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ECONOMIC EFFICIENCY ANALYSIS OF THE SYSTEM FOR METEOROLOGICAL DATA COLLECTION AND DESSEMINATION

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Abstract

In this paper, the system of meteorological information collection and dissemination that takes into account modern aviation requirements as well as technical achievements is presented. The study of the economic benefits of the system is discussed and analyzed. The decision-making model for Economic Efficiency Analysis is developed from the position of the decrease in expenses for fuel. Then, methods of linear extrapolation and linear regression are applied. Statistics of meteorological factors is taken into account to calculate economic efficiency with obtained formulas.

Keywords: meteorological Information; air traffic organization; dangerous meteorological phenomena; economic efficiency

1. The problem statement and analysis of the research and publications

Air transport and corresponding infrastructure make a significant influence on the cargo and passenger transportation development and onto the State economy [1]. Some demands of modern aviation infrastructure development are

- increasing flight safety as well as reliability and quality of air traffic service;
- introduction of the novel technology of service;
- modern equipment commitment;
- increasing the capacity of the routes and make new routes of flight.

To fulfill the mentioned demands, it is required to improve air traffic organization (ATO) by updating communication, navigation and surveillance systems as well as by introduction system-wide information management (SWIM) [2, 3].

In turn, flights operation, their economy, regularity, and safety depend on atmospheric conditions and phenomena significantly [4]. Areas of dangerous meteorological conditions should be avoided. This, in turn, connected with increased fuel consumption and the increase of flight time and distance, lost of airport and routes capacity and flights disruptions.

Nowadays information for flight planning consists of actual aerodrome weather and the set of prognoses including aerodrome forecast, takeoff and landing forecasts, prognostic charts for different flight levels. Actual information can be presented as well in aviation warnings that are composed on the base of the pilot's observations mostly. But the atmosphere is a very dynamic medium. The processes in it are constantly changed as well as location, intensity, and character of atmospheric phenomena. Therefore, it is crucial to have operational information about dangerous atmospheric phenomena along the different stages of flight, increase the quality of meteorological information and implement SWIM approach [5, 6]. At the same time, the economical interest of the states requires substantiations of the benefits of the improved system for meteorological information provision.

In this paper, the system of meteorological information collection and dissemination that takes into account modern requirements and achievements is presented. The study of economic benefits of the system is discussed and analyzed.

2. Concept of System Wide Information Management

ICAO and EUROCONTROL indicate SWIM as a complete change in paradigm of how information is managed along its full lifecycle and across the whole the Air Traffic Management (ATM) system. The SWIM concept is based on the global interoperability and standardization of solutions and technologies and implies assuring the provision of commonly understood quality information delivered to the right people at the right time. Information on the past, current and future state of earth's atmosphere relevant for air traffic also need to be shared in the frame of SWIM concept as well as Pilots Information, Airport Operations Centres Information, Airline Operations Centres Information, Air Navigation Service Providers Information, Military Operations Centres Information.

3. System for Meteorological information Collection and Dissemination

In papers [7, 8] the structural diagram of the global interactive system of meteorological data collection, dissemination an exchange was developed and presented. Main characteristics of the developed complex system are

- meteorological information collection from different spatial positions (ground, onboard, satellites);
- formation of the set of operational meteorological information along the flight route;
- delivering information to the "right people at the right time";
- efficiency improvement by use of present air and space vehicles as the platform for mobile sensors of meteorological data obtaining;
- efficiency improvement by novel technique and equipment commitment for meteorological data obtaining (particularly polarimetric radar system to get more diverse information about weather formation and its behavior).

SWIM concept requires meteorological information to be shared additionally to the aeronautical information, flight trajectory information, aerodrome operations, air traffic flow, surveillance, capacity, etc.

Therefore, the formed set of operational meteorological information can be considered as the component of the single information space. The functional diagram of the meteorological component of the single information space can be represented as it is shown in Fig.1.

