

NEW TECHNOLOGICAL AND INNOVATIVE TRENDS OF THE POST-INDUSTRIAL ERA IN AVIATION TRANSPORT

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Abstract

The article analyzes the technological and innovative changes taking place in civil aviation in the post-industrial era. It is noted that the transition from an industrial society to a knowledge and service economy has led to the digitalization, automation and transformation of the aviation sector into a high-tech system. Innovations such as artificial intelligence, big data, digital twin technology, biometric identification and smart airports increase safety, operational efficiency and passenger comfort in aviation. The article also examines the environmental problems and decarbonization directions of the aviation industry. SAF fuels, electric and hydrogen-powered aircraft, the use of lightweight materials and route optimization are indicated as the main solutions for reducing carbon emissions. Considering that in the post-industrial era, aviation has become not just a mode of transport, but also a high-tech and digital management system, one of the most important changes here is the widespread application of artificial intelligence and automation. Through these technologies, flight planning, early detection of technical malfunctions and air traffic control are carried out more effectively.

At the same time, problems such as the high financial cost of these technologies and the lack of infrastructure are also highlighted. At the same time, it is concluded that the aviation of the future is formed on three main principles: digitalization, sustainable development and human-technology integration. The author emphasizes that in the future, competitive advantage will be achieved by airlines and airports that adapt more flexibly to innovative technologies.

Keywords: *Post-industrial, civil aviation, artificial intelligence, digital transformation, smart airports, innovation, decarbonization, etc.*

AVIASIYA NƏQLİYYATINDA POSTİNDUSTRIAL DÖVRÜN YENİ TEKNOLOJİ VƏ İNNOVATİV MEYİLLƏRİ

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Xülasə

Məqalədə postindustrial dövrdə mülki aviasiyada baş verən texnoloji və innovativ dəyişikliklər təhlil olunur. Qeyd edilir ki, sənaye cəmiyyətindən bilik və xidmət iqtisadiyyatına keçid aviasiya sektorunun da rəqəmsallaşmasına, avtomatlaşdırılmasına və yüksək texnologiyalı sistemə çevrilməsinə səbəb olmuşdur. Süni intellekt, böyük verilənlər, rəqəmsal əkiz texnologiyası, biometrik identifikasiya və ağıllı hava limanları kimi innovasiyalar aviasiyada təhlükəsizliyi, əməliyyat səmərəliliyini və sərnəşin rahatlığını artırır. Məqalədə həmçinin aviasiya sənayesinin ekoloji problemləri və dekarbonizasiya istiqamətləri araşdırılır. SAF yanacaqları, elektrik və hidrogen mühərrikli təyyarələr, yüngül materiallardan istifadə və marşrutların optimallaşdırılması karbon emissiyalarının azaldılması üçün əsas həll yolları kimi göstərilir. Bununla yanaşı, bu texnologiyaların yüksək maliyyə dəyəri və infrastruktur çatışmazlığı kimi problemlər də vurğulanır. Post-sənaye dövründə aviasiyanın yalnız bir nəqliyyat növü deyil, həm də yüksək texnologiyalı və rəqəmsal idarəetmə sisteminə çevrildiyini nəzərə alsaq, burada ən vacib dəyişikliklərdən biri süni intellekt və avtomatlaşdırmanın geniş tətbiqidir. Bu texnologiyalar vasitəsilə uçuşların planlaşdırılması, texniki nasazlıqların erkən aşkarlanması və hava hərəkətinin idarə olunması daha effektiv şəkildə həyata keçirilir.

Eyni zamanda, gələcəyin aviasiyasının üç əsas prinsip üzərində formalaşdığı nəticəsinə gəlinir: rəqəmsallaşma, dayanıqlı inkişaf və insan–texnologiya inteqrasiyası. Müəllif vurğulayır ki, gələcəkdə rəqabət üstünlüyü innovativ texnologiyalara daha çevik uyğunlaşan aviaşirkətlər və hava limanları tərəfindən əldə olunacaq.

