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TRANSFORMING AIR TRAFFIC MANAGEMENT WITH BIG DATA AND ARTIFICIAL INTELLIGENCE

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ABSTRACT

The integration of Big Data and Artificial Intelligence (AI) has the potential to significantly transform air traffic management by offering innovative solutions to enhance safety, efficiency, and capacity of operations. With the growing demand for air travel and the increasing complexity of airport operations, these emerging technologies are becoming essential to tackle industry challenges and prepare aviation for the future. The main advantage of this integration is the improvement in decision-making, with the collection and analysis of large volumes of real-time data, such as weather information and flight data, allowing for the prediction of traffic patterns and identification of congestion. Furthermore, AI can predict and prevent failures in critical systems, such as radar and communication systems, enabling corrective actions before failures occur. The optimization of resource usage, such as flight routes and takeoff and landing operations, is also facilitated, increasing airport capacity and reducing wait times and delays. Safety is also enhanced, with the detection of hazardous flight conditions and more efficient coordination among airlines, controllers, and emergency services. However, the implementation of AI and Big Data faces challenges, such as the need for robust infrastructure, privacy protection, and the adaptation of industry professionals. Investing in secure technologies and properly training operators are key steps to fully leverage the potential of these innovations in air traffic management.

Keywords: Big Data. Artificial Intelligence. Air Traffic Management. Resource Optimization. Air Traffic Safety.

INTRODUCTION

The combination of Big Data and Artificial Intelligence (AI) has the potential to significantly transform air traffic control, offering innovative solutions to enhance the safety, efficiency, and capacity of air operations. With the continuous growth in demand for air travel and the increasing complexity of airport operations, these emerging technologies are becoming increasingly essential to address the challenges in the sector and prepare aviation for the future. One of the main advantages of integrating Big Data and AI is improved decision-making. The collection and analysis of large volumes of real-time data, such as weather information, flight data, and passenger behavior, enable the generation of valuable insights for air traffic controllers. The use of AI algorithms allows for the prediction of traffic patterns and identification of congestion areas, enabling more proactive decision-making, which not only improves operational efficiency but also minimizes delays and enhances the passenger experience.

Figure 1: AI in aviation.

Source: Futurism Technologies.

Additionally, AI plays a crucial role in predicting and preventing failures in air traffic control systems. Machine learning algorithms can analyze historical and real-time

data to identify patterns indicating failures in critical systems or equipment, such as radars and communication systems. This predictive capability allows operators to take corrective actions before failures occur, improving safety and preventing incidents. With the growing demand for air travel, increasing airport capacity without compromising safety remains an ongoing challenge. The integration of Big Data and AI can optimize the use of existing resources, enabling more efficient management of flight routes and takeoff and landing operations. Predictive analysis can adjust air traffic in real-time, redistributing aircraft to avoid congestion and optimizing time windows for takeoffs and landings, which not only increases airport capacity but also reduces waiting times and delays, improving the passenger experience.

The safety of air operations can also be significantly enhanced with real-time data analysis, coupled with predictive modeling. These technologies can detect dangerous flight conditions, such as severe turbulence or rapid weather changes, providing early warnings to pilots and controllers. This not only reduces the risk of accidents but also improves the response to emergency situations. AI can also help identify and prevent operational failures, as well as improve coordination between air traffic parties, such as airlines, airports, and emergency services. While the opportunities are vast, the integration of Big Data and AI in air traffic control also presents significant challenges. Managing large volumes of data and implementing AI algorithms require robust infrastructure and considerable investment in technology. Furthermore, data privacy and security are critical issues, especially given the sensitive nature of the information involved, such as flight data and aircraft location. Ensuring that technologies are secure and that information is protected from leaks and cyberattacks is essential.

