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Building a model of air passenger transport management process based on fuzzy logic

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Abstract. The research niche of this article is the application of fuzzy logic to optimize air passenger transport management, particularly in the context of Azerbaijan's aviation industry. The aim of the study was to develop a model of management processes of passenger air transport using fuzzy logic to improve the accuracy and efficiency of management decision-making in conditions of incomplete and variable information. The methodology includes the application of fuzzy logic principles to account for the uncertainty and complexity of management processes in the aviation industry, as well as the analysis of statistical data from official sources, focusing on the aviation industry in Azerbaijan. The results of the study showed that from 2019 to 2023, Azerbaijan's aviation passenger traffic is recovering, with an increase in passenger traffic and passenger turnover, confirming the growth of the industry after the decline caused by the COVID-19 pandemic. The introduction of modern technologies such as artificial intelligence, biometrics, and process automation is helping to improve service quality and operational efficiency. The experience of such countries as the USA, Germany, Japan, and Kazakhstan demonstrates successful examples of innovation implementation that can be adapted to improve the competitiveness and efficiency of Azerbaijan's aviation industry. The developed management model based on fuzzy logic takes into account fluctuations in passenger traffic, weather conditions and operational disruptions, which allows for more accurate forecasting of changes and real-time decision-making. This increases management flexibility, improves operational efficiency and helps to optimize resources, flight schedules and minimize delays. The results obtained confirm the effectiveness of fuzzy logic for the management of air passenger traffic in the Republic of Azerbaijan, which contributes to more accurate planning and optimization of processes in the aviation industry, and can improve the competitiveness and stability of airlines in the country.
Keywords: intelligent systems, process optimization, innovations in transport, international experience, modern technologies

Introduction

Air passenger transport plays a key role in the transport system of many countries, including Azerbaijan, where the aviation industry is an important component of the economy. With the dynamic growth in passenger numbers and the multitude of external factors affecting airlines, there is a need to optimize passenger traffic management processes. Traditional planning and forecasting methods are often insufficient to adequately account for the uncertainty and variability characteristic of this sector. In this regard, the use of innovative methods, such as fuzzy logic, to build adaptive management models capable of dealing with uncertainty and dynamic change is becoming increasingly relevant.

The research problem lies in the lack of understanding of how traditional air passenger management methods based on fixed models and forecasts are unable to adequately account for variability in factors such as passenger traffic, seasonal fluctuations, economic changes and pricing policies. This leads to inefficient use of resources and reduced quality of passenger service. The introduction of fuzzy logic methods for passenger air transport management in Azerbaijan will improve the accuracy of forecasting and optimize processes, but the practice of applying such methods in this industry is still underdeveloped and requires further study.

Kropiventseva (2018) analysed transport processes and elements of passenger transportation, which allowed her to propose optimization of bus routes and improve financial management and technical operation, as well as to develop approaches that can be adapted to improve the management processes of air passenger transportation, taking into account the factors affecting the efficiency of transportation and resource use. In the study by Imanova (2022), the author proposed a methodology of multi-criteria assessment of competitiveness of airlines in Azerbaijan, based on expert data and passenger surveys using adapted expert fuzzy analysis and Pareto and Borda methods, which made it possible to identify the key factors of competitiveness and develop recommendations to improve the quality of service and increase the efficiency of airlines in the passenger transport market. Özden et al. (2023) conducted a comparative analysis of airline service quality perceptions of consumers from Turkey and Azerbaijan using fuzzy FIPIA analysis, which allowed identifying the key attributes that require attention to improve service quality and also contributed to the development of fuzzy logic-based passenger transport management methods. The study by Mızrak (2023) examined the use of fuzzy logic in human resource management in the aviation sector, emphasizing the importance of employee satisfaction in decision-making and showing a positive relationship between high levels of satisfaction and successful human resource management results.

Whereas the study by Ali et al. (2024) highlighted the significant growth of aviation sector in the last ten years, developed artificial intelligence-based methods,

particularly fuzzy inference systems to accurately predict the demand for domestic low-cost air travel in Bangladesh. Shah et al. (2020) analysed the passengers' perception of service quality of Pakistan International Airline (PIA) using SERVQUAL methodology. The study revealed that passenger satisfaction plays a key role in the relationship between service quality and passenger intentions, thereby emphasizing the need to improve service quality to enhance customer loyalty. In turn, Kao et al. (2020) developed a model of perceptions of airline crisis management capabilities and their impact on brand trust and behavioural intentions of passengers after strikes. It is found that effective crisis management improves brand relationships and customer loyalty by providing airlines with practical recommendations to improve crisis management.

