The Journal of Applied Engineering and Agriculture Sciences
https://dergipark.org.tr/en/pub/umtd

RESEARCH ARTICLE

Enhancing Airport Efficiency by Simulating Passenger Waiting Times

Mehmet Taha Uyar [1], Güney Gürsel [2]

[1] Student in Department of Computer Engineering, Faculty of Engineering and Architecture, Konya Food and Agriculture University, Konya/TURKEY
[2] Department of Software Engineering, Faculty of Engineering and Architecture, Konya Food and Agriculture University, Konya/TURKEY

Corresponding author:
Güney Gürsel

E-mail address:
guney.gursel@gidatarim.edu.tr

Submitted: 19.07.2024
Revision Requested: 22.07.2024
Last Revision Received: 22.07.2024
Accepted: 22.07.2024

Citation: Uyar, M.T., Gürsel, G. (2024). Enhancing Airport Efficiency by Simulating Passenger Waiting Times. *The Journal of Applied Engineering and Agriculture Sciences* 1(1), 47-51.

ABSTRACT

In this study, a detailed simulation model of airport operations was developed using the SimPy library to analyze passenger waiting times at security, check-in, and boarding points. QuickPassenger was evaluated to reflect realistic scenarios of different passenger profiles, such as tourists and those requiring special assistance (e.g. disabled, pregnant). The primary objective was to evaluate how resource management and passenger prioritization affected overall waiting times. Simulation results showed that optimizing resource allocation significantly reduced wait times, especially at security checkpoints, which are often the bottlenecks. This study provides valuable information to airport managers to increase operational efficiency and improve passenger experiences through strategic resource planning and prioritization.

Keywords: Simulation, Airport Operations, Passenger Flow, Waiting Times, Resource Management

1. Introduction

Airport operations are complex systems that involve numerous processes and interactions between various entities, including passengers, security personnel, and airline personnel (Manataki, & Zografos, 2009). Efficient management of these processes is of great importance for the smooth and timely performance of operations (Ofoegbu, & Felix, 2024). Delays at any point, such as security, check-in or boarding, may create significant bottlenecks, impacting the overall passenger experience and operational efficiency of the airport (Anagnostopoulou, Tolikas, Spyrou, Akac, & Kappatos,2024).

Background and Motivation

Increasing air travel volumes places great pressure on airport infrastructure and management (Avogadro, Birolini, Redondi, & Deforza, 2024). Airports must accommodate many passengers with different needs and profiles, from business travelers with tight schedules to tourists and people requiring special assistance (Papatheodorou, 2021). Understanding and managing these diverse requirements is crucial to minimizing wait times and increasing passenger satisfaction (Li, An, & Zhang, 2024).

Literature has shown that discrete event simulation is a powerful tool for modeling and analyzing complex systems such as airports, by simulating passenger flow through different checkpoints, it is possible to detect bottlenecks, test different resource allocation strategies and evaluate their impact on the overall system performance (Oudani, Zkik, Belhadi, Kamble, Sebbar, & El Raoui, 2024, Luo, Fricke, Desart, Zapata, & Schultz, 2024).

Despite advancements in technology and management practices, many airports still struggle with long waiting times at security, check-in, and boarding points, because of inadequate resource allocation, unanticipated surges in passenger numbers, and the diverse needs of different passenger profiles (Akpur, 2024). There is a need for a comprehensive approach to optimize resource allocation and improve operational efficiency. Figure 1 shows the relation between the number of passengers and waiting times.

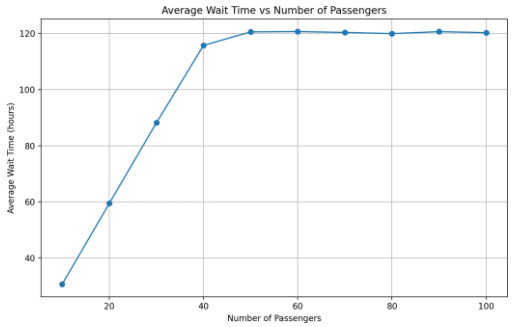

Figure 1: Average Wait Time and Number of Passengers

The application of simulation modelling in airport operations has been widely studied in the literature, focusing primarily on resource utilization and improvement of passenger flow(Scozzaro, 2024, Liu, Hu, Yin, Su, & Qiao, 2024, Xu, 2024). This section reviews key studies and identifies gaps that motivate the current research.

Recent studies established the foundation for using discrete-event simulation in modelling airport systems (Ma, He, Yang, Liao, & Liu, 2024, , Liu, Chen, Zhang, Wang, Luo, & Chen, 2024). They highlighted the importance of accurately representing passenger behaviors, such as arrival patterns, check-in procedures, and security screenings, to effectively simulate airport operations.

Gaps in Literature

Despite significant advancements, current literature often overlooks the impact of diverse passenger profiles on waiting times and operational efficiency. There is limited research on how different passenger categories, such as business passengers with priority needs or families requiring additional assistance, influence overall airport performance.

