Simulation And Optimisation for Decision Support

Coursework 2

Border Control Simulation and Optimisation for Hamburg Airport

Submitted By: Aparna Krishnakumar

Student Id: 20496010

1.The Conceptual Model

The conceptual model is a non-software specific description of the computer simulation model (that will be, is, or has been built), specifying the aims, inputs, outputs, content, assumptions, and simplifications of the model (Robinson 2008a). The conceptual model assists us in developing a fundamental blueprint for the model's implementation and in better comprehending the problem at hand.

1.1 Brief problem statement

To improve passenger experience at the airport, the Hamburg Airport Management Board (HAMB) has decided to look for opportunities in to develop any of their services, especially on reducing waiting times for passengers and workforce management.

As a company, HAMB must consider expenses even as it strives to give passengers a nice experience. To do this, HAMB wants to first use simulation and optimisation to figure out an effective and efficient workforce management system. The issue is how many employees are required overall, where they should work (if you are simulating service provision at various locations. They are also planning to release a smart app to help passengers to receive the specific services they require in the quickest way possible. Passengers will receive up-to-date information via the smart app about the service locations where they may locate the shortest line for the service they need. The smart software will eventually provide an estimate of how long the entire procedure will take depending on the location's distance, the amount of people in the queue, and typical wait times. The number of devoted app users required to notice a statistically meaningful influence on passenger wait times for each of the distinct services supplied is of special relevance to HAMB. At first, all the passengers randomly choose among the various services. Once the app is available, progressively more travellers will utilise it to find their destination (perhaps encouraged by word-of-mouth).

1.2 Investigating of Solution Techniques

We have chosen Border control services at international airports as the service under investigation. There are several passenger categories to consider, and demand for this service is likely to fluctuate depending on flights schedules and passenger traffic. Staff optimisation is crucial in this area since there may be many border control counters and personnel with a variety of responsibilities (such as immigration control personnel or security personnel) to consider. It is also beneficial to model the use of a smart app and investigate its effects on how passengers are distributed among border control services. The modelling focuses on only arrival process of international flights and only one gate side is modelled for the ease of simulation.

1.3 Objectives

The primary objective of the simulation model is to optimize the staffing levels and service process at border control to minimize passenger waiting times while ensuring efficient use of resources. This objective is achieved using the help of having certain number of passengers use the mobile application to upload the biometric details and travel documents pre arrival to minimise their time in the system. These passengers go through self-immigration checks which has less time delay compared to the manual immigration counters which facilitates the objective of minimizing the passenger waiting time inside the system.

The objective function for the optimization experiment in border control at an airport is to minimize the number of staff utilization.

The constraints include:

1. Number of staff: The total number of staff allocated to all stations cannot exceed a certain number.
2. Number of Mobile app users: Number of application users
3. Capacity: The number of passengers processed at each station must not exceed its capacity.

1.4 Experimental factors (Inputs)

1. Passenger arrival rates – On an average about 128,178 passengers go through an airport everyday (Heathrow Airport, 2022). The range for number of flights per day and rate of number of passengers per minute is calculated according to this data.
2. Staffing levels for border control.
3. Processing times for each step in the border control process (e.g., passport check, baggage screening, etc.). on an average immigration control at arrival takes 5 to 10 minutes and customs control take 1 to 5 mins (IATA, 2021). The delays and service times were calculated according to this.
4. Queue waiting times and other service delays like using the airport facilities.
7. Implementation of a smart app for passenger distribution to different services.

1.5 Responses (Outputs)

1. Time distribution of passengers at border control system.
2. Utilization rate of staff.
3. The number of dedicated smart app users required to achieve a statistically and practically significant reduction in passenger waiting time.
4. Staff requirement for each service.

These outputs are represented in the model by the charts shown in Figure 1.

