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Issues of estimating the flight hour cost of unmanned aircraft systems

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Abstract. The paper addresses the problematic issues of assessing the cost of the flight hour of the unmanned aircraft systems. It considers the approaches to "the early operational assessment" needed for the formation of the technical requirements and from the adoption of the optimal design solutions, which are the basis for the testing strategy and for the competitiveness of the developed products in the market economy at various stages of the life cycle of the manned and unmanned aircraft systems. It identifies the significant differences in the assessments between the manned and unmanned aviation, defines the structures of the operating costs and the cost of the flight hour of the manned and unmanned aircraft, makes a comparative analysis and draws conclusions allowing achieving an economic assessment by comparing the possibilities of using the manned and unmanned aviation.

Keywords: unmanned aircraft systems, life cycle, operating costs, cost per flight hour, operational and technical quality, operational assessment.

Problematika ocenjevanja stroškov letalne ure brezpilotnih letalskih sistemov

Članek obravnava problematiko ocenjevanja stroškov letalne ure brezpilotnih letalskih sistemov (BLS). Preučuje pristope k zgodnji operativni oceni, ki je ključna za oblikovanje tehničnih zahtev, projektnih rešitev in vrednotenje konkurenčnosti. S primerjalno analizo struktur operativnih stroškov med zrakoplovi s posadko in BLS prispevek identificira bistvene razlike ter podaja sklepe za zagotovitev primerljivosti ekonomskih ocen obeh vej letalstva.

1 INTRODUCTION

Recent events have highlighted the importance of the intelligent transport, logistics and telecommunications systems, especially the unmanned aircraft systems (UASs). Their implementation increases the economic efficiency, promotes the technological independence of the Russian Federation and requires standardization. The development of such systems is in line with the Transport Strategy of the Russian Federation until 2035 and the priorities of the National Security Strategy. Besides the Transport Strategy, released by the Government of the Russian Federation, the Strategy for the Development of the Unmanned Aviation until 2035 (UAS Strategy) was also developed and approved in June 2023. It is implemented by the Ministry of Industry and Trade, the Ministry of Transport and the Ministry of Education and Science of the Russian Federation. In January 2024, the national project "Unmanned Aircraft Systems" was implemented on its basis. The paper analyses the open issues of assessing the cost of the flight hour of the unmanned aircraft systems (UASs).

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2 MATERIALS AND METHODS

According to the literature (Khudolenko, 2006; Petrov, 2012; Rubah&Oprysko, 2013; Borodulina et.al, 2024), the flight hour assessment is an integral part of the UAS operational assessment characterizing the cost-effectiveness of such systems operation. Operational assessment assesses the operational properties and operational and technical characteristics of products, characterizing the ability of the product to perform functions when used for its intended purpose in accordance with the specified requirements. The operational and technical characteristics of products include the characteristics of the reliability, safety and cost-effectiveness of operation, testability, operational and repair manufacturability, as well as other characteristics and properties. The operational cost-effectiveness of operation is the ability of a product to meet its functional purpose at a minimal operating cost throughout its entire life cycle. The operational assessment is divided into the following phases:

- early operational assessment,
- operational assessment at the stage of the experimental design work (R&D),
- operational assessment at the production and operation stages.

The early product operational assessment defines the technical requirements, takes the optimal design decisions, reduces the pilot production risks, assesses the operational cost-effectiveness, flight hour cost, and provides a comparative analysis at similar samples. Early operational assessment provides the basis for the testing strategy and assesses the competitiveness of products under development in the market economy. An important part of the early operational assessment is modeling of the product life cycle implemented as the special tool for a predictive assessment of the functional efficiency of products in the form of a system for modeling the product life cycle using computer models. In the absence of such a tool, Russia's Strategy for the Development of Competitive Aviation Markets does not fully meet the requirements of the Strategy for the Development of Competitive Aviation Markets. At the same time, the Product Life Cycle Modeling on the global market is one of the key technologies designed to reduce the risks, improve the quality and cost-effectiveness of the product development, testing and operation. Therefore, the product (system) life cycle is understood as a set of the phenomena and processes that repeat at the frequency determined by the lifetime of a typical product (system) design from its conception to disposal or a specific product (system) from the moment of completion of its production to disposal. Computer models (digital twins of products) are a set of data and program code (mathematical model) required for a full-fledged virtual digital modeling of any stage of the life cycle of the product being developed. For UAS, the cost-effectiveness of the operation, as well as for the manned aviation, is mainly assessed on the loses of the cost and resource characteristics of the components and accessories, and on the costs of the fuel and electricity consumption. An optimal selection of the resource characteristics of UAS components and accessories reduces the number of their replacements during the designated service life, increases the product operational manufacturability and reduces the operating costs. Similarly, as for the assessment of the manned aviation, the main indicator for the assessment of the cost-effectiveness of the UAS operation is the cost of the flight hour.