Açar sözlər: *Postindustrial, mülki aviasiya, süni intellekt, rəqəmsal transformasiya, ağıllı hava limanları, innovasiya, dekarbonizasiya və s.*

НОВЫЕ ТЕХНОЛОГИЧЕСКИЕ И ИННОВАЦИОННЫЕ ТЕНДЕНЦИИ ПОСТИНДУСТРИАЛЬНОЙ ЭПОХИ В АВИАЦИОННОМ ТРАНСПОРТЕ

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Аннотация

В статье анализируются технологические и инновационные изменения, происходящие в гражданской авиации в постиндустриальную эпоху. Отмечается, что переход от индустриального общества к экономике знаний и услуг привел к цифровизации, автоматизации и трансформации авиационного сектора в высокотехнологичную систему. Инновации, такие как искусственный интеллект, большие данные, технология цифровых двойников, биометрическая идентификация и «умные» аэропорты, повышают безопасность, эффективность эксплуатации и комфорт пассажиров в авиации. В статье также рассматриваются экологические проблемы и направления декарбонизации авиационной отрасли. В качестве основных решений по сокращению выбросов углерода указаны топливо SAF, самолеты на электрическом и водородном топливе, использование легких материалов и оптимизация маршрутов. Учитывая, что в постиндустриальную эпоху авиация стала не просто видом транспорта, но и высокотехнологичной и цифровой системой управления, одним из важнейших изменений здесь является широкое применение искусственного интеллекта и автоматизации. Благодаря этим технологиям планирование полетов, раннее выявление технических неисправностей и управление воздушным движением осуществляются более эффективно. Одновременно с этим освещаются такие проблемы, как высокая финансовая стоимость этих технологий и недостаток инфраструктуры. При этом делается вывод, что авиация будущего формируется на основе трех основных принципов: цифровизация, устойчивое развитие и интеграция человека и технологий. Автор подчеркивает, что в будущем конкурентное преимущество будет достигнуто авиакомпаниями и аэропортами, которые более гибко адаптируются к инновационным технологиям.

Ключевые слова: *постиндустриаль, гражданская авиация, искусственный интеллект, цифровая трансформация, умные аэропорты, инновации, декарбонизация и др.*

INTRODUCTION

The concept of post-industrial society represents one of the main stages of modern economic and social development. At this stage, industrial production partially loses its former dominant position and gives way to the service sector, knowledge economy, information technologies and innovative solutions. These changes, like other sectors, have a serious impact on civil aviation. The aviation sector, which previously performed mainly transport and logistics functions, has today become a multi-faceted and high-tech system as a result of the application of digitalization, automation and artificial intelligence technologies.

In the modern post-industrial era, the development of civil aviation is not limited only to the increase in passenger and cargo transportation. Innovative technologies such as “smart airports”, digital management platforms, biometric identification and big data analysis are widely used in this field. As a result, aviation services are becoming safer, more flexible and user-oriented. In parallel, environmental sustainability issues have also become one of the priority directions. Steps taken to reduce carbon emissions, introduce alternative energy sources and increase energy efficiency are closely related to the concept of sustainable development, which is one of the main principles of a post-industrial society.

Fast and reliable air transport plays a vital role in expanding international economic relations and this system operates through thousands of airports around the world. Industry representatives consider civil aviation an integral part of global business and emphasize its important role in promoting economic growth, especially in developing countries. At the same time, the impact of the aviation industry on climate change is also widely recognized (Hasanov and Mirzayev, 2025).

