

Analysis and optimization of queueing systems in airports – Discrete event simulation

Rishabh Jain^a, Hrishikesh Bedekar^b, Jayakrishna K^{*c}, Vimal K E K^d, Vijay Manupati^e

^a School of Mechanical Engineering, Vellore Institute Technology, Vellore – 632014, India

^b School of Mechanical Engineering, Vellore Institute Technology, Vellore – 632014, India

^{*c} School of Mechanical Engineering, Vellore Institute Technology, Vellore – 632014, India

^d Department of Mechanical Engineering, NIT Patna, Bihar – 800005, India

^e Department of Mechanical Engineering, NIT Warangal, Telangana – 506004, India

*Corresponding author Email: jayakrishna.k@vit.ac.in

The objective of this paper is to present an authentic queuing scenario for airports both international and domestic including transit passengers in constant efforts to create a uniform flow of passengers and baggage. This study aims also at the simulation that can be used to identify bottlenecks in the systems as well as to gain insight into the whole process. Similarly, the study suggests multiple modified scenarios that provide a solution to the challenges in existing systems that can be adopted by the industry in the near future. More specifically these scenarios are rearrangements and modifications to the existing system. As security checkpoints are points in the system which can cause severe delays and are notorious for separation of individuals in a group. Therefore scenarios are considered wherein the number of checkpoints can be increased such that the total number of individuals waiting gets distributed effectively. Lastly, another scenario in which gate specific checkpoints are considered has been modeled for reference and can be seen on a few busy airports, it was also observed that the waiting times at security checkpoints reduced by 0.10 out of 0.43, 0.07 and 0.33. Though a longer queue time was observed at the last scenario than the second scenario, the third scenario would be a better replacement as it yields an optimum performance time without increasing the load on other points such as immigration, check-in and baggage claim unlike the second scenario wherein the queuing at security check point is reduced but pressure builds up on other parts of the system.

Keywords: Supply chain; airports; optimization; logistics; queuing; ARENA

1. Introduction

The identification of bottlenecks at the airport and their rectification would definitely make it a better and efficient system. The overall improvement of the system can be a critical factor influencing the success and efficiency of management at the airport [1]. Improved systems will reduce the time wasted unnecessarily due to stoppages at certain levels. Moreover, it will reduce the load on a single system and happy passengers would indeed be a key measure to organizational success [2]. The optimum utilization of resources would be an easier task if the system is well planned thereby reducing unnecessary expenditure and wasted capital.

The objective of this paper is to develop innovative methods of analyzing and optimizing queuing systems in a system with a special focus on airports. Principles of data collection, data interpretation by data fitting and modelling and simulation methodologies have been proposed. Different scenarios with varying arrangement of entities at the airport have been observed. The different scenarios to perform iterations towards improved results have contributed by depicting a unique solution. Using these methodologies, a novel structure of airports has been proposed. Major part of this research has been focused on modelling and simulation of systems in the manufacturing

and production domains. This work however aims to use these methodologies in the airports which have been rarely discussed. Moreover, the literature emphasizes on minor optimizations in the already established structure. However, this work tries to present an unconventional arrangement of queuing systems to achieve similar objectives.

2. Methodology

This part of the study mainly deals with developing innovative methods of modelling and simulating supply chains to minimize queuing times with an emphasis on airports. Data collection, interpretation, fitting coupled with modelling and simulation methodologies has been discussed in detail. The queueing theory forms a basis of this simulation and can be used for further calculations by considering the arrival time of passengers. The main equation derived is shown below,

$$P_0 = \frac{1}{1 + \sum_{n=1}^{\infty} \prod_{i=0}^{n-1} \frac{\lambda_i}{\mu_{i+1}}} \quad [4] \quad (1)$$

Where,

μ : Average service rate of a single service

λ : Average arrival rate

P: Probability of n customers in the system

n: Number of people in the system

It is best to start with a simple model and build toward greater complexity and it is not necessary to have a one-to-one mapping between the model and the real system [3]. In our case study large amounts of relevant data was collected in order to determine the probability distribution of the various processes involved. The logic of the system is converted to a computer understandable format using modules offered by the used application [4]. For example, the security check can be easily translated into a queuing module following “first come first serve” rule and the entities being served one by one by each module. Verification pertains to the computer program prepared for the simulation model [5]. Is the computer program performing properly or not? [6]. For example, increasing the number of people arriving level of the model must correspond to increase in the waiting times. If however, a decrease in waiting times is seen, a fallacy of the model is exposed which must then be rectified. Validation usually is achieved through the calibration of the model, an iterative process of comparing the model against actual system behaviour and using the discrepancies [4]. The alternatives that are to be simulated must be determined. Often, the decision concerning which alternatives to simulate will be a function of runs that have been completed and analyzed [3].