De Carvalho and de Medeiros (2021) conducted a comparative analysis of SERVQUAL and SERVPERF models to examine the factors influencing airline service quality perceptions and found that tangible values and empathy played a key role in shaping these perceptions, with their results enabling airline managers to effectively allocate resources and improve service quality to increase customer satisfaction. Noviantoro and Huang (2022) analysed passenger satisfaction, identifying that the key aspects requiring improvement were online/mobile boarding, Wi-Fi on board, baggage handling and entertainment services, which was effectively integrated into a fuzzy logic-based airline passenger management model to optimize service quality and improve customer satisfaction. La et al. (2021) proposed an air passenger market forecasting model considering factors such as gross domestic product (GDP) and population growth using equal weight, linear combination and Bayesian network methods, which serves as a basis for building a fuzzy logic-based air passenger management model.

The primary research problem centres on the limitations of traditional air passenger management methods, which struggle to adequately address the uncertainty and variability in factors such as passenger traffic, seasonal fluctuations, economic changes, and pricing policies. These limitations often result in inefficient resource utilization and reduced quality of passenger service. The challenge is to develop a more adaptive and precise management model capable of accounting for these uncertainties and dynamic changes, thereby optimizing decision-making processes in air passenger transport management in Azerbaijan. Based on this research problem and the outlined objectives, the research hypothesis can be formulated as follows:

The implementation of a fuzzy logic-based model for air passenger transport management is expected to significantly enhance the accuracy of forecasting and decision-making under conditions of uncertainty and variability in factors affecting air transport. This model aims to improve resource utilization efficiency and passenger service quality by effectively accounting for dynamic changes in passenger traffic, seasonal fluctuations, and other external factors.

This hypothesis suggests that by using fuzzy logic, the model will better handle imprecise and uncertain data, leading to more accurate predictions of passenger traffic and other relevant factors. The adaptive nature of fuzzy logic should allow the model to adjust to real-time changes, thereby improving the decision-making process in air transport management. So, the study focuses on the development of an air passenger transport management model using fuzzy logic methods, aimed at improving the accuracy and efficiency of decision-making under conditions of uncertainty and variability of factors affecting air transport.

To achieve this goal, the following tasks were set: to study modern methods of managing passenger air transportation, including traditional and innovative approaches to improve forecasting and managerial decision-making under conditions of uncertainty; to assess existing problems and challenges in the field of passenger air transportation management; to examine the impact of technology on air transportation management and the improvement of passenger service quality; to conduct an analysis of passenger flow and passenger turnover in Azerbaijan, taking into account regional characteristics; to consider international experience in applying fuzzy logic and other innovative methods in passenger air transportation management to identify best practices and opportunities for their adaptation in the context of Azerbaijan's aviation industry; to develop a passenger air transportation management model based on fuzzy logic, which will allow for the consideration of factor uncertainty and enhance the accuracy of forecasting and managerial decision-making.

By means of comparative analysis, international experience of applying fuzzy logic and other modern methods in passenger air transport in other countries such as the USA, Germany, Japan, and Kazakhstan was studied. In turn, the data collected allowed not only studying international approaches, but also adapting them to the specifics of the aviation industry in Azerbaijan, identifying the most effective practices for further implementation. This analysis also helped to identify key factors that may affect the success of the introduction of such technologies in the Azerbaijani market. The modelling method was used to develop a model of passenger air transport management using fuzzy logic. With the help of BP Simulator service, the model was modelled using fuzzy logic methods, which takes into account the uncertainty of factors and allows for more accurate forecasting of various scenarios. To analyse passenger traffic and passenger turnover in Azerbaijan, statistical data provided from the official source – State Statistical Committee of the Republic of Azerbaijan (2024a), as well as information from Statistical Yearbook "Transport in Azerbaijan" (2024b) and IATA Annual Review 2024 (2024) were used.

Overview of Air Passenger Management Methods

Modern air passenger management techniques play a key role in improving efficiency and quality of service in a highly uncertain environment. Traditional methods based on strict algorithms often fail to cope with the dynamic environment of the airline industry, where external factors such as weather conditions and operational disruptions can significantly affect schedules and passenger satisfaction. In this context, modern techniques such as fuzzy logic and machine learning provide new opportunities for more accurate forecasting and management decisions (Belytskyi et al., 2023; Orazbayev et al., 2023). These techniques are able to take into account the uncertainty and variability of the external environment, allowing airlines' operations to be adapted more effectively.

