DOI: 10.18372/2310-5461.63.19760
UDC 621.337.12:656.7.022.1(045)

Oleksandr Bondik,
National Aviation University
e-mail: oleksandr.bondik@npp.kai.edu.ua;

Iryna Zarubinska,
National Aviation University
e-mail: iryna.zarubinska@npp.kai.edu.ua

Oleksandr Kosohov
National Aviation University
e-mail: kosohov.oleksandr@npp.kai.edu.ua

ON THE ASSESSMENT OF THE FLIGHT OPERATIONS MANAGEMENT SYSTEM'S EFFICIENCY IN INCOMPLETE INFORMATION CONDITIONS

Introduction

A Flight Operations Management System (FOMS) as an essential tool for Airlines, enabling them to operate efficiently, safely and in compliance with all regulatory requirements. It integrates various aspects of flight operations, from planning and scheduling to real-time monitoring and reporting, providing a comprehensive solution for managing a organization's operational needs. According to EU Commission Regulation, the Operator shall establish, implement and maintain a FOMS that includes: clearly defined lines of responsibility and accountability; a description of the overall philosophies and principles with regard to safety, referred to as the safety policy; the identification of safety hazards entailed by the activities of the Operator, their evaluation and the management of associated risks, including actions to mitigate the risk and verify their effectiveness; maintaining personnel trained and competent to perform their tasks; documentation of all management system key processes; a function to monitor compliance of the Operator with the relevant requirements [1]. Compliance and quality monitoring shall include a feedback system of findings to the accountable manager to ensure effective implementtation of corrective actions as necessary; and other additional requirements [1–3]. The FOMS shell correspond to the size of the Operator and the nature and complexity of its activities, taking into account the hazards and associated risks inherent in these activities. Regarding this, one of the main factors which can significantly impact FOMS efficiency is incomplete information in flight operations.

Incomplete information in flight operations can significantly impact efficiency in several ways and in a few key areas, as follows:

In Flight Planning and Routing – with inaccurate weather data pilots and flight planners cannot rely on real-time weather data for route optimization. If the information is incomplete or outdated, flights may encounter unexpected turbulence, adverse weather conditions, or need to take longer routes, leading to inefficiencies in fuel use and time; it can lead to Air Traffic Control (ATC) information gaps with missing or inaccurate ATC data about airspace congestion, restricted zones, or ongoing delays can result in inefficient routing, unnecessary delays, and increased fuel consumption;

In Maintenance Scheduling – with incomplete aircraft data and missing or inaccurate maintenance logs can lead to overlooked issues, causing unscheduled maintenance, delays, and potential safety risks. This disrupts the flow of operations and increases downtime, impacting overall fleet utilization; also delayed aircraft inspections if critical flight readiness data isn't communicated in a timely manner, planes might face unplanned delays due to last-minute inspections or repairs;

In Passenger Handling and Communication – it can lead to miscommunication following incomplete information regarding passenger manifests, baggage loads, or even special requirements (e.g., medical needs) can lead to boarding delays, mishandled baggage, or safety concerns; also expect some scheduling inaccuracies if flight schedule data isn't updated in real-time (e.g., changes in gate assignments or delays), passengers may be inconvenienced, leading to a less efficient boarding process and potential missed connections;

In Crew Scheduling and Availability – expect staff shortages if crew availability data (due to regulatory constraints, health, or personal issues) isn't fully communicated, it can lead to last-minute substitutions or delays. Furthermore, incomplete data on crew duty times or qualifications may lead to compliance issues or delays due to crew unavailability; also inaccurate duty rostering with incomplete or delayed updates to crew rosters can result in inefficiencies in crew deployment, leading to understaffed flights or missed duty requirements;

In Fuel Management – during fuel load planning incomplete data on flight conditions or aircraft performance may lead to inaccurate fuel load calculations. Underestimating fuel requirements could result in emergency fuel stops, while overloading can be inefficient and costly;

In Logistics and Ground Operations – uncoordinated turnaround expected if information about the previous flight's delays, maintenance, or passenger load isn't communicated to ground crews in real-time, it can lead to inefficient turnarounds and delays. A lack of complete information can also result in poor coordination between ground handling teams, leading to missed or delayed departures;

In Safety and Compliance – during Regulatory Oversight incomplete or missing data on regulatory compliance (e.g., flight hours, equipment inspections, or weather conditions) can lead to violations or safety risks, resulting in delays or cancellations for the sake of compliance checks.