Another important challenge is the need for industry professionals, such as air traffic controllers, to adapt and be trained to use these new technologies effectively. This will require changes to operational protocols and a reevaluation of training processes to ensure professionals can fully utilize the new tools. The study by Shmelova, Sterenharz, and Dolgikh (2020) explores the opportunities for applying Artificial Intelligence (AI) in the aviation and aerospace industries, highlighting its innovative potential to improve the effectiveness of building aeronautical systems throughout their life cycle. The research emphasizes the role of AI in the Air Navigation System Sociotechnical System (ANSTS), a highly complex and risky area where its

applications can enhance safety and the ability to anticipate and manage difficult situations. The study presents decision-making models for AI system operators, such as Expert Systems and Decision Support Systems for pilots of manned and unmanned aircraft, air traffic controllers, and engineers. The quality of operator decisions is directly influenced by the development of innovative AI technologies and related areas such as Big Data, Data Mining, Multi-Criteria Decision Analysis, Collaborative Decision Making, Blockchain, and Artificial Neural Networks.

The study by Degas et al. (2022) highlights the growing complexity of Air Traffic Management (ATM) in the coming decades due to the growth and complexity of aviation, emphasizing the need for significant improvements to maintain aviation safety. The authors argue that without these advancements, the safety objectives set by international organizations will not be achieved, potentially leading to more incidents and accidents. Despite the significant role of computer science in data management and decision-making in ATM, Artificial Intelligence (AI), one of the most researched areas of computer science, has not yet reached end-users in the ATM domain. The article analyzes the state of the art of AI in aviation/ATM, examining research from the past decade, identifying trends and relevant characteristics, and extracting representative dimensions. The study also explores the functioning of Explainable Artificial Intelligence (XAI) in general and in ATM, investigating where and why XAI is needed, its current implementation, and its limitations. The findings are synthesized into a conceptual framework, the DPP (Descriptive, Predictive, Prescriptive) model, with an example scenario for 2030. The article concludes that AI systems in ATM require further research for end-user acceptance, with the development and validation of appropriate XAI methods being critical for successful implementation.

The study by Kumar et al. (2022) discusses the significant role of Artificial Intelligence (AI) in transforming the aviation and Air Traffic Management (ATM) sectors, reducing human workload, and improving capabilities in complex scenarios. AI is increasingly supporting managers and operators, including airlines, air traffic controllers, and airport staff, in various aviation applications. As the aviation industry faces interconnected new challenges such as energy transition, environmental protection, greater capacity flexibility, drone integration, and system resilience to disruptions like economic crises and pandemics, AI is positioned as a key tool to address these issues. The study highlights how AI can improve air traffic coordination, safety, and efficiency

by managing tasks such as maintaining safe aircraft spacing, guiding flights during takeoff and landing, rerouting them in adverse weather conditions, and reducing delays. Furthermore, the research focuses on AI's potential to simplify operations, including automatic communication between airports and aircraft, and resolving issues such as manual checks of weather conditions, runway parameters, and air traffic. By incorporating technologies like GSM to automate tasks, AI can reduce manual effort and human errors, ensuring more efficient and smoother air transport operations.

The study by Westin et al. (2020) explores the potential of Artificial Intelligence (AI) as a key enabler for improving the efficiency of future air traffic management systems. As automation in air traffic control becomes more sophisticated, there is a growing challenge in understanding and interacting effectively with these systems. The research addresses this issue by focusing on two main areas: increasing automation transparency and personalization. The paper discusses strategies to balance these two aspects in the context of machine learning systems used for conflict detection and resolution in air traffic control. The MAHALO project, highlighted in the study, aims to create and empirically evaluate a decision support system that combines supervised and reinforcement learning approaches, offering both personalization and transparency. The system would adapt to individual preferences, ensuring optimal performance while explaining the reasoning behind its suggestions, especially when they differ from the operator's preferences, justifying why the alternative solution is considered superior.