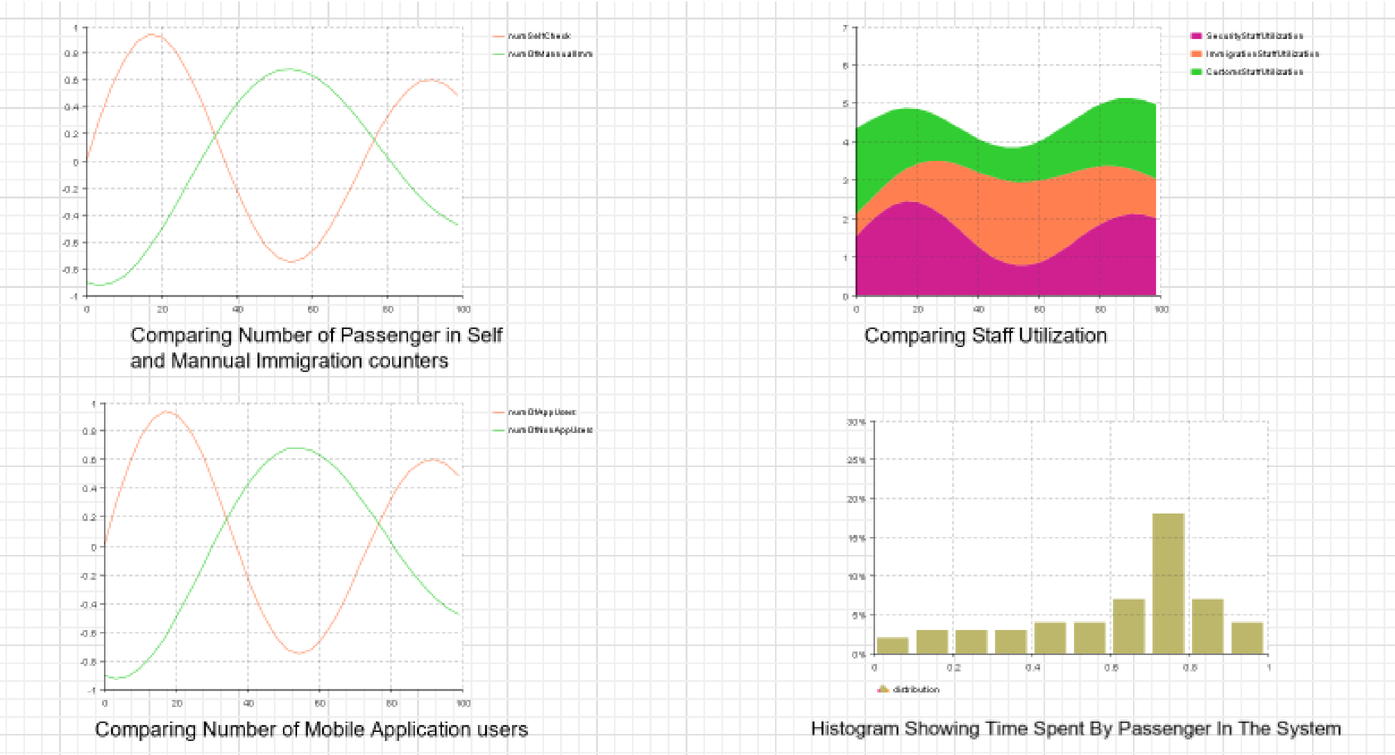

Figure 1.1 Output charts form the simulation model.

1.6 Content

The model will simulate the flow of passengers through border control, including any necessary queues or waiting times. The model will also include staffing levels, as well as the processing times for each step in the border control process. The model will be based on statistical distributions for passenger arrivals, processing times, and delays, and will be run for different scenarios and staffing levels. Level of detail and scope tables are created to get a better understanding of the contents included and not included in the model as shown by Table 1.1

Model Scope	**Detail**	**Decision**	**Justification**
Passengers		Include	Flow through service process
Staff	Border Control Staff	Include	Required for response
	Security Screening	Include	Material shortage not significant
	Management (Cleaning and Passenger InformationDesk)	Exclude	Not related to speed of service
Queue at service counter	Queue at both border control and security checks	Include	Required for response
Waiting area		Exclude	Not related to customers waiting
Flight Schedule		Exclude	Single Gate is considered and average number of flights and passenger per day is calculated from existing data
Gates		Include	Only one considered
Mobile App Usage	Used for easy immigration process fast moving through the airport	Include	Required for response
Level of Detail	**Detail**	**Decision**	**Comments**
Passengers	Passenger Arrival Time	Include	Experimental Factor
	Passenger Processing Time	Exclude	Represented by service time
	Average Walking Time from Gate to Border Control	Include	Required for response
Service Staff	Border Control Process Time	Include	Experimental Factor
	Security Screening Time	Include	Experimental Factor
	Staffing Schedule	Exclude	Experimental Factor
Queue at service counter	Passenger Queue	Include	Required for response
	Capacity	Exclude	Assumption:Unlimited
	Queue Behaviour: jockey;balk;leave	Exclude	Not well understood

Table 1.1 LoD and Scope tables.