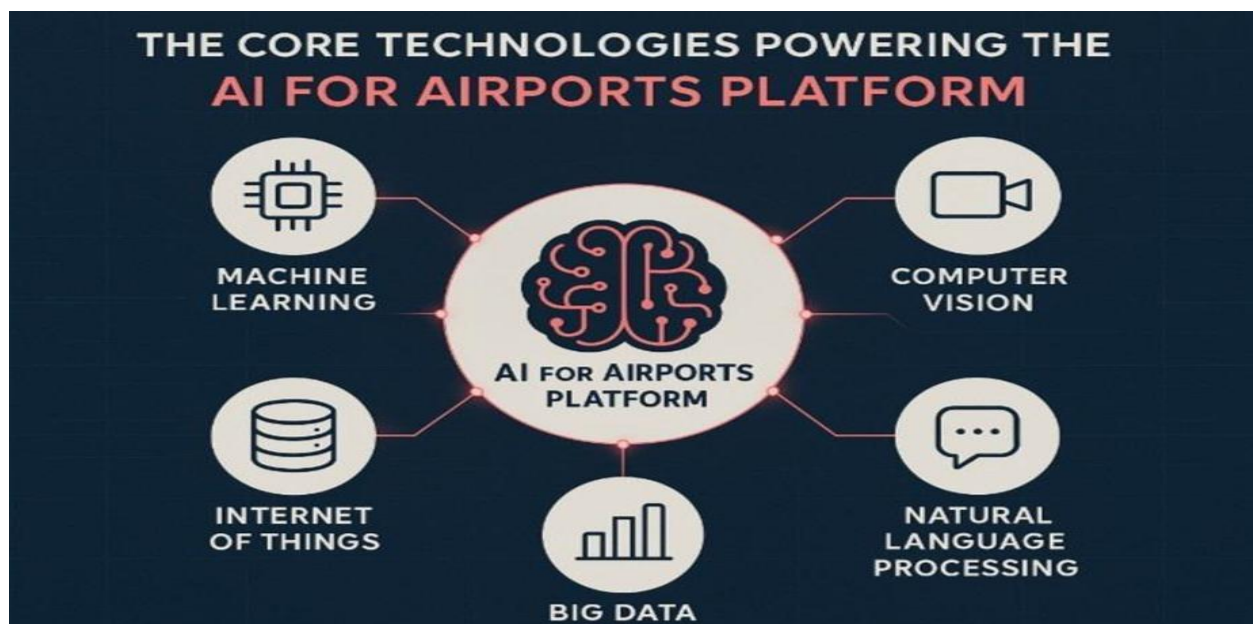
Technological challenges in civil aviation in the post-industrial era

The transformation taking place in civil aviation also has a direct impact on the development of global economic relations. The expansion of international trade, the growth of tourism and the strengthening of global integration have made aviation a strategically important sector. In these conditions, the application of innovative technologies not only increases operational efficiency, but also becomes one of the main indicators of competitive advantage. As a result, airlines and airports face difficulties in maintaining their positions in the market without adapting to technological innovations.

The study and research of new technological and innovative trends of the post-industrial era in air transport is associated with several important factors. First of all, digital transformation and technological innovations are rapidly spreading globally, and this process leads to the formation of new management models in the aviation sector. Artificial intelligence technologies are reshaping various operational areas in the aviation industry by enhancing automation, efficiency and innovation. This includes air traffic management, predictive maintenance, improving the passenger experience and ensuring sustainability, etc (Communications Earth & Environment, 2023).

As in all fields, the rapid development of artificial intelligence is seriously affecting the aviation industry and bringing fundamental changes to its structure. Technologies such as machine learning, natural language processing and computer vision are already widely used at various stages, from flight planning to technical maintenance.

Figure 1. Artificial intelligence ecosystem of the “AI for Airports” Platform



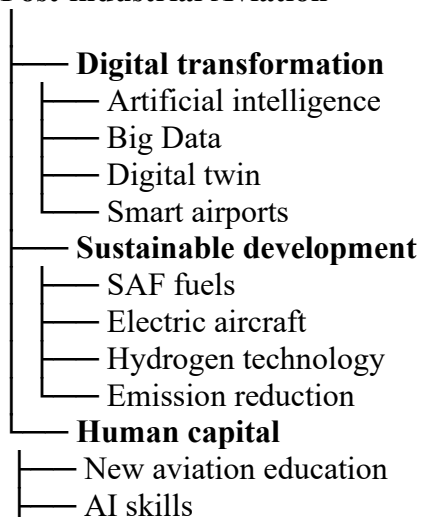
Source: https://www.safran-group.com/pressroom/safran-forefront-aviation-decarbonization-pas-bourget-2023-2023-06-15?utm_