In general, the impact of incomplete information on the flight operations efficiency can result in increased delays, higher operational costs, greater risk, and diminished customer satisfaction. Regarding this, Airlines and flight operations teams need to prioritize the accuracy, timeliness, and sharing of critical information across all departments to maintain smooth and efficient operations.

The primary questions we aim to address in this article are as follows: How does incomplete information affect the overall performance and effectiveness of a managed system? And how can this impact be minimized?

Analysis of the research and publications

Numerous related studies have separately examined the impact of management and operational conditions on the performance and efficiency of managed systems. Some authors [4] have developed a rule-based approach for detecting logical failure events to support dynamic workflow adaptations. Their approach has been implemented within the different adaptation systems. Such systems use a rule-based approach for the detection of logical failure events (exceptions). Moreover, their approach only deals with logical failure events, while we also address the problem of adapting instances to maintain a specified level of Quality of Service (QoS).

M. Adams, D. Edmond, and A. Hofstede broaden the scope of Activity Theory to facilitate the implementation of more flexible adaptation systems [5]. Activity Theory offers a number of interesting solutions for workflow adaptability, flexibility, evolution and exception handling. Their research describes the Activity Theory principles that should be implemented when developing FOMSs.

Unfortunately, no implementation has been carried out, and their work does not address Quality of Service (QoS) issues. In contrast, R. Siebert [6] proposes an integrated approach for supporting adaptive workflows.

However, the impact of incomplete information on the performance of managed systems appears to be insufficiently explored, especially when the managed and management systems are considered as a unified entity. This variability of performance captures the impact of incomplete information on the performance and efficiency of a managed system. A metric to quantify this impact needs to be established. It should relate the performance and effectiveness of both the management system and the managed systems. To address this challenge, we propose an analytical model that integrates the performance of both management and managed systems, considering varying management profiles and an impact factor.

Problem statement

The assessment of a Flight Operations Management System's efficiency under incomplete information conditions is a complex and multi-dimensional task that requires an understanding of both the operational components of flight management and how uncertainty and lack of complete information affect the decision-making processes.

This decision-making process is directly influenced by the fundamental management profiles, which encompass the characteristics, skills, roles, and responsibilities associated with various types of managers within an organization. These profiles help define the expectations for managers at various levels and in different functions, guiding their actions and decision-making processes. But desperate the wide variety of management technologies and products, most FMOS infrastructures fall into an architecture pattern referred to as Manager-to-Agent. There are three basic components in this architecture: managed system, agent and management application. The management application responsible for providing the infrastructure and user interfaces to manage a system and it is conducted by a management profile or strategy that defines manageability tasks and patterns (see fig. 1).

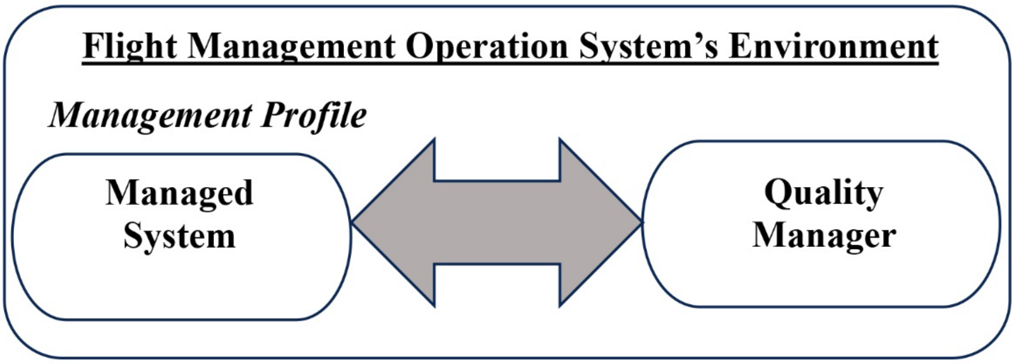

Fig. 1. The main FOMS components

As a management profile is a quantitative characteristic of how a system is managed, the profile summarizes key interaction parameters between the FOMS environment and the managed system. So, a management profile covers the most important parameters related to its interaction with the managed system. It is important to identify those parameters, which, if varied, will change the management profile within the managed system. Parameters that differ between management profiles are referred to as influence modifiers, which, when altered, can significantly affect the performance of the managed system. The impact modifiers might improve, maintain or degrade a given managed system performance and the management profile is controlled by the management workload that includes management requests. The management workload characteristic parameters represents the set of influence factors, which denote a set of influence variables, determined by the management profile within the managed system. The influence metric is analysed by varying the impact factor within a management profile. The table 1 displays a non exhaustive list of management profiles and factors that affect a managed system's performance and efficiency.