1.7 Assumptions

1. Service times vary based on service locations and are modelled using appropriate distributions. Passenger processing time can vary based on different factors such as passport type, travel purpose, and baggage screening requirements.
2. Arrival time distribution of passengers is known but may not be perfectly predictable due to external factors such as flight delays. Although the arrival time distribution of passengers can be estimated based on historical data and flight schedules, there may be external factors that can cause deviations from the expected distribution.

3. Staff members can be reassigned between service locations, but there may be some limitations to their flexibility due to skill requirements or other constraints. Staff members are assumed to be always available and there are no constraints on their working hours or breaks.

1.8 Simplifications

1. Passenger behaviour is simplified to arrival time and nationality/visa requirements: This simplification is made to reduce the complexity of the model by not considering more detailed passenger behaviours that may not be significant in determining waiting times and staff utilization rates.
2. Passenger satisfaction is not explicitly modelled, but is indirectly measured through waiting times and service times: This simplification is made to keep the model focused on the key performance measures, i.e. waiting times and staff utilization rates, which are used as proxies for passenger satisfaction.
3. Service process is simplified to include only the basic steps (passport check, baggage screening, etc.) without accounting for any additional checks or procedures that may occur.
4. Infrastructure limitations, such as limited physical space or equipment, are not considered in the model.
5. Staff preferences, such as preferred shifts or service locations, are not considered in the model.
6. Passengers are assumed to arrive only through one entrance and proceed through the border control process linearly without any deviations or interruptions.
7. The physical layout of the border control area is not considered, and any potential bottlenecks or constraints related to the space are ignored.
8. Interactions between passengers, such as grouping or separating, are not considered in the model.

1.9 Process Flow and State Diagrams

Using different types of diagrams is a common practice in modelling and simulation, and it allows for a comprehensive and clear representation of the system being modelled. The process flow diagram and the state chart diagram are two types of diagrams commonly used in conceptual modelling, and they both play important roles in understanding the behaviour of the system (Robinson, 2008a). Computer simulation is an effective tool for exploring complex systems, and it allows for the testing of different scenarios and "what-if" questions. By using different types of diagrams in modelling, it is possible to create a more accurate representation of the system being modelled and to gain a deeper understanding of how it works (Bommel and Müller, 2008).

Process Flow Diagram (Figure 1.2): A process flow diagram can be used to represent the overall system of the airport border control. This diagram will show the different steps in the process, such as passport check, baggage screening, and customs inspection. It will also show the flow of passengers through the process, including any decision points where passengers may be directed to different service locations.

State Chart Diagram (Figure 1.3): A state chart diagram can be used to represent the different states that objects can be in during the simulation. For example, a passenger may be in the "waiting in line" state or the "processing at passport check" state. The state chart diagram will show the transitions between states and the conditions that trigger those transitions.