To analyse the different methods of air passenger management, including traditional and modern methods, under uncertainty, Figure 1 presents the key methods used in this area.

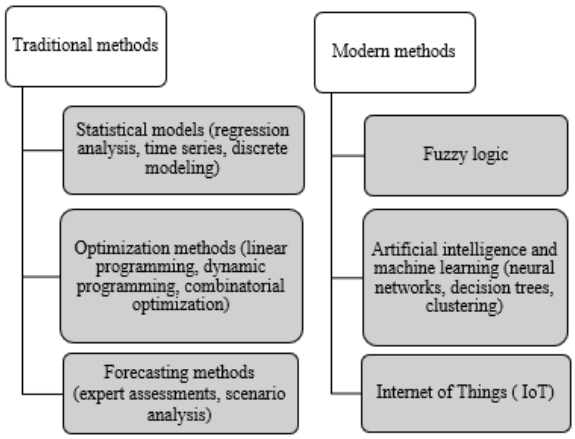

Fig. 1. Types of passenger air transportation management methods
Source: compiled by the author based on Poulaki et al. (2021).

Table 1 below compares traditional methods with modern methods and analyses their application under uncertainty.

Table 1. Comparison of traditional methods and modern methods in passenger air transportation management

Criterion	Traditional methods	Modern methods
Main characteristics	Based on historical data and rigorous algorithms	Account for uncertainty and variability in factors
Application in conditions uncertainties	Limited to prediction based on experience	Effective in volatile and uncertain situations
Flexibility and adaptability	Less flexible, require significant modifications to adapt to new conditions	Highly flexible, able to adapt to new and unexpected situations
Forecasting accuracy	High accuracy in stable conditions	Highly accurate under conditions of uncertainty
Influence of external factors	Limited, require data pre-processing	Consider a wide range of external factors and their variability
Time to make decisions	Long-term, especially in complex environments	Fast, thanks to automation and intelligent data analysis
Ease of implementation	Requires significant resources during the implementation and customization phase	Complex implementation requiring specialized knowledge
Application	Route planning, resource allocation	Demand forecasting, schedule disruption management
Advantages	Well-researched, predictable results	More accurate management under uncertainty, self-learning capability
Flaws	Less effective in highly variable environments	Difficult to implement and requires large amounts of data for training

Source: compiled by the author based on Voice of the World's Airports (2024)

Traditional methods based on historical data and rigorous algorithms work effectively in stable conditions. They provide high forecasting accuracy, but their ability to take into account external factors is limited, which requires preliminary data processing. Modern methods such as fuzzy logic and artificial intelligence, on the contrary, demonstrate high performance in changing and uncertain environments (Tkachenko et al., 2025). They are highly flexible and able to adapt to new and unexpected situations.

Under uncertainty, traditional methods are limited because their predictions are based on experience (Orazbayev et al., 2024). Modern methods consider a wide range of external factors and their variability to achieve high accuracy under such conditions. Due to automation and data mining, modern methods can significantly speed up the decision-making process, whereas traditional methods require significant time to make decisions, especially in complex environments (Biliuk et al.,

2023; Ginters et al., 2018). However, the implementation of traditional methods may require significant resources during the implementation and customization phase.

In practice, traditional methods are used for route planning and resource allocation, providing predictable results. Whereas, state-of-the-art methods are used for demand forecasting and managing schedule disturbances, offering more accurate control under uncertainty and self-learning capability. Despite their high performance, state-of-the-art methods can be complex to implement and require significant resources for training and data processing.

Taken together, all these aspects emphasize the importance of selecting an appropriate method depending on the context and objectives of air passenger management. Traditional methods are well researched and provide predictable results under stable conditions, while modern methods offer more accurate management and greater flexibility under uncertainty, as demonstrated in this comparison.

Next, it is necessary to assess the key problems and challenges faced in managing air passenger transport under uncertainty. Figure 2 summarizes the key issues and challenges faced by airlines, highlighting the need for modern techniques to improve management under uncertainty.