Table 1

The management profiles parameters and influence factors

Management Profile Impact Modifiers	Management Impact Factors
Incomplete information identification: – weather-related uncertainty; – operational data; – air traffic control limitations; – passenger-related data.	– Number of management requests; – Number of notifications; – Number of management objects within the managed system; – Management requests mixed: * Read requests; * Write requests.
Incomplete information assessment: – delays; – increased fuel consumption; – suboptimal route planning.	
FMOS's efficiency modeling via KPIs: – on–time performance; – fuel efficiency; – crew scheduling & management; – resources allocation.	
Assessment techniques: – simulation; – Decision Support Systems (DSS); – data analytics and machine learning.	
Decision–making impact: – Risk Management; – flexibility and adaptability.	
Efficiency metrics: – Time efficiency; – Cost efficiency; – Safety metrics.	
Strategies to improve efficiency: – Redundancy and backup systems; – Real–time data integration; – Predictive analytics.	
Case studies and applications: – predictive maintenance systems; – flight simulation for training pilots.	

As defined in [7–9], some key aspects/factors should be considered in evaluating the performance and efficiency of such a FOMS, as follows:

1) *Incomplete information identification* via sources of incomplete information in a flight operations environment, incomplete information can stem from

---

various sources such as: weather-related uncertainty (sudden changes in weather conditions or lack of accurate forecasts); operational data (missing/ outdated information on aircraft performance, fuel consumption, maintenance status, or crew availability); air traffic control limitations (delays or lack of real-time data on airspace congestion); passenger-related data (uncertainty regarding the number of passengers, cargo, or their needs).

2) *Incomplete information impact assessment* to the FMOS's efficiency – incomplete data can lead to inefficiencies such as delays, increased fuel consumption, or suboptimal route planning.

3) *FMOS's efficiency modeling,* which can be modeled in terms of several key performance indicators (KPIs): on-time performance – via system's ability to ensure that flights arrive and depart as scheduled despite incomplete information; fuel efficiency – via extension of which the system optimizes fuel consumption, taking into account possible inaccuracies in flight planning or fuel estimations; crew scheduling and management – via effective allocation of crew members while accounting for uncertainties in crew availability and regulatory limits; resources allocation – via the optimal use of aircraft and other resources under uncertain conditions.

4) *FOMS's efficiency assessment techniques* – to assess efficiency in incomplete information environments, various techniques can be used: simulation – these models allow the creation of different scenarios based on varying degrees of incomplete or uncertain information, such as: simulating weather disruptions, technical failures, or scheduling conflicts helps in understanding how the system responds to unexpected situations; Decision Support Systems (DSS) help by providing recommendations under uncertainty, using algorithms like fuzzy logic or Monte Carlo simulations, which model decision-making in situations of incomplete or ambiguous data; data analytics and machine learning – historical data can be used to train predictive models that forecast future operational challenges despite the presence of incomplete data. These models help anticipate issues such as weather disturbances, traffic delays, or maintenance needs.

5) *Decision-making impact under uncertainty*, which in flight operations is highly dependent on real-time data and can result in: Risk Management – the system's ability to assess and mitigate risks based on partial data. This involves contingency planning for unexpected events like equipment failures or adverse weather; flexibility and adaptability – a robust FOMS must be capable of quickly adjusting to new information, such as sudden weather changes or flight delays, and re-optimizing schedules, resources, and routes accordingly.

6) *FOMS's efficiency metrics* – several metrics can be applied to evaluate efficiency in the context of incomplete information: time efficiency – the degree to which a flight operation can meet scheduled times despite missing or delayed information, which includes measuring delays caused by misinformed decisions or unforeseen operational bottlenecks; cost efficiency – evaluating the operational costs in a system where incomplete information leads to overuse of resources, such as fuel, crew, or aircraft, and whether cost-saving strategies are effective in mitigating these inefficiencies; safety metrics – incomplete information can lead to unsafe conditions, such as improper fuel load, incorrect weather forecasts, or mismanaged aircraft resources. Safety-related data should be monitored, even when the system is working under uncertainty.