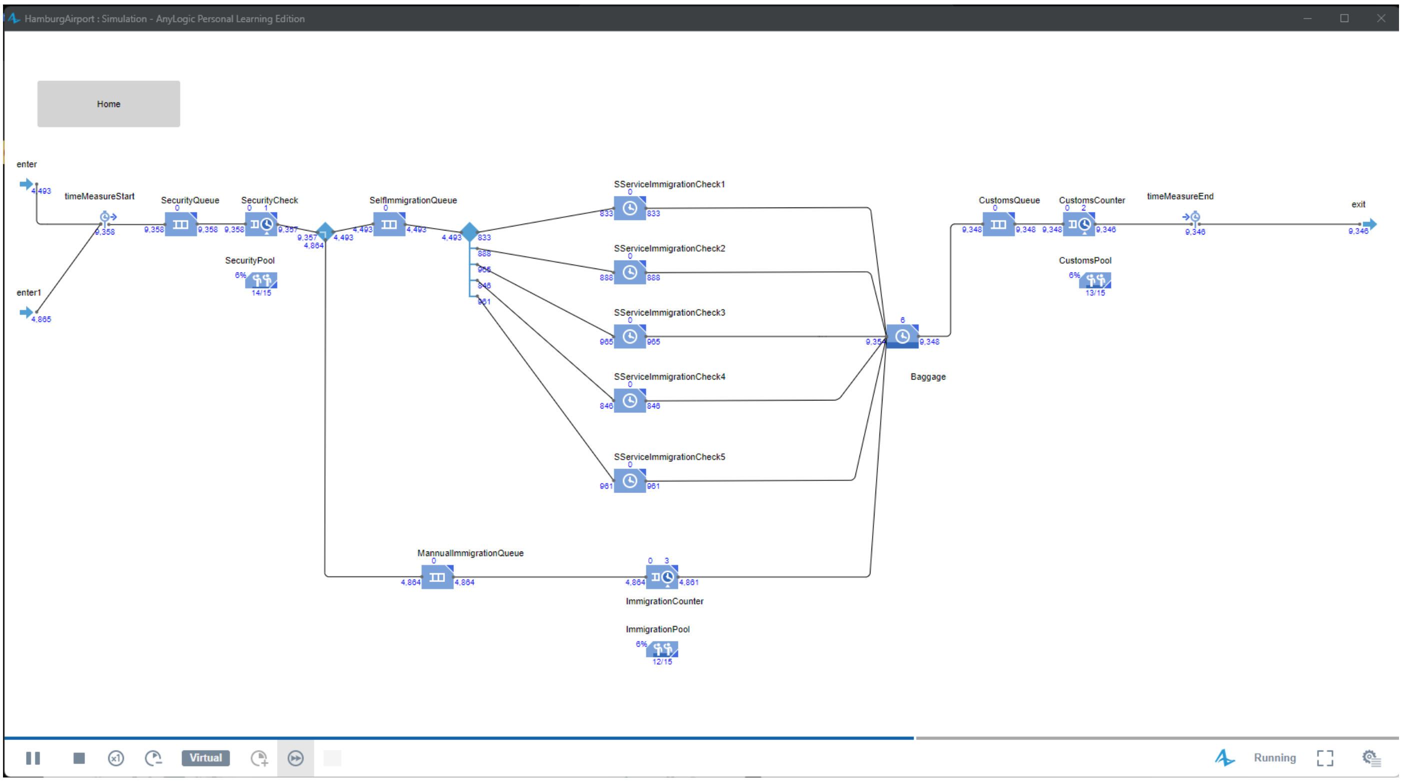

Figure 1.2. The Process Flow diagram Of the model suggested

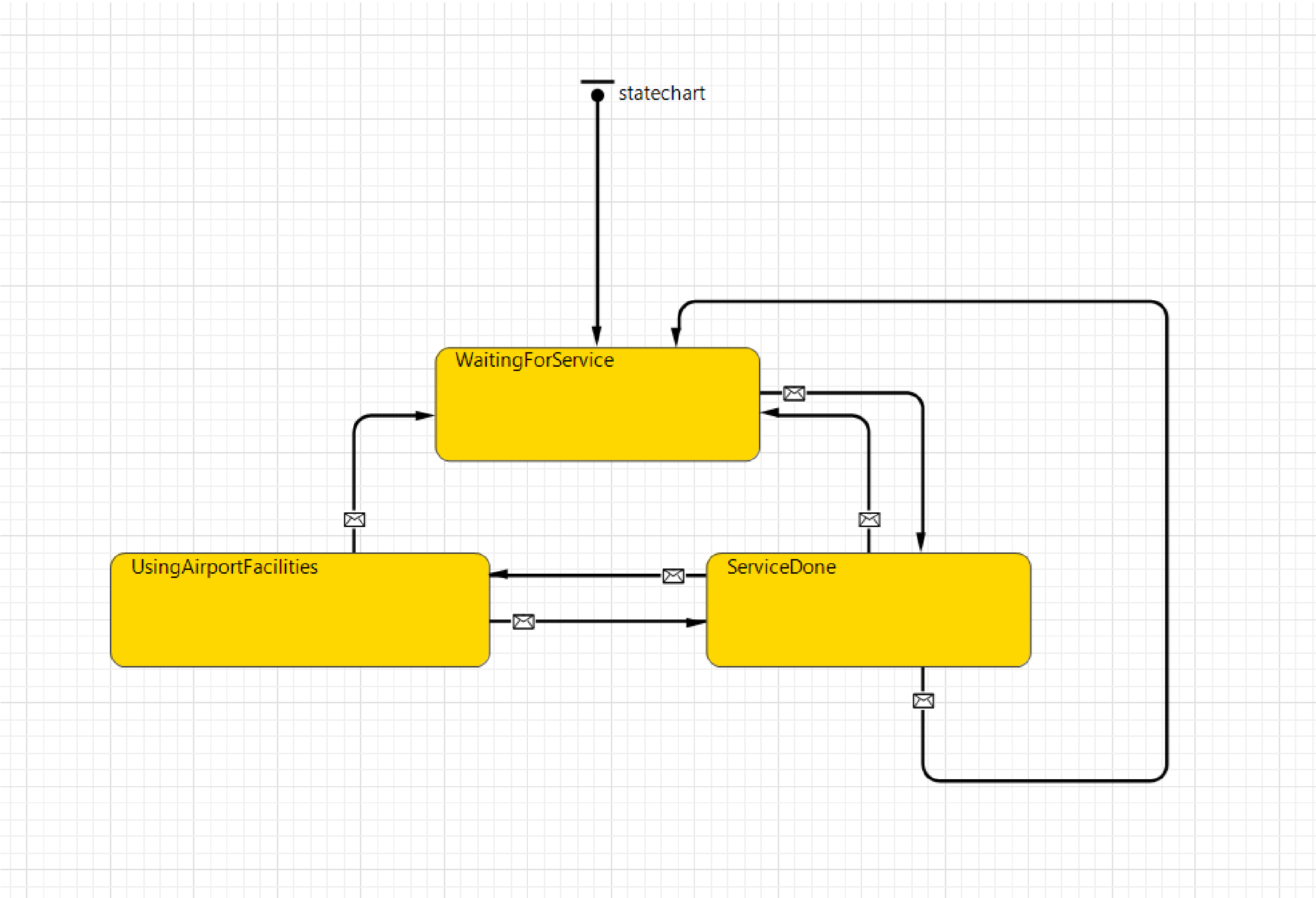

Figure 1.3. State Diagram for passengers

In designing the airport border control model, the following design decisions were made:

1. Process Flow: The overall system process flow was represented as a queuing system, with passengers arriving at the border control and joining a queue.
2. Agent Classes: Two agent classes were defined - passengers and staff members
3. Smart App Implementation: A smart app was introduced to make the process of immigration easier and faster and analyse its impact on service utilization.
4. Experimental Factors: Experimental factors such as arrival rates, staffing levels, and process times were included to study their impact on passenger waiting times and staff utilization.
5. Performance Measures: Performance measures such as average passenger waiting time and staff utilization rates were used to assess the effectiveness of the model in optimizing border control operations.

These design decisions were made based on the objective of the model to optimize the staffing levels and service process at border control to minimize passenger waiting times while ensuring efficient use of resources. The process flow and agent classes were designed to accurately represent the real-world system while keeping the model simple enough for efficient computation. The implementation of a smart app assumed that it could potentially improve passenger distribution and reduce waiting times. The inclusion of experimental factors and performance measures was necessary to study the impact of different factors on the system's performance and to evaluate the effectiveness of the model.

1.10 Data requirements

The data requirements for the hybrid DES/ABM model of the airport border control system would include:

1. Arrival rates of passengers at border control.
2. Staffing levels and schedules
3. Process times for each step in the border control process (e.g. passport check, baggage screening, etc.)
4. Average delay time spent inside the airport using facilities.
5. Average passenger processing times for different types of passengers.