The cost of the UAS flight hour can also be used to solve the following problems:

- evaluation of the functional efficiency of the promising products and their comparison with the existing analogues;
- evaluation of the R&D cost, including the cost of product testing;
- feasibility study (FS) of projects for the development of new and modernization of the existing products;
- development of technical requirements (TR) and technical assignments (TA) for the development of prototypes of products;
- development of the scenarios for the using UAS as part of the higher-level systems (monitoring system, air transportation system, agrochemical work system and other systems);
- development of business plans for the development, production and use of UAS, including pricing of the aviation goods and services, investment payback periods, profitability and financial results of aviation companies and manufacturing enterprises.

3 Results

The product functional efficiency is understood as a measure of the operational and technical quality of a product, characterizing its ability to perform its intended functions at a minimal operating cost. The operational and technical quality of a product is a set of operational properties that determine the ability of a product to maintain a working condition when used for its intended purpose, adaptability to the performance of the work of bringing it into readiness for the use for its intended purpose at a standard labor cost, time and material resources. The feasibility study for the product development projects is a set of research methods and calculations for assessing the economic, financial, technical and other investment conditions in order to decide on the feasibility of the project implementation and selection of optimal solutions. The technical specifications are the initial technical document for the creation of a prototype (product), establishing the basis and purpose of the development, the tasks to be solved and the structure of the prototype (product) construction, a set of technical requirements for the characteristics and requirements for the volume, timing of the work, the content and form of presentation of the work results. The technical requirements are an official document of the general customer, establishing the functional purpose and basic requirements for the properties and characteristics of the developed product. Estimation of the flight hour cost should be a mandatory procedure for the UAS operational assessment. However, due to the significant diversity of the UAS design and aerodynamic schemes, sizes, classes of functional purposes, there is currently no generally accepted methodology for such an assessment. As a rule, the efficiency of the UAS use is estimated based on the actual costs. As the industry develops, the issue of an early operational assessment of the functional efficiency of newly created UASs is becoming ever more relevant. To assess of the cost of the UAS flight hour of various types, a single standard methodology should be developed, allowing already at the development stage a reasonable assessment and comparison the economic efficiency of using UASs.

The differences in the operating economy and the cost of the flight hour of the various types of the aviation systems (UASs, small aircraft and manned aircraft) require the development of individual methods for assessing the cost of the flight hour of such systems. The generalized results of the conducted analysis of the cost of the flight hour of various manned aircraft of the military and civil aviation, light and ultra-light aircraft of the general aviation, as well as UASs of various size classes, are presented in Fig. 1.

A detailed analysis of the operating cost structure affecting the cost of the flight hour of the manned aircraft (ACs) and fixed-wing UASs shows significant differences in the structure (see Figures 2 and 3). Figures 4 and 5 show the proposed structures of the cost of the flight hour of manned ACs and fixed-wing UASs most frequently used to perform long-term missions, such as the aerial photography, monitoring of large territories and extended objects. Aerodrome services, ground ATC services and the maintenance of crew members for manned ACs are an integral part of the cost of the flight hour, since their specific weight is comparable with other operating costs.

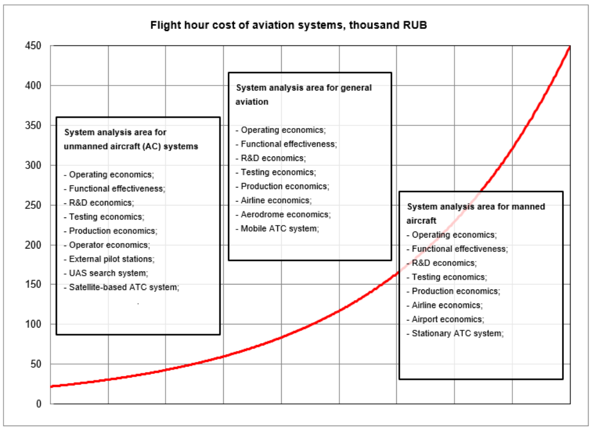


Fig. 1. Differences in the operating economy and cost per flight hour of various types of the aviation systems.

Source: Compiled by the authors.