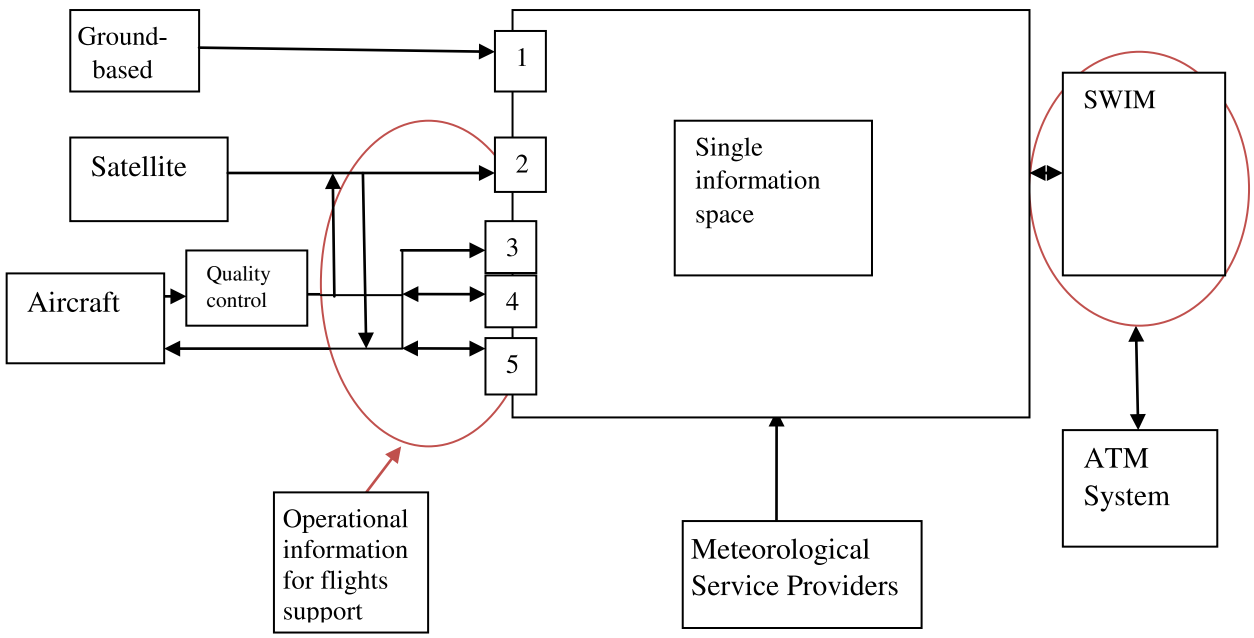

Fig. 1. Functional diagram of the meteorological component of the single information space

In Fig.1.:
1 is a direct communication line
2 is a satellite communication line
3 is AMDAR
4 is ADSB
5 is ground-to-air communication.

Information from the components of the global interactive system of meteorological data collection, dissemination an exchange via the correspondent communication lines (1-5) flows to the single information space. Then information can be combined and disseminated or delivered to the "right people at the right time" using the SWIM.

4. Economic Efficiency Analysis

The increased fuel consumption is one of the factors that can indicate the aviation company's losses due to the adverse meteorological conditions along the flight routes. Therefore the decision-making model for Economic Efficiency Analysis can be preliminarily developed from the position of the decrease in expenses for fuel. This, in turn, allows applying methods of linear extrapolation and linear regression. The peculiarity of the methods is the regularization that allows obtaining a sparse solution and reset some components. This can be important in the case when some elements are insignificant or information about them cannot be obtained. The similar approaches to evaluate economic benefits of meteorological information were applied in [9, 10].

The model is based on the fact that aviation companies take a decision on additional fuel transportation by particular flight using aviation meteorological forecasts. The additional fuel is expected to be spent in a case when adverse weather or dangerous weather phenomena forecasted along the flight route. Other aviation companies financial losses connected with flight plan deviation can be - additional transfer, financial compensation, airport taxes, reputation deterioration as well. Therefore the additional fuel transportation, in this case, serves as peculiar insurance to prevent other financial losses.

The result of decision-making depends on the real weather conditions along the flight route and on the additional fuel available on the aircraft board [11]. The weather conditions along the flight can be considered as favorable (good) or adverse (dangerous for flight). The model assumes that flight is always possible under good weather conditions. In case of adverse weather condition the flight is possible with probabilities *P* and P_1:

- Probability *P* corresponds situation when additional fuel is onboard;
- Probability P_1 corresponds situation when there is no additional fuel on the board of aircraft.

Therefore flight deviation has probability *1-P* when additional fuel is on the board of aircraft and probability $1- P_1$ when there is no additional fuel on the board. The decision making according to the proposed model is shown in Fig.2. The model considers two situations – one with the conventional meteorological provision and the second with the improved meteorological system.