3. Analysis

A in depth analysis of a few airports revealed the airports with widely varying structures. In this case study a traditional model is adapted and improved upon to reduce queuing times. Here, real case data is collected from Chatrapati Shivaji International Airport to carry out simulations.

4. Model conceptualization

In order to translate the system into a discrete event simulation model in arena an extensive analysis of the system was done. Various points of queuing and delays were investigated. Data

was collected and the appropriate probability distributions were estimated for the data to be input into the simulation [6].

4.1 Data fitting

In order to simulate the model using DIS fitting the data obtained into the appropriate distribution of probability was carried out in a systematic method [6]. Random number generating methods were used in order to simulate the inter arrival times of the PAX [4]. Triangular distribution of data was used in cases wherein the maximum amount of population completed the given task in a given amount of time.

4.2 Models

Table 1 illustrates the different modules being used in the ARENA simulation each representing an entity. These entities represent the actual component involved in the system of queueing at the airport. Further details of the representation and their significance is mentioned in Table 1. Using the following modules coupled with sets queues in ARENA a comprehensive and realistic model was developed of the airport system. Using this system three scenarios (A, B and C) were considered for which simulations were run. Scenario B and C eventually evolved as a viable solution that could help mitigate the current problems faced by conventional queueing systems today. The three scenarios encompassing three types of airport systems are [6]:

Scenario A - A representation of the layout of Airport queueing systems in operation (Refer Figure 1)

Scenario B - A modified system with increased security points before the gates

Scenario C - A system with gate specific individual security point

Table 1 Model description

<i>Module</i>	<i>Explanation</i>
Gate Security Check	Simulated the inter arrival times of the patients intended to depart from the airport
Check in counter	Checking of documents followed by issue of tickets
Incorrect passenger detail failure	Case checking for failure of details to comply
Dispose 1	Passengers leave the system due to incorrect details
Check if international passenger	To check if the passenger in the system is flying international or not
Immigration	Immigration facility for international passengers
Immigration check	Immigration check
Immigration fail	Case checking the failure of immigration
Security check	Security check for airport
Gate international	International gates
Aircraft international	Boarding an international aircraft
Security check domestic	Security check for domestically flying passengers
Gate domestic	Domestic gates
Aircraft domestic	Boarding a domestic aircraft
Arrival	Simulating the inter-arrival times for passenger arrival to the airport

<i>Module</i>	<i>Explanation</i>
If international	Checks if arrived passenger is an international passenger
Immigration arrival	Immigration for arriving patients in transit
Immigration check arrival	Immigration check for arriving passenger in transit
Quarantine or held back	Passenger held back on immigration failure
Baggage claim	Baggage claim for passengers
Customs arrival	Customs for international passengers
Customs pass	Check if the passenger passed customs
Confiscated fined	Passenger fined on custom failure
International exit	International passengers leave the system