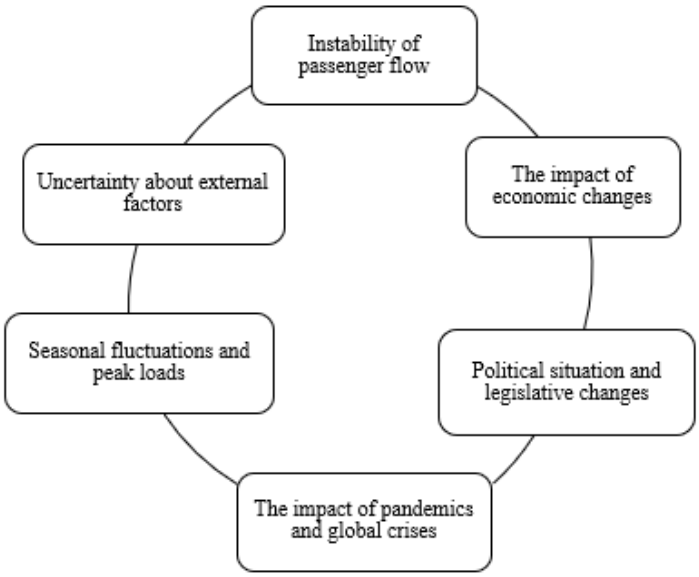

Fig. 2. Existing problems and challenges in the field of passenger air transportation management
Source: compiled by the author based on Leopold (2024), Top 10 Risks & Problems Facing the Aviation Industry in 2023 (2023), Reed (2023).

Air passenger management faces a number of serious problems and challenges in an uncertain environment. One of the most significant is passenger traffic volatility, which is caused by several factors, including seasonal fluctuations, economic crises and external emergencies. These fluctuations in passenger traffic require airlines to be highly flexible in route planning and resource management, which is a challenging task under uncertainty (Leopold, 2024). Economic changes also play an important role in air transport management. Fluctuations in fuel prices, exchange rate changes and inflationary processes directly affect the cost of transport and profit of airlines (Jakubik et al., 2017; Kukharchuk et al., 2017). At the same time, in order to ensure the profitability of carriage, it is necessary to quickly adapt to changes, which requires the use of flexible forecasting and pricing tools (Top 10 Risks & Problems Facing the Aviation Industry in 2023, 2023). In addition, the impact of external factors such as political instability, changes in legislation, new environmental standards can significantly affect the operational activities of airlines, forcing them to revise their strategic and operational plans.

Particular attention should be paid to global crises, such as pandemics, which have a direct impact on demand for air travel (Panchenko et al., 2023). These events emphasize the importance of being prepared for unpredictable changes and the need to develop effective management practices in the face of uncertainty. In addition, seasonal fluctuations and peak loads also pose challenges to effective airline management (Babak et al., 2005). During summer months or holiday seasons, there is an increase in passenger traffic, which requires an increase in the number of flights and schedule optimization (Reed, 2023). In turn, during the off-season, airlines face a decrease in passenger traffic and the need to reallocate resources. All these challenges require the application of innovative methods and technologies such as big data, artificial intelligence and analytics to effectively adapt to changes and minimize risks.

Technological Integration and the Development of the Fuzzy Logic Model

The use of technologies such as air traffic control systems and the Internet of Things not only improves operational processes but also enhances flight safety by enabling accurate real-time tracking of aircraft and baggage (IoT in Aviation, 2024). Also, big data analytics helps airlines to forecast passenger traffic more accurately, optimize routes and personalize offers, which has an impact on improving customer satisfaction (Khoda et al., 2024; Srivastava, 2024). The experience of successful international examples shows that these innovations can be effectively implemented in the Azerbaijani aviation industry as well. Adaptation of modern technologies in

air transport management will increase their competitiveness, improve passenger experience and increase the overall efficiency of airlines in today's market conditions.

In turn, passenger air travel in Azerbaijan, as in other countries, has undergone significant changes over the past few years, due to the impact of economic and external economic factors, such as the COVID-19 pandemic, which have had an impact on the demand for air travel and, as a consequence, on passenger traffic and passenger turnover in the country between 2019 and 2023 (Figure 3).