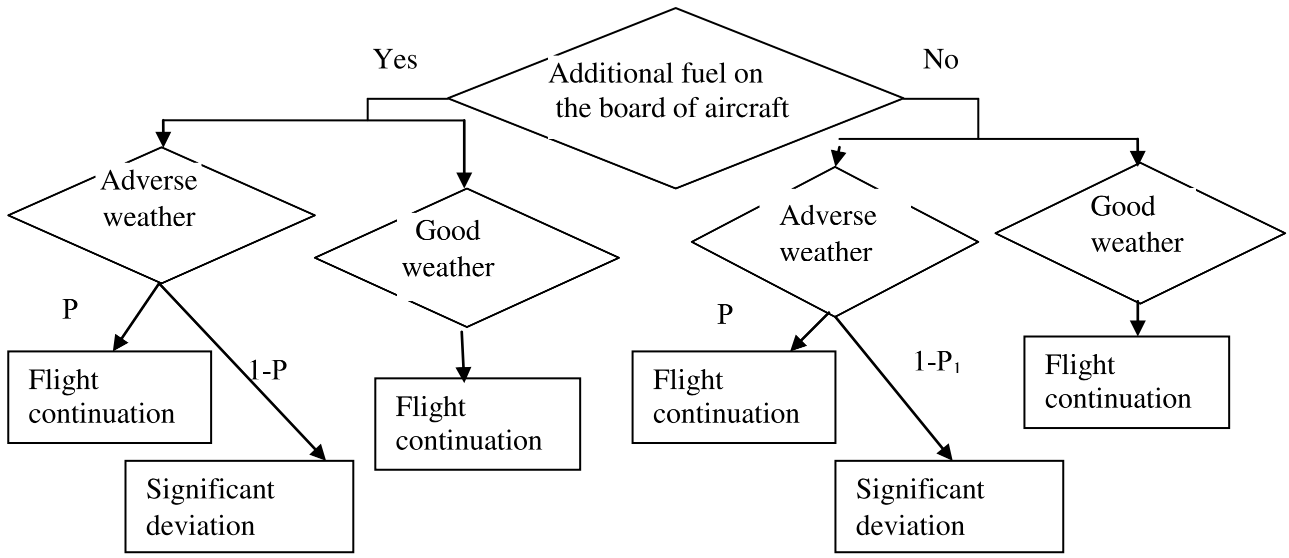

Fig.2. Decision-making process for the economic efficiency analysis model

To make economic efficiency analysis of the application of the improved system for Meteorological information Collection and Dissemination, it is reasonable to compare expected expenses according to each of the considered situations. These costs include expenses due to deviation from the flight plan when it is impossible to use additional airport (*B*) and expenses for insurance when additional fuel is present on the board (*I*). To determine the expected expenses when the proposed system of meteorological service is under operation we introduce the expenses variable for each combination of real situations. These combinations are given in Table.1.

In Table 1 the C2 is the expenses of aviation companies in case of expected adverse weather conditions along the flight path. But in the real situation, the implementation of the improved system of meteorological information provision increases the probability to make the flight without significant deviation. Component C2 corresponds to the insurance cost *I*. This is because the aviation company takes a decision to provide aircraft with additional fuel but there are no expenses for flight deviation as the real weather situation is appeared to be "good." Components C1 and H are calculated as the insurance cost and final cost of flight path deviation *B* taking into account probabilities *P* and P_1.

$$C1 = C2 + [(1 - p)\cdot B] \qquad (1)$$

$$H = [(1 - P_1)\cdot B] \qquad (2)$$

Table 1

Expenses connected with different weather situations along the flight path

		Real-time information on weather situation along the flight path	
		Favorable	Adverse
Forecasted information for flight planning	Favorable	C1	H
	Adverse	C2	0

To take into account the possible economic benefits of the improved system of meteorological information provision, it is reasonable to identify the coincidence rate of forecasted information and real-time information. For this purpose, we identify the time intervals that correspond to the adverse and good weather conditions. This information is given in Table 2.

Table 2

Coincidence rate of forecasted information and real-time information

		Real-time information on weather situation along the flight path		Conventional systems only
		Good	Adverse	
Forecasted information for flight planning	Good	T 11	T21	T01
	Adverse	T 12	T22	T02

Expected costs that are connected with improved meteorological service (*IEC*) can be calculated with the cross-multiplication of the components of Table 1 and Table 2:

$$IEC = T11C1 + T12C2 + T21H \qquad (3)$$

In most of the cases, the aircraft is provided with significant fuel to reach the alternative airport in case of dangerous conditions along the flight path. The fuel cost to reach at least two alternating airports (*A*) is included in the expenses calculation when conventional meteorological service provision (*CEC*) the next way:

$$CEC = T01C1 + T02C2 + A \qquad (4)$$

Economic Efficiency of airlines operation with the improved meteorological service can be calculated as the difference between the expected costs with conventional meteorological service provision and with improved meteorological service:

$$EE = CEC - IEC \qquad (5)$$

Meteorological and economic factors should be taken into account to calculate economic efficiency with formula (5). The statistical information from [12] was used to consider meteorological data.