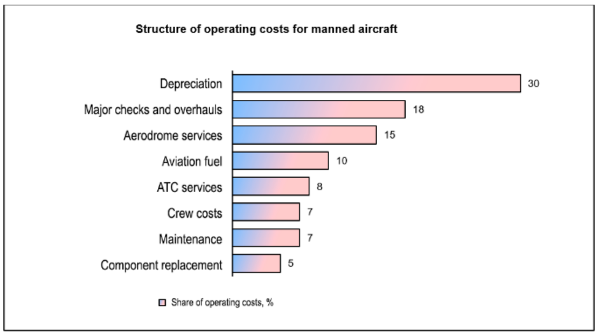


Fig. 2. The manned aircraft operating cost structure. Source: Compiled by the authors.

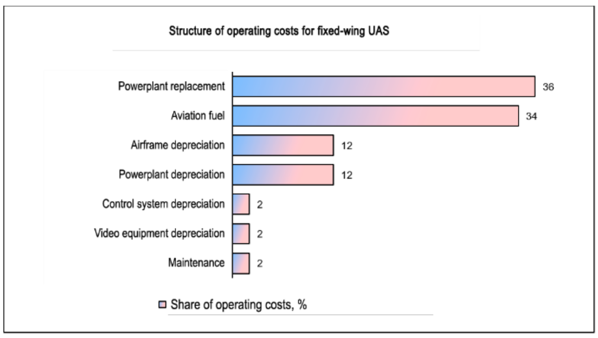


Fig. 3. UAS operating cost structure. Source: Compiled by the authors.

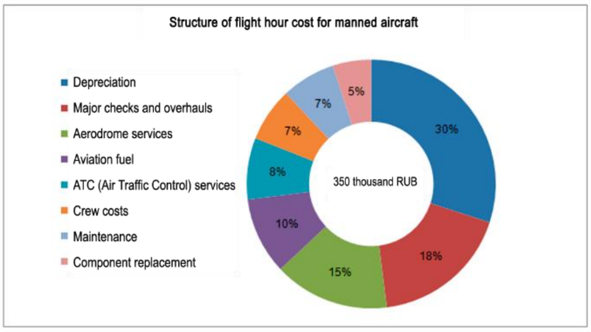


Fig. 4. The manned aircraft cost structure of the flight hour. Source: Compiled by the authors.

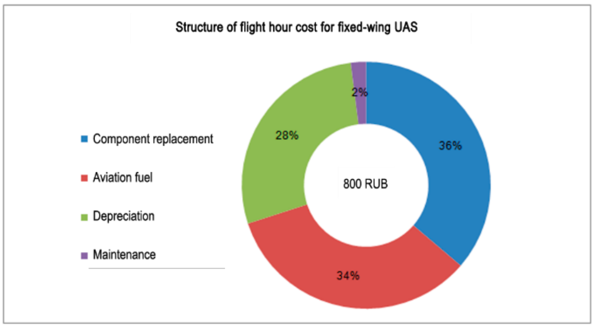
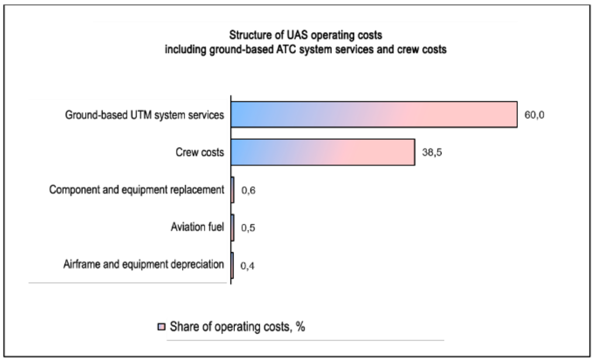


Fig. 5. UAS cost structure of the flight hour. Source: Compiled by the authors.

Ground ATC system services (named for UAS as unmanned traffic management - UTM) and the maintenance of the crew members should not be an integral part of the cost of the UAS flight hour, as the analysis of the cost of the ATC system services for UAS shows that their specific weight significantly exceeds other operating costs (see Figure 6). They cannot be an integral part of the cost of the UASs flight hour.



UTM

Fig. 6. Structure of the UAS operating costs, taking into account ground UTM services and crew maintenance.

Source: Compiled by the authors.

The results of our assessment of the impact of the key elements of the technical operation system on the design cost of the UAS flight hour are presented in Figure 7. The shown disproportion between the high costs of the ground ATC/UTM services and the maintenance of the remote pilot crew members may be the reason for the insufficient competitiveness of UASs compared to manned aviation systems (MAS).

The results of our analysis of the effectiveness of using satellite technologies for the UTM services to the UAS operators and users show that the transition to such technologies may allow, (see Figure 8), to reconsider the costs of the UTM services as an integral part of the cost of the UASs flight hour, since their specific weight becomes comparable with other operating costs.