The study by Shmelova and Sikirda (2020) proposes the application of Artificial Intelligence (AI), specifically expert systems and neural networks, to estimate the mental workload of air traffic controllers working in various control centers, such as terminal, approach, and area centers. The research focuses on the tasks performed by controllers in these centers, including coordination between units, aircraft traffic, ascent, and descent. Using AI technologies, it is possible to assess the controllers' mental workload under different traffic conditions, compare workload intensity across sectors, and optimize the distribution of workload among sectors and control centers. The main advantage of an AI system over traditional software is its ability to learn, improve, and predict outcomes. The study involved real air traffic controllers, students, graduate students, and faculty members from the National Aviation University.

The study by Kolotusha (2022) combines two approaches to enhance the professional training of air traffic controllers: the use of AI for mental workload

monitoring and the use of simulation technologies. The research focuses on creating a system that enables controllers to prepare for intensive traffic situations and increasing complexity. The study also involves the development of methods for continuous monitoring of controllers' mental workload using systems that evaluate physiological and psychological data, improving the safety and well-being of controllers during their work.

In conclusion, the integration of Big Data and Artificial Intelligence (AI) holds immense potential to revolutionize air traffic management by enhancing safety, efficiency, and capacity. As the aviation industry faces growing challenges due to increased demand for air travel and the complexity of airport operations, these emerging technologies become indispensable in addressing sector-specific difficulties and preparing aviation for the future. Through improved decision-making, predictive capabilities, and the prevention of system failures, AI and Big Data can optimize air traffic flow, reduce delays, and improve passenger experiences. Furthermore, these technologies contribute to better coordination and communication, ensuring safer operations while responding to unexpected situations such as adverse weather or technical malfunctions. However, despite the opportunities, the integration of AI and Big Data in air traffic control also presents challenges, such as the need for robust infrastructure, data security, and professional training. The aviation industry must continue to invest in these technologies and adapt its workforce to fully realize the potential benefits, while also addressing concerns related to privacy and data protection. Ultimately, AI and Big Data are essential tools for shaping the future of air traffic management and ensuring a safe, efficient, and sustainable aviation system.

REFERENCES

1. Degas, A., Islam, M., Hurter, C., Barua, S., Rahman, H., Poudel, M., Ruscio, D., Ahmed, M., Begum, S., Rahman, M., Bonelli, S., Cartocci, G., Flumeri, G., Borghini, G., Babiloni, F., & Aricó, P. (2022). A survey on artificial intelligence (AI) and explainable AI in air traffic management: Current trends and development with future research trajectory. *Applied Sciences, 12*(3), 1295. https://doi.org/10.3390/app12031295

2. Kolotusha, V. (2022). Application of artificial intelligence technology in the process of individualized training of air traffic controllers. In *2022 12th International Conference on Dependable Systems, Services and Technologies (DESSERT)*, 1-4. https://doi.org/10.1109/DESSERT58054.2022.10018816

3. Kumar, P., Hussain, M., Reddy, K., & Deep, S. (2022). Methods of air traffic management using artificial intelligence in India. *International Journal of Scientific Research in Science and Technology.* https://doi.org/10.32628/ijsrst229490

4. Shmelova, T., & Sikirda, Y. (2020). Artificial intelligence for evaluating the mental workload of air traffic controllers. In *Advances in Human Factors and Ergonomics* (pp. 184-212). https://doi.org/10.4018/978-1-7998-1052-0.ch009

5. Shmelova, T., Sterenharz, A., & Dolgikh, S. (2020). Artificial intelligence in aviation industries. In *Advances in Human Factors and Ergonomics* (pp. 1-35). https://doi.org/10.4018/978-1-7998-1415-3.ch001

6. Westin, C., Hilburn, B., Borst, C., Kampen, E., & Bång, M. (2020). Building transparent and personalized AI support in air traffic control. In *2020 AIAA/IEEE 39th Digital Avionics Systems Conference (DASC)*, 1-8. https://doi.org/10.1109/DASC50938.2020.9256708