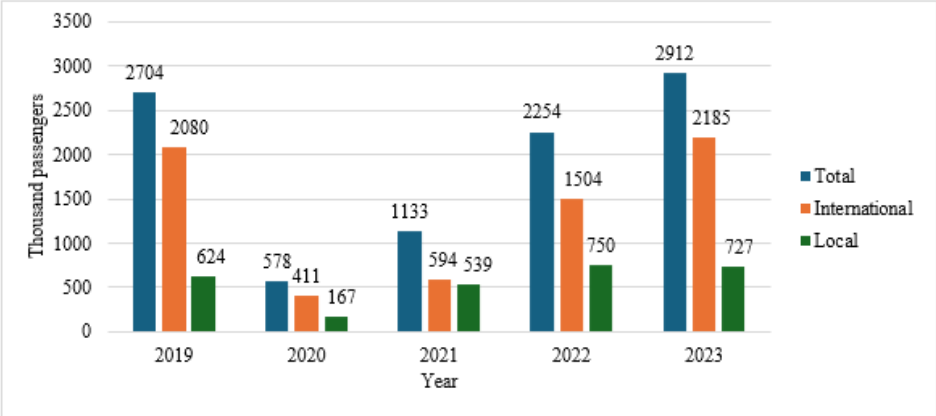

Fig. 3. Volume of passenger transportation by air transport of the Republic of Azerbaijan from 2019 to 2023, thousand passengers

Source: compiled by the author based on State Statistical Committee of the Republic of Azerbaijan (2024a)

An analysis of air passenger traffic data for the Republic of Azerbaijan from 2019 to 2023 shows significant fluctuations, particularly in 2020 when passenger numbers fell sharply to 578,000. This was due to the effects of the global COVID-19 pandemic, when travel restrictions and flight reductions led to a sharp drop in demand for air travel. However, there has been a gradual recovery since 2021 and by 2022 passenger numbers had returned to 2019 levels. In 2023, passenger numbers continued to grow to 2,912,000, even higher than pre-pandemic levels. This indicates the recovery and growth of air passenger traffic in the Republic of Azerbaijan after the crisis, due to the resumption of tourist and business travellers. Nevertheless, despite the positive trends, the dynamics of passenger traffic continues to be influenced by factors such as seasonal fluctuations, changes in the global economy and possible foreign economic and political crises, which requires constant analysis and adaptation of management strategies in the aviation industry.

Figure 4 presents the passenger traffic of the Republic of Azerbaijan for the period from 2019 to 2023. The data shows the changes in the volume of traffic on both international and domestic routes, reflecting the impact of external factors on the dynamics of passenger turnover in the country.

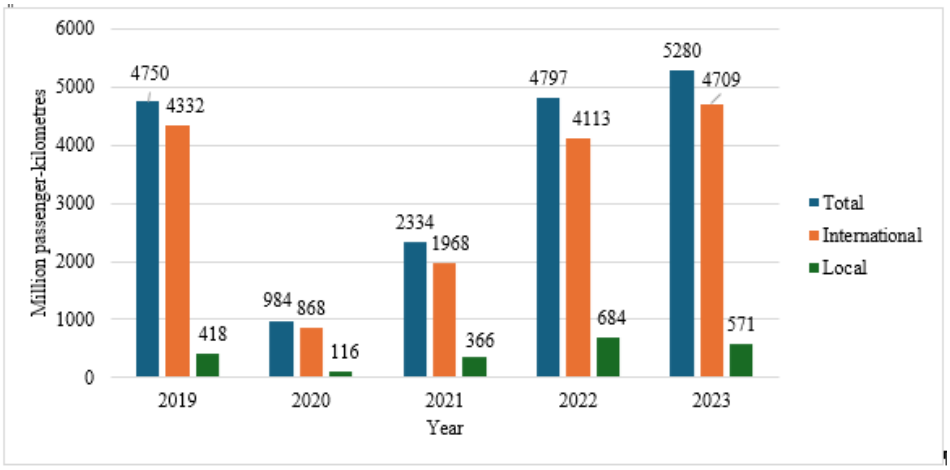

Fig. 4. Passenger turnover of the Republic of Azerbaijan from 2019 to 2023, million passenger-km
Source: compiled by the author based on State Statistical Committee of the Republic of Azerbaijan (2024a, 2024b)

An analysis of Azerbaijan Republic's passenger turnover data from 2019 to 2023 shows the significant impact of the pandemic on air travel. In 2020, passenger traffic declines strongly, especially in international flights, due to global travel restrictions. However, there is a steady recovery from 2021 onwards, and by 2022 performance is almost back to 2019 levels. Despite a temporary decline in 2020, passenger traffic started to grow again in the following years, with an increase in both international and domestic flights. International traffic still accounts for the majority of total passenger turnover, but there has been an increase in domestic demand, which also indicates the recovery and development of local air travel. Overall, passenger turnover in Azerbaijan continues to recover and even exceeds pre-industrial levels, reflecting the improving situation in the industry and the growing interest in air travel both domestically and abroad.