Furthermore, while many studies focus on optimizing specific checkpoints like security or boarding, holistic approaches that integrate all operational aspects of an airport are not common. This gap hinders a comprehensive understanding of the interconnectedness among various airport processes and their combined effect on passenger experiences.

Contribution of the current Study

This study addresses these gaps by developing a comprehensive simulation model that incorporates diverse passenger profiles and evaluates their impact on waiting times at security, check-in, and boarding points. By considering real-world scenarios and using empirical data, this study aims to provide insights that support informed decision-making and enhance airport operations.

This study aims to develop a detailed simulation model of airport operations using the SimPy library by phyton in google Colab. The specific objectives are to:

1. Analyze passenger waiting times at security, check-in, and boarding points.
2. Evaluate the impact of different passenger profiles on waiting times.
3. Assess the effectiveness of various resource allocation strategies.
4. Provide recommendations for airport managers to optimize operations and enhance passenger experiences.

2. Methods

In this study, the SimPy simulation library was employed in phyton to model and analyze airport operations. The objective was to assess the impact of different passenger profiles (e.g., QuickPassenger, Tourist, disabled, pregnant) on waiting times at security, check-in, and boarding points. Additionally, the study examined the effects of resource management strategies and passenger prioritization policies on overall waiting times.

Simulation Model

The simulation model is designed to simulate passenger flow at the airport, taking into account realistic scenarios and operational parameters. Key elements included:

1. Passenger Profiles: Various passenger profiles were defined based on typical behaviors and needs, such as different arrival times, check-in times, and security screening times.

2. Resource Allocation: Resources such as security checkpoints, check-in counters, and boarding gates are modeled as SimPy resources with defined capacities and processing times.

3. Event Generation: Passenger arrivals were simulated according to established distributions (e.g., Poisson process for arrival times) and sequential security screening, check-in, and boarding processes were applied to each passenger.

Collection and Analysis of Data

Empirical data and realistic assumptions were used to parameterize the simulation model. Key metrics such as average wait times and overall production rates at each checkpoint were collected and analyzed to evaluate the performance of different scenarios.

Experimental Setup

The simulation experiments were conducted over multiple iterations to capture variability in passenger arrivals and operational conditions. Sensitivity analyses were performed to assess the robustness of the findings under different scenarios and parameter settings.

3. Results

The simulation experiments yielded valuable insights into passenger waiting times and operational efficiencies at the airport. Key findings are summarized below:

1. Impact of Passenger Profiles: Different passenger profiles significantly influenced waiting times. QuickPassengers, characterized by shorter security screening times, experienced minimal delays compared to Tourists and passengers requiring special assistance (e.g., disabled, pregnant).

2. Checkpoint Bottlenecks: Security checkpoints emerged as critical bottlenecks, with longer waiting times observed during peak hours and under scenarios with increased passenger volumes. Figure 2 gives the problem in this point.

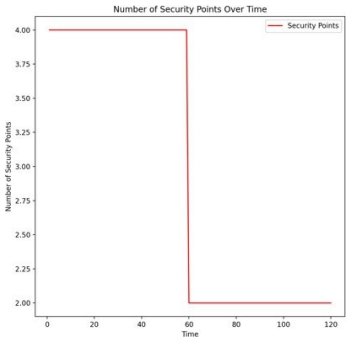

Figure 2: Security Point and Time Relation

3. Resource Utilization: Optimal resource allocation strategies, such as adjusting the number of security lanes based on real-time passenger flow, effectively reduced overall waiting times.

4. Effectiveness of Prioritization Policies: Prioritizing certain passenger profiles (e.g., business travelers or those with special needs) at checkpoints showed mixed results, highlighting the need for balanced resource allocation strategies.

4. Discussion

The findings underscore the complexity of airport operations and the importance of adaptive strategies to manage varying passenger demands. By accurately simulating passenger behaviors and operational processes, the study demonstrated the following:

- **Operational Efficiency** Implementing flexible resource allocation policies based on real- time data can mitigate congestion at critical checkpoints, enhancing overall operational efficiency.
- **Passenger Experience**: Improving waiting times at security, check-in, and boarding points directly enhances passenger satisfaction and reduces stress levels during travel.
- **Policy Implications**: Airport managers can use simulation modeling to test and refine operational strategies, leading to better resource utilization and improved service quality.

This study utilized simulation modeling to evaluate the impact of diverse passenger profiles on airport operations, focusing on waiting times at security, check-in, and boarding points. The findings highlight several key insights:

- **Passenger Profile Influence**: Different passenger profiles, such as QuickPassenger and Tourist, significantly affect waiting times due to varying processing speeds and needs.
- **Operational Efficiency**: Optimal resource allocation strategies, informed by simulation results, can effectively reduce congestion and waiting times at critical checkpoints.

- **Policy Recommendations**: Airport management can benefit from adopting adaptive strategies that prioritize resource allocation based on real-time passenger flow and profile characteristics.