5. Conclusions

The analysis made on the base of meteorological and economical factors has shown that economic efficiency varies from 80 to 1600 US dollars per flight depending on the flight distance and duration. The calculation and analysis did not consider the cost for development and production of novel systems for data obtaining and dissemination. The calculation also did not consider the possible cost reduction due to the utilization of commercial aircraft as the platform for novel systems of meteorological data obtaining and dissemination. In paper [13] it is indicated that the cost of information obtained with commercial aircraft that participate in the AMDAR program is only 1% from the cost of meteorological data obtained with sounding balloons.

Therefore the presented in the paper meteorological component of the single information space can be considered as the basis for the provision of air traffic participants with real-time meteorological information and allows increasing flight safety as well as reliability and quality of air traffic service delivering information to the "right people at the right time."

References

[1] National Transport Strategy of Ukraine 2030 Available at: https://mtu.gov.ua/files/Zakypivli/Ukraine%20Transport%20Strategy%20Part%201%20-%20POLICY%20NOTE.pdf

[2] Strategy of Air Transport Development, Order of Ministry of Infrastructur of Ukraine # 546 from 21.12.2015.

[3] SWIM – System Wide Information Management Available at: https://www.eurocontrol.int/swim

[4] ICAO International Standards and Recommended Practices (2016), Annex 3 to ICAO Convention "Meteorological Service of International Air Navigation" Issue18, ICAO.– 180 p.

[5] ICAO Doc.9750- AN/963, Global Air Navigation Plan 2016-2030, 2016, International Civil Aviation Organization, Published in Montréal, Canada.– 142 p.

[6] ICAO Doc. 10013, Operational Opportunities To Reduce Fuel Burn And Emissions First Edition – 2014, International Civil Aviation Organization, Published in Montréal, Canada.

[7] Averyanova Yu.A., Yanovsky F.J., Dynamic interactive system of meteorological data obtaining and dessemination, Tltctronics and control sysytems. – 2011. - №2(28). – P. 95–99.

[8] Averyanova Yu.A., Interactive Global Network for Meteorological Data obtaining, exchange and dessimination, Visnyk - К.: NAU, 2012. Volume 4.– P. 26–30.

[9] Leigh, R. J., 1995: Economic benefits of terminal aerodrome forecasts (TAFs) for Sydney Airport, Australia. Meteor. Appl., 2.– P. 239–247, doi:10.1002/met.506002030

[10] Economic Value of Meteorological Services to Switzerland's Airlines: The Case of TAF at Zurich Airport. Available at: https://www.researchgate.net/publication/275469001_Economic_Value_of_Meteorological_Services_to_Switzerland%27s_Airlines_The_Case_of_TAF_at_Zurich_Airport [accessed Mar 22 2019].

[11] Valuing Weather and Climate: Economic assesment Meteorological and Hydrological Service. WMO - №1153. Available at: http://library.wmo.int/pmb_ged/wmo_1153_ru.pdf138

[12] Final Report on National Aviation Weather program 10-Year Accident Reduction Initiative.

[13] World Meteorological Organization Aircraft Meteorological Data Relay Panel. Aircraft Meteorological Data Relay: The international AMDAR Program. – Geneva,Switzerland: AMDAR Panel Flyer, WMO, 2007.

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Аналіз економічної ефективності системи одержання та розподілу метеорологічної інформації

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В роботі презентовано систему одержання та розповсюдження метеорологічної інформації з урахуванням потреб сучасної авіації та технічних досягнень. Зроблено аналіз розрахунків економічної ефективності розробленої системи. Модель прийняття рішень для аналізу економічної ефективності розроблена з точки зору зниження витрат на пальне. В подальшому використовуються методи лінійної екстраполяції та лінійної регресії. Статистику метеорологічних факторів враховано для розрахунку економічної ефективності за допомогою одержаних виразів.

Ключові слова: метеорологічна інформація; організація повітряного руху; небезпечні метеорологічні явища; економічна ефективність

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Анализ экономической эффективности системы получения и распространения метеорологической информции

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В работе разработана система получения и распространения метеорологической информации с учетом потребностей современной авиационной отрасли, а также последних технических достижений. Проведен анализ экономической эффективности представленной системы. Модель принятия решения для анализа экономической эффективности разработана на основании снижения затрат на топливо. В дальнейшем используются методы линейной экстраполяции и линейной регрессии. Для расчета экономической эффективности с помощью полученных выражений использовались статистические данные о метеорологических факторах.

Ключевые слова: метеорологическая информация;, организация воздушного движения; опасные метеорологические явления; экономическая эффективность

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