These technologies, in addition to increasing safety and efficiency, also create new challenges for aviation education and personnel training. It is considered essential for modern aviation specialists to acquire new knowledge and skills in order to operate in an AI-integrated work environment. At the same time, there are still cautious approaches to fully automated decision-making systems, especially the replacement of pilots and the full management of routes by AI. This indicates that human control still plays an important role in aviation. Taking into account the above, based on analysis and research, we can see that the aviation of the future is formed on three main principles:

- Digitalization - data-based management and automation;
- Sustainability - reducing carbon emissions and green technologies;
- Human-technology integration - preserving human control despite the development of artificial intelligence.

These principles, in fact, also reflect the main development directions of air transport in the post-industrial era. Thus, the implementation of the above principles generally creates certain tasks for the system, which can be schematically described as follows (Lohmann, 2022; WIPO, 2025):

Post-industrial Aviation



— Technological competencies

The scheme clearly expresses which principle implementation gives rise to which tasks and challenges. Considering that in the post-industrial era, aviation has become not just a mode of transport, but also a high-tech and digital management system, one of the most important changes here is the widespread application of artificial intelligence and automation. Through these technologies, flight planning, early detection of technical malfunctions and air traffic control are carried out more effectively. As a result, both safety and operating costs are increased. In this regard, another important direction is the concept of “smart airports”. Biometric identification, digital registration and contactless services minimize the loss of time of passengers, which is why the application of these technologies has accelerated, especially after the COVID-19 pandemic. The pandemic has made the need for digitalization in the aviation sector more clear.

The application of artificial intelligence as the key to major technological innovations in civil aviation

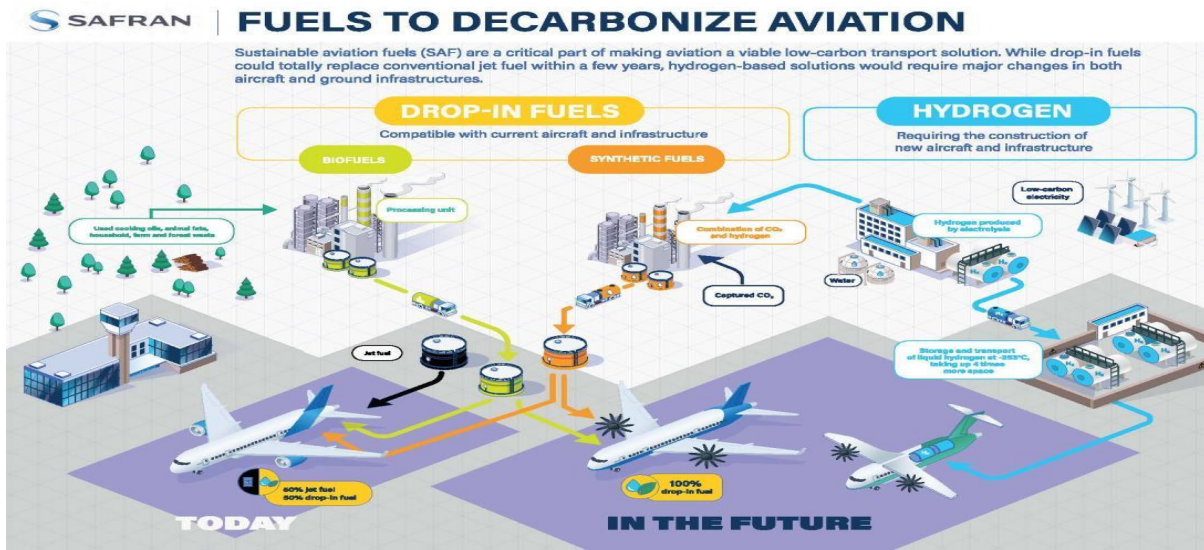
Studies show that passengers accept that artificial intelligence creates significant advantages in terms of more effective airspace management, timely detection of technical malfunctions and increasing flight safety. At the same time, the application of AI in areas such as providing personalized services, reducing fuel consumption and minimizing carbon emissions is positively assessed. Surveys conducted by various airlines also show that participants have a positive attitude towards the use of artificial intelligence to optimize flight operations and reduce delays. However, there is some skepticism regarding the issues of fully independent decision-making and pilot replacement. It is observed that young and frequent travelers in particular trust AI more, while older passengers are more cautious about automation.