The study of international experience in the application of fuzzy logic and other innovative approaches in the management of air passenger traffic represents an important step in identifying best practices that can be adapted and implemented in the context of the Azerbaijani aviation industry. Table 3 depicts successful examples from other countries such as the USA, Germany, Japan and Kazakhstan, which will help to identify the most effective methods and technologies that can contribute

to improving the quality of passenger service, optimizing resources and improving the overall efficiency of air transport management in Azerbaijan.

Methods and technologies successfully introduced in other countries to improve air transport efficiency can be effectively adapted to improve the management of the aviation sector in Azerbaijan. In particular, countries such as the USA, Germany, Japan, and Kazakhstan have demonstrated significant achievements in automation, integration of transport systems and improvement of passenger service quality, which can be a good basis for introducing innovations in Azerbaijan.

One of the most promising areas for adaptation in Azerbaijan is the use of artificial intelligence (AI) and biometric technologies actively used in the USA (Amarnath, 2024). The introduction of AI for passenger flow management and passenger registration using biometrics can significantly speed up processes at all stages, from registration to security checks. This would not only increase comfort and safety for passengers, but also improve the efficiency of airport operations. The use of such technologies in Azerbaijan would reduce queues, improve the accuracy of flight schedules and reduce delays, which in turn would improve the overall competitiveness of air travel in the country.

The example of Germany with the automation of service processes and optimization of schedules is also valuable for Azerbaijan (Hughes, 2023). The introduction of intelligent systems for flight planning and coordination would avoid human error, reduce delays and improve the accuracy of air carriers. A particularly important step for Azerbaijan could be the creation of a unified information system for all air transport participants, which would ensure effective interaction between airlines, airports, and passengers.

Japan has demonstrated successful experience of integrating different modes of transport, for example, using high-speed trains, which helps passengers to get to airports easily and quickly (Japan Smart Airport Market Size…, 2024). This model can be useful for Azerbaijan, especially in connection with the development of transport infrastructure and improving transport links between regions. For Azerbaijan, an important step would be to improve connectivity between air and ground transport, which would speed up passenger movement and improve the overall comfort of travelling.

Kazakhstan, for its part, has implemented centralized air transport management through a single information system (Thales Modernises Air Traffic Management at Kazakhstan's Astana and Almaty Airports, 2024). This has improved coordination and reduced operational costs. For Azerbaijan, the introduction of such a system would be a significant step towards improving air transport management, as well as the development of logistics hubs and terminals, which would contribute not only to the growth of passenger traffic, but also to the development of freight traffic.

Thus, the use of international experience and the introduction of modern technologies such as AI, automation, biometrics, as well as the improvement of

transport infrastructure, can significantly improve the efficiency of air transport management in Azerbaijan. These steps contribute not only to improving the quality of passenger service, but also to optimizing the use of resources and increasing the overall competitiveness of the airline sector.

Air passenger management is a key element in the efficient operation of the aviation industry, especially in an unstable and uncertain environment. To improve the management of air passenger transport under conditions of uncertainty, a model based on fuzzy logic has been developed. Such a model allows taking into account the variability of factors and significantly improve the accuracy of forecasting and management decision-making. The use of fuzzy logic allows flexible response to changes in the external environment, such as unpredictable fluctuations in passenger traffic, weather conditions or operational failures (Kiurchev et al., 2023; Yermolenko et al., 2024). Using the BP Simulator service, the algorithm of the developed model of passenger air transport management was simulated in Figure 5, demonstrating the main stages and components of the process based on fuzzy logic.

The model illustrated in Figure 5 leverages fuzzy logic to enhance forecasting and management in air transportation by effectively addressing uncertainties and variabilities in factors such as passenger traffic and seasonal fluctuations. By defining input variables like passenger traffic and seasonal changes, and output variables such as the projected number of flights, the model uses fuzzy sets with membership functions (low, medium, high) to create flexible and adaptive rules. These rules allow the model to estimate the number of flights based on real-time input values and apply defuzzification methods to convert fuzzy values into precise flight numbers. For example, during a high season with medium passenger traffic, the model can dynamically adjust flight schedules to optimize resource allocation and improve operational efficiency. This approach not only enhances the accuracy of forecasts and decision-making but also improves passenger satisfaction by minimizing delays and efficiently managing resources, ultimately increasing the overall competitiveness of the airline sector.