7) *Strategies to improve FOMS's efficiency in incomplete information conditions:* redundancy and backup systems via implementing backup systems for critical information (such as multiple weather sources, secondary communication lines, or contingency crew assignments) can minimize disruptions due to missing data; real-time data integration – integrating real-time data from various sources (aircraft sensors, weather stations, air traffic control) can help compensate for some of the missing or delayed information; predictive analytics – using machine learning to predict operational challenges based on partial data and adjust schedules, routes, and resources dynamically.

8) *Case studies and applications:* Airlines that adopt predictive maintenance systems to preemptively address equipment failures may operate more efficiently even in the face of incomplete maintenance data; Companies using flight simulation for training pilots in managing operations under incomplete information can reduce the impact of uncertain events during real-world operations.

Current architectures do not incorporate adequate solutions that enhance FOMSs' adaptation. So, its necessary to present a set of comprehensive techniques to be used in the development of FOMSs to increase their level of adaptation. There is not only target adaptation from a functional perspective, but also from an operational perspective. Consequently, taking into account all the aforementioned inputs, it is crucial to develop a comprehensive set of decision-making systems for airlines, encompassing both strategic and tactical planning. Applying scientific methods to solve and analyze these issues is of utmost importance.

Problem Solution

The major prerequisite in the achievement of the Airline's Flight Operations Mission is to support compliance with the ISO (International Organization for Standardization) standards, EASA strategy and Flight Operations Policy [1–3]. Go out there, the Flight Operations Management System is a single integrated system used by the Airline to manage the totality of its processes, in order to meet its objectives and equitably satisfy the stakeholders. So, all the Airline planning, tasking, monitoring, checking and continual improvement should be organized within the FOMS by utilising the tools and methodology set up for it.

Thus, the Airline must take action to ensure full compliance with safety regulations and relevant regulatory requirements. Consequently, the Airline identifies the customers who should benefit from the safest and the most environmentally friendly civil stakeholder.

Therefore, when assessing the Flight Operations Management System's efficiency, we have to take into account next several key factors/modifiers, as follows [7–9]:

1) *FOMS's Operational Efficiency*, which measure improvements in scheduling, dispatching, and resource allocation. Look at metrics such as on-time performance and turnaround times;

2) *FOMS's Safety Compliance*, which means evaluate adherence to regulatory standards and safety protocols. Analyze incident reports and safety audits pre- and post-implementation;

3) *FOMS's Cost Reduction*, which means assess cost savings from reduced delays, optimized fuel usage, and streamlined operations. Compare operational costs before and after system adoption;

4) *User Satisfaction* as a gather feedback from pilots, crew, and operational staff about system usability and effectiveness. Surveys and focus groups can provide insights;

5) *Data Integration:* analyze the system's ability to integrate with existing tools (e.g., maintenance, HR) and data sources for seamless information flow;

6) *Real-Time Decision Making:* evaluate how well the system supports decision-making through real-time data analytics and reporting;

7) *FOMS's Scalability:* assess the system's capacity to scale with growing operational demands and adapt to changing regulatory requirements;

8) *Training and Support:* review the effectiveness of training programs and ongoing support for users, as these impact overall system adoption and performance.

By focusing on these areas, Operators (Airlines) can effectively measure the impact of their FOMS to the Airlines operational efficiency and identify areas for its improvement.

To evaluate the effectiveness of a Flight Operations Management System through a mathematical model, it is possible to develop a framework that integrates key performance indicators (KPIs) and pertinent data. The following presents an approach for constructing such a model:

1st step – define Key Performance Indicators (KPIs) – select KPIs that reflect the system's performance and efficiency, such as:

– On-Time Performance (OTP): Percentage of flights that depart/arrive on time;

– Cost Efficiency (CE): Cost per flight hour;

– Safety Incidents (SI): Number of safety incidents per flight;

– Resource Utilization (RU): Utilization rate of aircraft and crew;

– User Satisfaction (US): Survey scores from operational staff.

2nd step – formulate the Model via expressing the effectiveness (E_{FOMS}) of the FOMS as a weighted sum of the KPIs:

$$E_{FOMS} = w_1OTP+w_2CE+w_3(1-SI)+w_4RU+w_5USE= \\ = w_1OTP+w_2CE+w_3(1-SI)+w_4RU+w_5US \qquad (1)$$

where: w_1, w_2, w_3, w_4, w_5 – are weights reflecting the importance of each KPI (sum of weights should equal 1).