Formation of highly qualified personnel potential is of particular importance for the successful application of artificial intelligence in the aviation sector. In this regard, the transformation of aviation education in line with the AI-oriented future is one of the pressing issues. The industry already requires graduates from universities with competencies in new technologies. For this reason, it is considered important to include components related to artificial intelligence and digital technologies in educational programs. Updating aviation curricula, taking into account labor market requirements, and applying best practices can make a significant contribution to the training of aviation specialists of the future (İgor Kabashkin and etg., 2023).

In the post-pandemic period, the importance of innovative approaches for the recovery and sustainable development of the aviation sector has increased even more. The COVID-19 pandemic has caused one of the largest crises in the history of civil aviation, and global passenger traffic has sharply decreased as a result of the closure of international borders. Thousands of aircraft have been taken out of service, and airlines have faced serious financial difficulties. At the same time, as a result of the increase in demand for cargo transportation, some passenger aircraft have been converted to cargo aircraft. The pandemic has also accelerated the introduction of technologies such as biometric identification, digital health passports, and contactless services. Although the aviation sector recovered rapidly after the lifting of restrictions, it has faced problems such as labor shortages and rising fuel prices. However, since 2024, global air traffic has recovered to pre-pandemic levels and exceeded them in some indicators (İCAO, 2023; İATA, 2023, OAG, 2023).

One of the main problems facing the aviation industry in modern times is environmental challenges. Although the sector makes a significant contribution to global economic development and the expansion of international relations, it also has a serious impact on the increase in carbon emissions. The volume of emissions generated by aviation has increased significantly in recent years, and it is predicted that the demand for flights will increase even more in the future. For this reason, the application of sustainable aviation technologies is considered necessary.