To transition from a theoretical algorithm to a practical application of an air transport management model based on fuzzy logic, it is essential to use real-world data for both input and output. This process begins with data collection, where historical data on passenger traffic, seasonal fluctuations, weather conditions, and other relevant factors influencing air transport are gathered from various sources such as airline databases, weather services, and passenger surveys. Output data, including the actual number of flights operated, flight delays, passenger satisfaction scores, and resource utilization metrics, should also be collected.

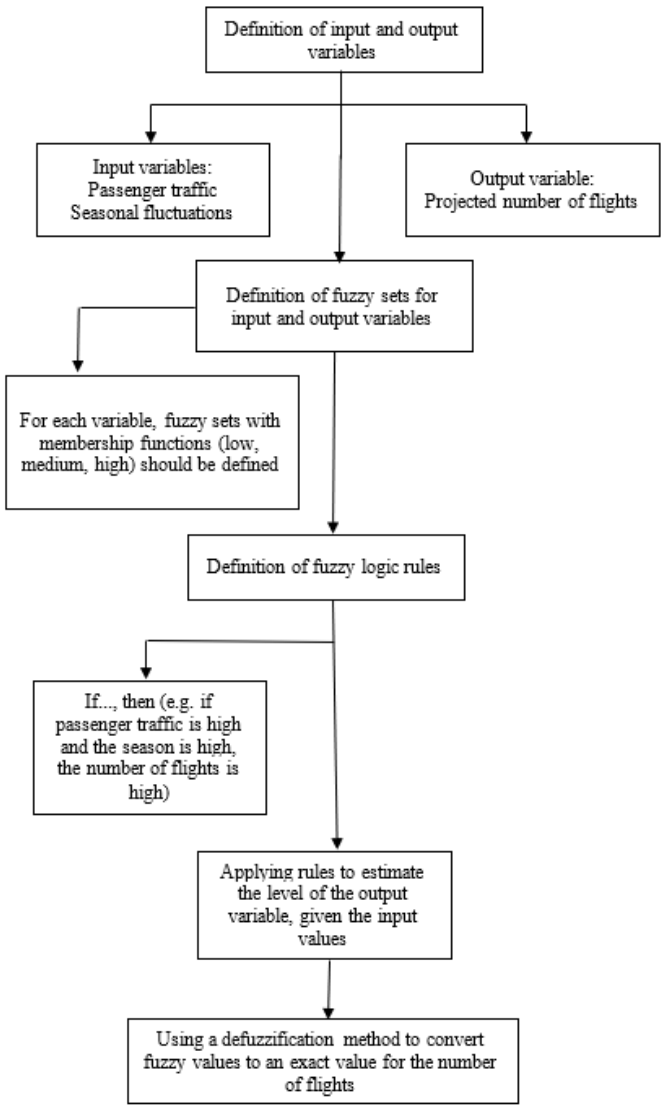

Fig. 5. Algorithm for graphical representation of the passenger air transportation management model based on fuzzy logic

Source: compiled by the author

The next step involves data preprocessing, which includes cleaning the data to handle missing values, outliers, and inconsistencies, and normalizing it to ensure all variables are on a similar scale, a crucial step for fuzzy logic systems. Using the preprocessed data, fuzzy sets and membership functions for each input variable

are defined. For example, "low," "medium," and "high" membership functions for passenger traffic can be established based on historical data distributions.

Following this, fuzzy logic rules are developed based on expert knowledge and historical data patterns. These rules map input variables to output variables, such as "If passenger traffic is high and the season is high, then the number of flights is high." The fuzzy logic model is then implemented using a suitable programming language or software tool, with libraries such as scikit-fuzzy in Python being particularly useful.

The model is trained and validated using portions of the historical data, applying the fuzzy logic rules to the input data and comparing the model's output to the actual historical output data. Performance metrics such as accuracy, precision, recall, and mean squared error are used to evaluate the model's performance, providing insights into how well it can predict the number of flights and other output variables.

Once validated, the model can be deployed in a real-world setting to assist in air transport management. Continuous monitoring and adjustments based on new data and changing conditions are necessary to maintain the model's accuracy. Establishing a feedback loop to incorporate new data and insights back into the model helps it adapt to changing conditions and improve its accuracy over time. By following these steps, the theoretical algorithm can be transformed into a practical application grounded in actual data, providing actionable insights for decision-making in air transport management.