Moving forward, future research could explore more advanced modeling techniques and incorporate real-time data analytics to further enhance airport operations. By continuously refining operational strategies, airports can better meet the demands of an evolving travel landscape while improving passenger satisfaction.

5. Conclusion

This simulation study aimed to understand the impact of airport congestion on passengers' boarding times and ability to catch their flight. By changing passenger profiles and manipulating wait times at key airport checkpoints (security, check-in and boarding), the study observed how these factors affected overall airport efficiency and passenger punctuality.

Key findings include:

- **Operational Insights**: Optimal resource allocation strategies, derived from simulation experiments, played a crucial role in mitigating airport congestion and enhancing passenger flow.
- **Implications for Airport Management**: Implementing adaptive strategies based on real- time data analytics can significantly
- **Policy Recommendations**: Airport management can benefit from adopting adaptive strategies that prioritize resource allocation based on real-time passenger flow and profile characteristics.
- **Passenger Profile Influence**: Different passenger profiles, such as QuickPassenger and Tourist, significantly affect waiting times due to varying processing speeds and needs.
- **Passenger Punctuality**: Adjustments in waiting times directly affected passenger punctuality rates, highlighting the importance of efficient queue management and operational planning.

Future research directions may involve integrating more sophisticated modeling techniques and expanding the scope to include dynamic passenger behaviors and real-world data validation.

Acknowledgments

This study is the project report of CENG 4205 Modelling and Simulation Lecture of 4th grade student Mehmet Taha UYAR supervised by Güney Gürsel.

References

Akpur, A. (2024). Adapting to the skies: evolution of qualified personnel in airline operations amid technological advancements. *Worldwide Hospitality and Tourism Themes*, 16(3), 13-24.

Anagnostopoulou, A., Tolikas, D., Spyrou, E., Akac, A., & Kappatos, V. (2024). The Analysis and AI Simulation of Passenger Flows in an Airport Terminal: A Decision-Making Tool. *Sustainability*, 16(3), 1346

Avogadro, N., Birolini, S., Redondi, R., & Deforza, P. (2024). Assessing airport ground access interventions: An integrated approach combining mode choice modeling and microscopic traffic simulation. *Transport Policy*, 148, 154-167.

Gadzhimusieva, D., Gorelova, A., Beigbeder, S. M., & Lledó, G. L. (2024). Enhancing Accessibility in Academic Buildings: A Discrete Event Simulation Approach for Robotic Assistance. *IEEE Access*.

Ofoegbu, W. C., & Felix, O. O. (2024). OPERATIONS MANAGEMENT AND ITS CRUCIAL ROLE TO STABILIZE THE NIGERIAN ECONOMY. GPH-*International Journal of Business Management*, 7(02), 46-58.

Li, X., An, X., & Zhang, B. (2024). Minimizing passenger waiting time in the multi-route bus fleet allocation problem through distributionally robust optimization and reinforcement learning. *Computers & Operations Research*, 164, 106568.

Liu, C., Chen, Y., Zhang, Y., Wang, H., Luo, Q., & Chen, L. (2024). Reliable and robust scheduling of airport operation resources by simulation optimization feedback and conflict resolution. *Neurocomputing*, 573, 127212.

Liu, Y., Hu, M., Yin, J., Su, J., & Qiao, P. (2024). Adaptive airport taxiing rule management: Design, assessment, and configuration. *Transportation Research Part C: Emerging Technologies*, 163, 104652.

Luo, M., Fricke, H., Desart, B., Zapata, S. R., & Schultz, M. (2024) High-Fidelity Digital Twin Applied Agent-Based Model for Supporting Predictable Airport Ground Operations. Available at SSRN 4806351.

Ma, X., He, Z., Yang, P., Liao, X., & Liu, W. (2024). Agent-based modelling and simulation for life-cycle airport flight planning and scheduling. *Journal of Simulation*, 18(1), 15-28.

Manataki, I. E., & Zografos, K. G. (2009). A generic system dynamics based tool for airport terminal performance analysis. *Transportation Research Part C: Emerging Technologies*, 17(4), 428-443.

Oudani, M., Zkik, K., Belhadi, A., Kamble, S., Sebbar, A., & El Raoui, H. (2024). Organizational resilience of the airline industry using an Integrated epidemic and airline hub location model with traffic prediction. *Annals of Operations Research*, 1-26.

Papatheodorou, A. (2021). A review of research into air transport and tourism: Launching the Annals of Tourism Research Curated Collection on Air Transport and Tourism. Annals of Tourism Research, 87, 103151.

Scozzaro, G. (2024). Optimization of airport operations during access mode disruptions to improve passengers experience (Doctoral dissertation, Université de Toulouse).

Xu, Y. (2024). Perspectives on Modelling Airline Integrated Scheduling Problem: a Review on State-of-the-Art Methodologies. Journal of the Air Transport Research Society, 100023