Figure 2. Current and future decarbonization landscape in aviation

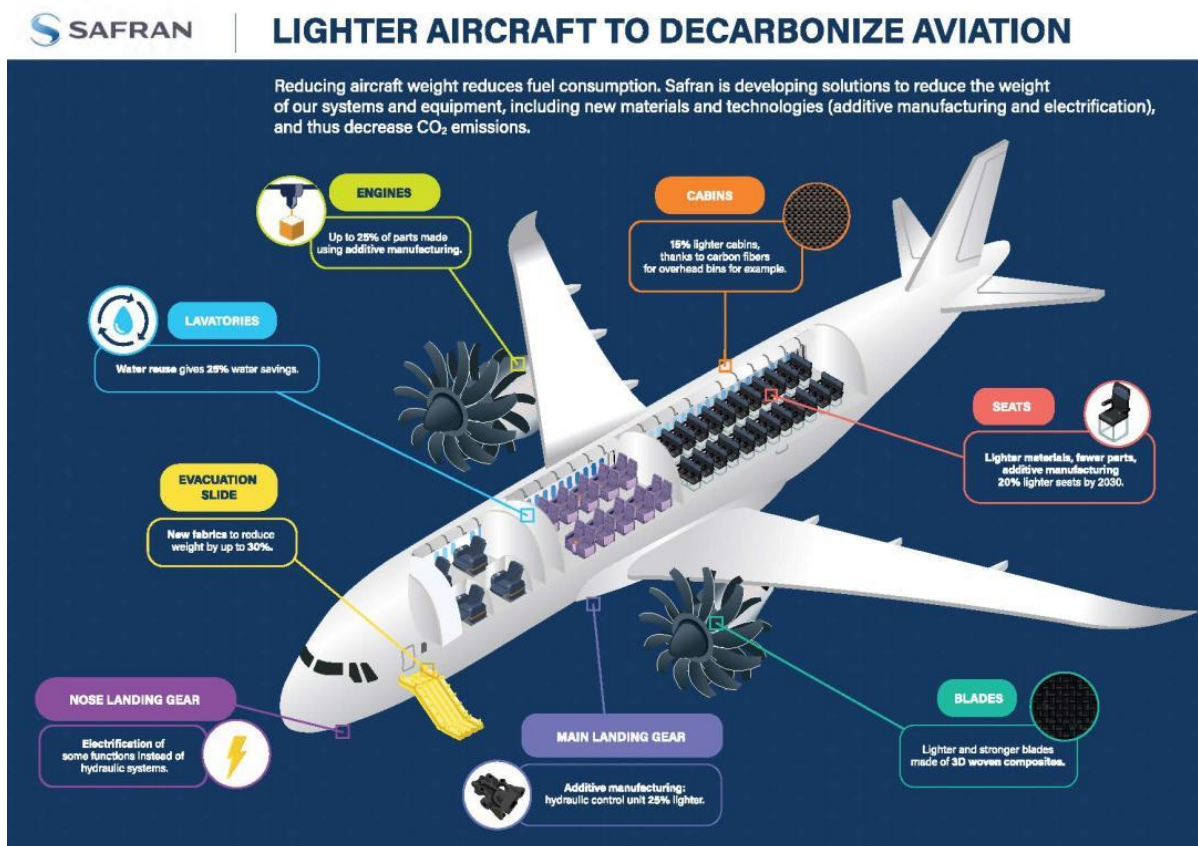


Source: <https://www.safran-group.com/pressroom/safran-forefront-aviation-decarbonization-pas-bourget-2023-2023-06-15?utm>

As can be seen from the diagram presented by Safran Group, one of the main technological challenges is the ecological transformation of aviation. International organizations and states are accelerating the transition to green technologies to reduce carbon emissions. Sustainable aviation fuels (SAF), electric and hydrogen-powered aircraft are considered the main directions of the future. SAF fuels are considered one of the most realistic solutions for decarbonization in the near future. These fuels, obtained from renewable sources, can significantly reduce carbon emissions compared to traditional fuels. In addition, aircraft powered by hydrogen and electric engines, hybrid-electric systems, new aerodynamic designs and lightweight composite materials are considered promising directions in terms of reducing the environmental impact of aviation. At the same time, the high cost of these technologies and the lack of infrastructure currently prevent their widespread application (Aliyev and Guliyeva, 2025; Safran Group, 2025).

Optimization of flight routes, more efficient airspace management and improvement of ground operations also contribute to reducing fuel consumption and emissions. In addition, zero-emission targets set by ICAO, the European Union and other countries are aimed at accelerating the green transformation in aviation. Artificial intelligence and digital twin technologies play an important role in optimizing aviation systems. Digital twin technology provides real-time monitoring and optimization capabilities by creating virtual models of physical systems. These technologies are important in terms of reducing fuel consumption, minimizing emissions and improving decision-making processes (ICAO, 2023).

Figure 3. Illustration of lighter aircraft being used to reduce carbon emissions



Source: <https://www.safran-group.com/pressroom/safran-forefront-aviation-decarbonization-pas-bourget-2023-2023-06-15?utm>

As can be seen, the use of lighter aircraft is recommended to reduce carbon emissions. In fact, the use of green technologies is perceived as a necessity arising from serious economic and technological challenges. The persistent high cost of aviation fuels, the fact that new technologies are still in the early stages of development and infrastructure deficiencies, and the calls for decarbonization encourage the widespread use of light aircraft. In addition, the diversity and severity of environmental issues, the existence of different regulatory mechanisms in different regions increase the need for global coordination.