The application of fuzzy logic provides greater adaptability and agility in decision-making, taking into account a wide range of factors such as seasonal fluctuations in passenger traffic and unforeseen external circumstances (Kerimkhulle et al., 2022; 2023). This is particularly important in an environment where traditional management techniques cannot sufficiently account for the uncertainty associated with such variables. As a result, by using this model, airlines can plan their resources more accurately and optimize flight schedules, which helps to reduce delays and improve passenger satisfaction. In turn, this improves overall operational efficiency by reducing the cost of flight service and minimizing potential losses.

Discussion

With the rapid development of civil aviation, the issues of efficient management of air passenger services are becoming particularly relevant. Research in this area is focused on improving the quality of service and optimizing processes. The application of fuzzy logic to build a management model allows taking into account the uncertainties and complexity of factors affecting the operation of airlines, which contributes to accurate forecasting and improved decision-making in the dynamic

air transport market. Active research in the field of fuzzy logic application opens new opportunities for improving the efficiency of passenger transport management in the airline industry.

In the studies of Sudakov (2021), Mijović et al. (2021), Keskin and Salman (2020), the authors proposed innovative approaches to the management of passenger air transport using fuzzy logic and modern technologies. Methods and algorithms for decision support in planning passenger air transport under uncertainty have been developed. The approach includes the reconstruction of a fuzzy departure-destination matrix and the use of optimization models to improve the transport graph, which is particularly important in conditions of decreasing demand for passenger air travel due to pandemic. Two metaheuristics are applied to tune a fuzzy logic model aimed at determining the market share of airlines on long-haul routes, which significantly improved the performance of the model. Emphasis is placed on the implementation of building information modelling in smart airports, which improves operational efficiency by integrating data and digital technologies.

These results coincide with the findings of the study emphasizing the use of fuzzy logic for decision-making under uncertainty. Such an approach also enables transport graph optimization and improved route planning, which is particularly important in the face of variability in air travel demand. In addition, as in the study, digital technology integration is utilized to improve the efficiency of air transport process management, which facilitates more accurate resource allocation and improved passenger service.

While studies by Banerjee et al. (2020), Jin et al. (2020), Dixit and Jakhar (2021) focus on demand forecasting and capacity management using various techniques such as machine learning, optimization techniques and stochastic models, the results of the current study, focusing on the development of an air passenger management model using fuzzy logic techniques, are slightly different. Much emphasis was placed on forecasting and capacity management to optimize operational processes, applying the extreme learning machine method to improve demand forecasting. Complex aspects of management under uncertainty have also been considered, but fuzzy logic, which is the basis in the results of the current study, is not used. Unlike other methods, the developed model is based on fuzzy logic, which can improve the accuracy and efficiency of decision-making under the variability of factors affecting air passenger transport. Thus, this model creates more flexible and appropriate solutions to problems associated with uncertainty and dynamic conditions.

The analysis of various studies has shown that the application of fuzzy logic for process optimization in air passenger transport and resource management under uncertainty is an effective method. The importance of using fuzzy systems to manage schedules, passenger, and resource reallocation has been recognized in studies concerning the recovery of disrupted flights. However, unlike most works that consider these aspects separately, the model proposed in this study integrates all these factors

into a single system, which allows for more accurate and effective decision-making under uncertainty and variability of factors affecting airline operations.

Fuzzy Logic in Air Passenger Transport Management

A fuzzy logic-based model has been developed to improve air passenger transport management under uncertainty, accounting for factors like passenger traffic fluctuations, weather conditions, and operational disruptions. This model enhances forecasting accuracy, flexibility, and decision-making, allowing airlines to optimize resources, schedules, and minimize delays. Modern technologies, including fuzzy logic, artificial intelligence, and machine learning, offer significant improvements over traditional methods, providing quicker and more accurate decisions in response to external changes. These innovations enhance the passenger experience and operational efficiency, ensuring airline competitiveness and growth.

Managing air passenger operations faces challenges such as fluctuating traffic, economic instability, and global crises like pandemics. To address these, AI, big data analytics, and dynamic pricing are essential for effective forecasting and risk reduction. The adoption of technologies like biometrics, AI, and process automation can greatly improve airline efficiency, security, and service speed, reducing waiting times and optimizing resources. Passenger traffic in Azerbaijan from 2019 to 2023 showed a post-pandemic recovery, with significant growth in 2023. International practices, such as AI and biometrics in the US and process automation in Germany, offer valuable insights for improving Azerbaijan's aviation sector.

Limitations include the need for real-world validation and the high cost of fuzzy logic integration. Further research should explore combining fuzzy logic with AI and big data analytics for more accurate systems.

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