3d step – Data Collection via gathering data for each KPI from operational records before and after implementing the FOMS:

– On-Time Performance: Percentage of flights on time;

– Cost Efficiency: Average operational cost per flight;

– Safety Incidents: Total incidents per number of flights;

– Resource Utilization: Ratio of utilized resources to total resources available;

– User Satisfaction: Average score from user surveys.

4th step – normalize the Data via normalization each KPI to a scale (e.g., 0 to 1) for comparison:

– for KPIs where higher values are better (like OTP, CE, RU, US):

$$Normalized\ KPI=KPI-KPImin/KPImax-KPImin \quad (2)$$

– for KPIs where lower values are better (like SI):

$$Normalized\ KPI=1-SI-Simin/SImax-SImin \qquad (3)$$

5th step – calculate Effectiveness – substitute the normalized values into the effectiveness formula to compute FOMS's efficiency.

6th step – analyze Results:

– Compare FOMS’s efficiency values before and after the FOMS implementation;

– Conduct statistical analyses (e.g., t-tests) to determine the significance of changes in effectiveness;

– Use sensitivity analysis to see how changes in weights affect the overall effectiveness.

7th step – Continuous Improvement via incorporating feedback loops to continuously refine the model based on user input and operational changes.

This mathematical model provides a structured way to quantify and assess the FOMS’s effectiveness, allowing for data-driven decisions and improvements via comprehensive software solution designed to manage and optimize the various activities involved in airline flight operations. Based on this, FOMS implementation are ensuring the safe, efficient, and cost-effective operation of an airline's fleet.

Conclusions

The new requirements of modern management systems in our highly technological flight operations demand that critical systems be adaptable, especially in incomplete information conditions. This work focuses on the FOMS adaptation and presents a set of comprehensive techniques to be used in the development of FOMSs to increase their level of adaptation during incomplete information conditions in flight operations. That’s why the assessing the Flight Operations Management System’s efficiency under incomplete information requires considering the role of uncertainty, data gaps, and real-time decision-making.

The most efficient systems are those that can adapt to changing conditions, leverage advanced analytics, and continuously improve through feedback mechanisms to reduce the impact of incomplete information.

By implementing robust decision support tools, predictive models, adaptive strategies, and especially the effective FOMS’s airlines can better handle the complexities of incomplete information, maintain efficient operations and can significantly support Airline’s business process and bring them some Benefits that result from previous studies can be formulated, namely:

– *Increased Operational Efficiency* – by automating many of the tasks associated with flight operations, FOMS improves efficiency and reduces the likelihood of human error;

– *Cost Savings* – by optimizing fuel consumption, crew utilization, and fleet management can lead to significant cost reductions;

– *Enhanced Safety* – helps ensure that all aspects of flight operations comply with safety regulations and best practices, reducing the risk of incidents;

– *Real-time Decision Making* – with real-time data and monitoring capabilities, airlines can make informed decisions quickly to manage disruptions and optimize operations;

– *Regulatory Compliance* – by automating the compliance tracking process helps airlines stay up-to-date with the latest regulations and avoid penalties.

When processes are critical, it is fundamental that FOMSs’ infrastructures continue to provide pre-established service levels to users in the face of disruptions.

This study focuses solely on the degradation effect of incomplete information on the performance and efficiency of a managed system. Future research will explore scenarios where management activities, such as load balancing and admission control, could enhance and sustain the FOMS’s performance and efficiency.

REFERENCES

[1] Commission Regulation (EU) No. 965/2012 – Air Operations – EASA – European Union. https://www.easa.europa.eu/en/document-library/regulations/commission-regulation-eu-no-9652012 (access data 10/10/2024)

[2] Law of Ukraine “On the National Program Adaptation of the Ukraine Legislation to the European Union Legislation”. № 1629-IV on 18 March, 2004.

[3] Aviation Rules of Ukraine "Technical requirements and administrative procedures for flight operations in Civil Aviation", approved by the SAAU order № 682 on 5 July, 2018.

[4] Greiner, U., Ramsch, J., Heller, B., Löffler, M., Müller, R., & Rahm, E. Adaptive Guideline-based Treatment Workflows with AdaptFlow. Paper presented at the Proc. of Symposium on Computerized Guidelines and Protocols (CGP 2004), Prague, (2004).

[5] Adams, M., Edmond, D., & Hofstede, A. t. The application of Activity Theory to dynamic workflow adaptation issues. Paper presented at the 7th Pacific Asia Conference on Information Systems (PACIS 2003), Adelaide, South Australia, (2003).