Key technological trends in aviation transport in the post-industrial era

Although the decarbonization of civil aviation transport is a complex and long-term process, it is possible to achieve significant progress in this direction through scientific research, technological innovations and international policy initiatives. The application of cleaner technologies, advanced materials and digital solutions can create conditions for aviation to become both an efficient and environmentally responsible transport system. In general, we can classify the main technological trends or innovative directions of the post-industrial era in aviation transport as follows (Hasanov and Mirzayev, 2025; John and etg., 2011):

Table 1. Key technological trends in aviation transport in the post-industrial era

Technological direction	Application area	Main advantages	Current problems
Artificial intelligence (AI)	Flight planning, maintenance, air traffic control	Increased safety and efficiency, reduced delays	Low confidence in full automation
Big Data	Passenger analytics, route optimization	Acceleration of decision-making	Cybersecurity risks
Biometric identification	Airport check-in and security checks	Contactless and fast service	Privacy and data protection
Digital twin technology	Airplane and airport systems monitoring	Real-time optimization	High cost
Smart airports	Automated terminal management	Passenger comfort and operational flexibility	Expensive infra-structure investments
SAF (Sustainable aviation fuel)	Decarbonization policy	Reduction of carbon emissions	High cost of fuel
Electricity and hydrogen engines	Green aviation	Reduced environmental impact	Technology in early development stage

Source: Compiled by the author based on research.

Thus, research shows that in the post-industrial era, the aviation sector is facing a number of technological challenges. In particular, digital and ecological transformation has become an inevitable necessity. Artificial intelligence, automation and green technologies determine the future development directions of aviation. In addition, in parallel with technological modernization, issues of personnel training, legal regulation and international coordination are also of strategic importance. For this reason, in the future, competitive advantage will be achieved mainly by airlines and airports that adapt to innovations faster and can easily and flexibly implement technological changes.

Conclusions and recommendations

Studies show that in the post-industrial era, the civil aviation sector has become one of the fastest transforming sectors. Digitalization, artificial intelligence, big data, digital twin technology and automation systems play an important role in improving operational efficiency, safety and service quality in aviation. At the same time, biometric identification and the concept of smart airports allow for more flexible and convenient organization of passenger services.

As mentioned in the article, the future development directions of civil aviation are mainly formed on three principles: digitalization, sustainable development and human-technology integration. Although the application of artificial intelligence creates significant advantages in flight planning, maintenance and air traffic management, cautious approaches to the issue of complete replacement of human control still remain. This indicates that the human factor retains its strategic importance in aviation. Studies also show that one of the main problems facing the aviation industry is environmental challenges. In order to reduce carbon emissions, SAF fuels, electric and hydrogen-powered aircraft, lightweight composite materials and optimized routing systems are considered the main technological directions of the future. In addition, high costs, technological limitations and lack of infrastructure are among the main factors preventing the widespread application of these innovations. In general, in the future, competitive advantage will be achieved by airlines and airports that adapt to innovative technologies faster and apply the principles of sustainable development. To this end, it would be advisable to take into account the following:

- Strengthening public-private sector cooperation may be effective in expanding the application of artificial intelligence and digital technologies in the aviation sector;
- It is necessary to accelerate the application of smart management systems, biometric identification and contactless service technologies at airports;

- It would be advisable to include new subjects on artificial intelligence, Big Data, cybersecurity and digital management in aviation education programs;
- It is necessary to promote the use of SAF fuels and increase investments in green technologies in order to reduce carbon emissions;
- Creating an appropriate infrastructure and technical base for the application of electric and hydrogen-powered aircraft is an environmental challenge;
- Expanding cooperation with international aviation organizations is considered advantageous in terms of applying global practices in decarbonization and digital transformation;

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