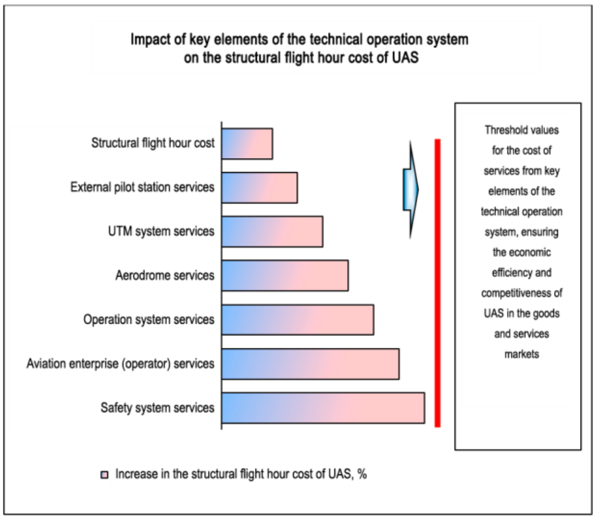


Fig. 7. Impact of the key elements of the technical operation system on the UASs design cost.

Source: Compiled by the authors.

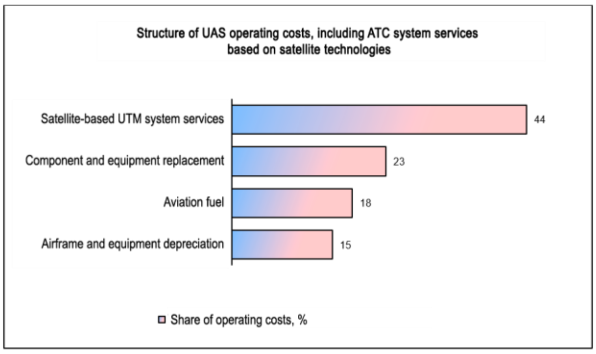


Fig. 8. Structure of the UAS operating costs taking into account the services of the UTM system based on the satellite technologies. Source: Compiled by the authors.

4 Discussion

The presented results clearly show that an adequate estimate of the cost of a UAS flight hour cannot be obtained using modeling techniques similar to those used to model and estimate the cost of a MAS flight hour. It is proposed to estimate the UAS economic efficiency, in contrast to MAS, by taking into account the costs associated with the maintenance of the crew of remote pilots, as well as with the services of the ground ATC/UTM system, as separate expense lines when calculating the cost of a typical aviation work performed using UAS. Thus, for UAS it is advisable to distinguish between two concepts - "the design cost of the flight hour" and "the cost of a typical aviation work". The design cost of the flight hour, as one of ETC, is set and estimated during the UAS development. It undergoes compliance testing at the testing stage and remains constant throughout the entire life cycle. The cost of a typical aviation work formed by a separate expense line as an added value to the design cost of the flight hour depends on the UAS application scenarios and the selected key elements of the technical operation system. The need to distinguish between the design cost of the UAS flight hour and the cost of a typical aviation work performed using UAS indicates the existence of a problem that requires a solution, and is formulated as the impossibility of directly comparing the costs of the MAS and UAS flight hour. A possible solution, may be a transition from the currently accepted regulatory UAS remote control by a crew of external pilots, that would implement the principle of "one external pilot - one UAS ground control point – one unmanned aerial vehicle (UAV)", to network-centric control by building an ATC/UTM system based on satellite technologies (Panteleimonov et.al, 2020), or by deploying a ground infrastructure that ensures control of multiple UASs through multiple ground control points united in a network by trusted communication channels (Akhaev et.al, 2024).

5 Conclusion

The paper proposes, an approach to assessing the cost of the UAS flight hour, based on distinguishing between the structural cost of a UAS flight hour and the cost components defined as the costs of the UTM services and the costs of maintaining the crew of remote pilots. The presented technical solution enables a comparative estimation of the cost of the UAS flight hour and the cost of the flight hour of the manned aircraft, namely the construction of the UTM systems based on satellite technologies, or the deployment of the NPU networks united by secure communication channels, within which many UASs can be operated simultaneously. The cost of a flight hour significantly affects to the cost of the UAS operation and its functional efficiency, pricing of the aviation goods and services, payback periods for investments, profitability and financial results of aviation companies and enterprises. Therefore, the assessment of the cost of the flight hour should be one of the mandatory procedures for the UAS operational assessment. For the cost assessment of a flight hour of UAS of various types (aircraft, helicopter, multirotor and mixed), the authors propose to develop a unified standard methodology using computer modeling, compliable to the Strategy for the UAS Development Industry adopted in the Russian Federation in terms of the economic efficiency of using such systems. Moreover, the requirements for the modeling procedure should be established in order to provide optimal indicators of the functional efficiency of using UAS in regulatory documents.

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