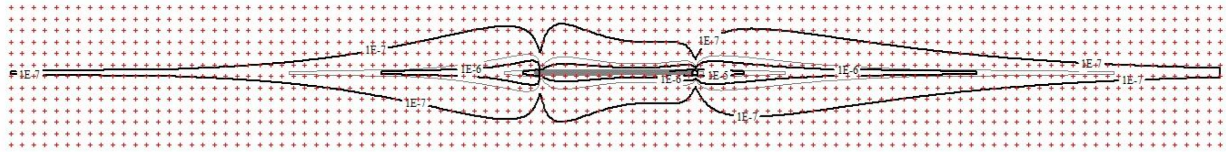


Figure 4 – IR contours for 10^{-4}, 10^{-5}, 10^{-6}, 10^{-7} from 3PRisk for 2026 scenario

Conclusion. All the models model are still under the development, PolEmiCa is following currently in two important directions: improving of jet/wake transportation modelling by CFD codes and verification of the modelling results with measurement’s data in various airports of the world, which were done with various techniques. The optimisation can be used to search for cost-minimal balances of controls of all the factors under consideration over the various scenarios in aviation sector that simultaneously achieve user-specified targets for human health impacts, ecosystems protection, etc. Thus in addressing the problem of decision making process in possible airport scenarios ModIST allows to assess ability of effective using operational procedures,to forecast schedule and aircraft fleet for installed capacity, and to rank environmental problems in the airport vicinity.

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Запорожець О.І. ГІС-МОНІТОРИНГ ЧИННИКІВ ДОВКІЛЛЯ В ОКОЛИЦІ АЕРОПОРТУ

У статті виконано узагальнення та порівняння наявних відомостей щодо ГІС моніторингу чинників довкілля в околиці аеропорту. Акцент зроблений на інвентаризаційному аналізі і моделюванні розсіювання, також були розроблені ряд, так званих, моделей другого покоління (наприклад, PolEmiCa, Isobella, 3PRisk) для підтримки управління забрудненням повітря, шумом, безпекою. Розроблені національні моделі порівнюються з аналогічними засобами розрахунку, розробленими у світі. Відмінності між результатами розрахунків засобами оцінки шуму та емісії знаходяться в межах 10 %, що є прийнятним значенням, беручи до уваги відмінності між застосовуваними підходами для моделювання. На сьогоднішній день ці моделі досить ефективно використовуються в цілях оцінки впливу на ГІС-платформах, частково через їх високу вимогу стосовно даних, особливо просторових. Результати статті можуть бути впроваджені у процесі експлуатації авіатранспортних засобів в умовах реалізації інтелектуальних систем управління транспортом.

Ключові слова: аеропорт, ГІС, моніторинг, шум, безпека, якість повітря, електромагнітні поля.

Запорожец А.И. ГИС-МОНИТОРИНГ ФАКТОРОВ ОКРУЖАЮЩЕЙ СРЕДЫ В ОКРЕСТНОСТИ АЕРОПОРТА

В статье выполнено обобщение и сравнение имеющихся сведений по ГИС мониторинга факторов окружающей среды в окрестности аэропорта. Акцент в основном был на инвентаризационном анализе и моделировании рассеяния, также был разработан ряд, так называемых, моделей второго поколения (например, PolEmiCa, Isobella, 3PRisk) для поддержки управления загрязнением воздуха, шумом, безопасностью в окрестности аэропорта. Разработанные национальные модели сравниваются с аналогичными средствами расчета, разработанными в мире. Различия между результатами расчетов средствами оценки шума и эмиссии находятся в пределах 10%, что представляет приемлемое значение, принимая во внимание различия между применяемыми подходами для моделирования. На сегодняшний день эти модели достаточно эффективно используются в целях оценки воздействия на ГИС-платформах, частично из-за их высокой требование относительно данных, особенно пространственных. Результаты статьи могут быть внедрены в процессе эксплуатации воздушных средств в условиях реализации интеллектуальных систем управления транспортом.

Ключовые слова: аэропорт, ГИС, мониторинг, шум, безопасность, качество воздуха, электромагнитные поля.

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