[6] Siebert, R. (1999). An Open Architecture for Adaptive Workflow Management Systems. Transactions of the SDPS: Journal of Integrated Design and Process Science, 3(3), 29–24.

[7] Doc. MA.IMS.00001-012 – EASA IMS Manual. – 2020.

[8] Doc. PO.IMS.00002 – EASA Strategy and IMS policy. – 2020.

[9] Bass, L., Clements, P., & Kazman, R. Software Architecture in Practice: Addison Wesley, 1998.

Бондік О., Зарубінська І., Косогов О.

ПРО ОЦІНКУ ЕФЕКТИВНОСТІ СИСТЕМИ УПРАВЛІННЯ ПОЛЬОТНОЮ ЕКСПЛУАТАЦІЄЮ В УМОВАХ НЕПОВНОЇ ІНФОРМАЦІЇ

Нові вимоги до сучасних систем управління в наших високотехнологічних польотах вимагають адаптації критичних систем, особливо в умовах неповної інформації. Ця робота зосереджена на адаптації FOMS і представляє набір комплексних методів, які будуть використовуватися при розробці FOMS для підвищення їхнього рівня адаптації в умовах неповної інформації під час польотів. Ось чому оцінка ефективності системи управління польотами в умовах неповної інформації вимагає врахування ролі невизначеності, прогалин у даних та прийняття рішень у реальному часі.

Метою даної статті є представлення нового підходу до оцінки ефективності функціонування системи управління польотами авіакомпаній (FOMS) в умовах неповної інформації. ***Методи****: у статті описується метод виконання, який підвищує ступінь адаптації FOMS авіакомпаній до функціонування в умовах неповної інформації, наприклад, метод оцінки впливу якості управління на продуктивність керованої системи за допомогою спеціального показника під назвою Ефективність FOMS EFMOS для оцінки цього впливу за допомогою змінних факторів впливу, пов'язаних із системою управління в рамках її стратегії управління.* ***Результати****: Аналітична модель впливу якості управління на ефективність FOMS авіакомпанії.* ***Обговорення****: Запропонований новий підхід дозволить підвищити ефективність функціонування FOMS авіакомпанії в умовах високого ступеня невизначеності та неповної інформації.*

У майбутніх дослідженнях вивчатимуться сценарії, за яких дії з управління, такі як балансування навантаження та контроль допуску, можуть покращити та підтримувати продуктивність і ефективність FOMS.

Ключові слова: льотна експлуатація; система управління; ефективність; архітектура адаптації; ефективність управління якістю, неповнота інформаційних умов.

Bondik O., Zarubinska I., Kosohov O.

ON THE ASSESSMENT OF THE FLIGHT OPERATIONS MANAGEMENT SYSTEM'S EFFICIENCY IN INCOMPLETE INFORMATION CONDITIONS

The new requirements of modern management systems in our highly technological flight opera-tions demand that critical systems be adaptable, especially in incomplete information conditions. This work focuses on the FOMS adaptation and presents a set of comprehensive techniques to be used in the development of FOMSs to increase their level of adaptation during incomplete information conditions in flight operations. That's why the assessing the Flight Operations Management System's efficiency under incomplete information requires considering the role of uncertainty, data gaps, and real-time decision-making.

The purpose of this article is to present a new assessment approach of the Airlines Flight Operations Management System's (FOMS) functioning efficiency in incomplete information conditions. ***Methods:*** *The article describes the runtime method which increase the adaptation degree of Airlines FOMS to functioning in incomplete information conditions, such as the assessing method of management quality influence on the managed system's performance with a specific metric called FOMS's Effectiveness* E_{FMOS} *to evaluate this influence by varying influence factors related to the management system within it's management strategy.* ***Results:*** *An analytical model of management quality influence on the Airlines FOMS's effectiveness.* ***Discussion:*** *The proposed new approach will allow to increase the Airlines FOMS's functioning efficiency in a high degree of uncertainty and incomplete information conditions.*

Future research will explore scenarios where management activities, such as load balancing and admission control, could enhance and sustain the FOMS's performance and efficiency.

Keywords: flight operations; management system; efficiency; adaptation architecture; management quality effect ratio, incomplete information conditions

Стаття надійшла до редакції 20.10.2024 р.
Прийнято до друку 11.12.2024 р.