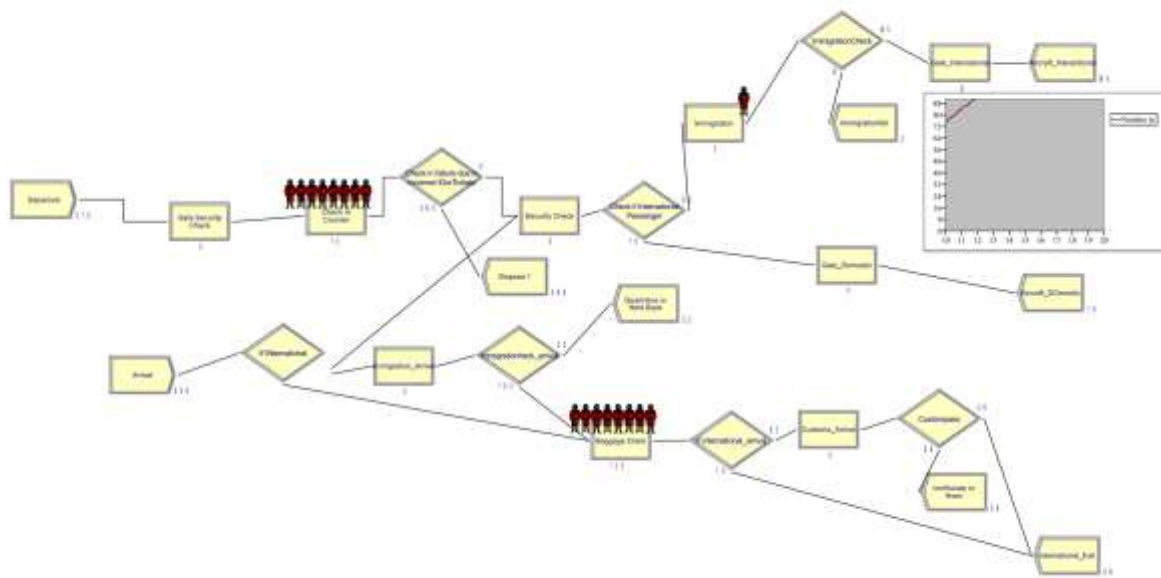


Fig 1. Model for layout of Airport Queuing systems in operation.

5. Results and Discussions

It can be clearly inferred from the statistics that the serious bottlenecks of the system are security check, immigration and baggage claim respectively in Scenario A. This will be evident when comparing the results to the other scenarios. As we have achieved a baseline for various performance measures like: Baggage claim waiting time as around 30 seconds and Check in counter as 7.58 minutes. In the scenario B, it can be seen that the above problem is solved by using more human resource to handle the passengers efficiently thereby reducing the time spent at each process. It was observed that though the scenario reduced queuing time at screening checkpoints, immigration, check-in counters and boarding gates were flooded with queues with increased entities waiting as 1, 9 and 40 respectively [7]. There is an increase in the baggage claim queuing waiting times (less than 10 seconds) but a decrease in check in counter waiting times (1 minute or less) can be seen. In the scenario C, the security check takes place separately at each of the gates thereby reducing load on the system by eliminating a common chaotic channel. In the final analysis a considerable decrease in waiting, baggage claim and gate security times have been decreased to 0.43, 0.07, 0.33minutes respectively.

6. Conclusions

As observed in the study, modifications can be made to the layout to make it more flexible leading to less crowding in the bottlenecks especially the security-check channel, immigration desks and the baggage counters [8, 9]. Modifications such as having separate security gateways at each gate instead of a common gateway reduce the burden on the system and also the total lead time involved in the formalities. The total cost to make this layout flexible and add the modifications is less when compared to the cost after incurring losses in the long run as customers-passengers are directly affected thereby holding the reputation of the Airport at stake. Similarly, such simulations can also be applied to the planning of other industries as it is easier and faster to analyze scenarios and identify pitfalls before developing the model into a defective entity thereby saving a lot of time and capital which can otherwise be used for more important things or where it is most required.

References

1. Ju, Y., Wang, A. and Che, H., 2007, September. Simulation and optimization for the airport passenger flow. In 2007 International Conference on Wireless Communications, Networking and Mobile Computing (pp. 6605-6608). IEEE.
2. Brown, J.R. and Madhavan, P., 2011. Examining Passenger Flow Choke Points at Airports Using Discrete Event Simulation.
3. Prinz, R., Väättäinen, K., Laitila, J., Sikanen, L. and Asikainen, A., 2019. Analysis of energy efficiency of forest chip supply systems using discrete-event simulation. *Applied energy*, 235, pp.1369-1380
4. Banks, J., Carson, I.I., Nelson, B.L. and Nicol, D.M., 2005. Discrete-event system simulation. Pearson.
5. Kleijnen, J.P., 1998. Experimental design for sensitivity analysis, optimization, and validation of simulation models. *Handbook of simulation: Principles, methodology, advances, applications, and practice*, pp.173-223.
6. De Neufville, R., Budd, L. and Ison, S., 2016. Airport systems planning and design. *Air transport management: An international perspective*, 61.
7. Joustra, P.E. and Van Dijk, N.M., 2001, December. Simulation of check-in at airports. In *Proceedings of the 33rd conference on Winter simulation* (pp. 1023-1028). IEEE Computer Society.
8. Pritsker, A.A.B., 1979. Compilation of definitions of simulation. *Simulation*, 33(2), pp.61-63.
9. Szymanczyk, O., Dickinson, P. and Duckett, T., 2011, June. Towards agent-based crowd simulation in airports using games technology. In *KES International Symposium on Agent and Multi-Agent Systems: Technologies and Applications* (pp. 524-533). Springer, Berlin, Heidelberg.