6. Number of dedicated smart app users needed to see a statistical and practical significant impact on passenger waiting times.

These data would be used as inputs to the simulation model to create a realistic representation of the airport border control system.

2. Implementation

A hybrid DES/ABM model for airport border control model is developed, by integrating two different modelling approaches, discrete-event simulation (DES) and agent-based modelling (ABM). The DES part of the model will simulate the physical processes and the flow of passengers through the different checkpoints, such as passport control, baggage screening, and customs. The DES will model the queuing of passengers at each checkpoint and the allocation of staff resources to the checkpoints. The DES component will use arrival rates, processing times and delays (waiting time) to estimate passenger waiting times and staff utilization rates.

The ABM part of the model will simulate the behaviour of individual passengers, including their waiting time, time in service and others. To integrate the DES and ABM components, we will use a hybrid approach where the agents in the ABM component will interact with the DES component, and the DES component will update the state of the agents in the ABM component. This will allow the model to simulate the interactions between individual passengers and the physical processes at the different checkpoints.

To implement the model in Any Logic, we can create agent types for passengers and staff. We also create discrete-event blocks along with resource pools for each step in the border control process, such as passport control and security check, with parameters for processing times and staff requirements. The simulation can run for a period of 10 days, with output variables such as average passenger waiting times, staff utilization rates, and the impact of the smart app on passenger distribution. The model uses moderate amount of Java code only for initialization and for calculating variables and parameters. Both 3D and 2D GUI along with view navigation is build using the libraries for easy understanding of the mode. The 3D and 2D states of the simulation is represented by Figure 2.1 and Figure 2.2 as shown below.

Figure 2.1. 3D model simulation of Border control along with parameters.

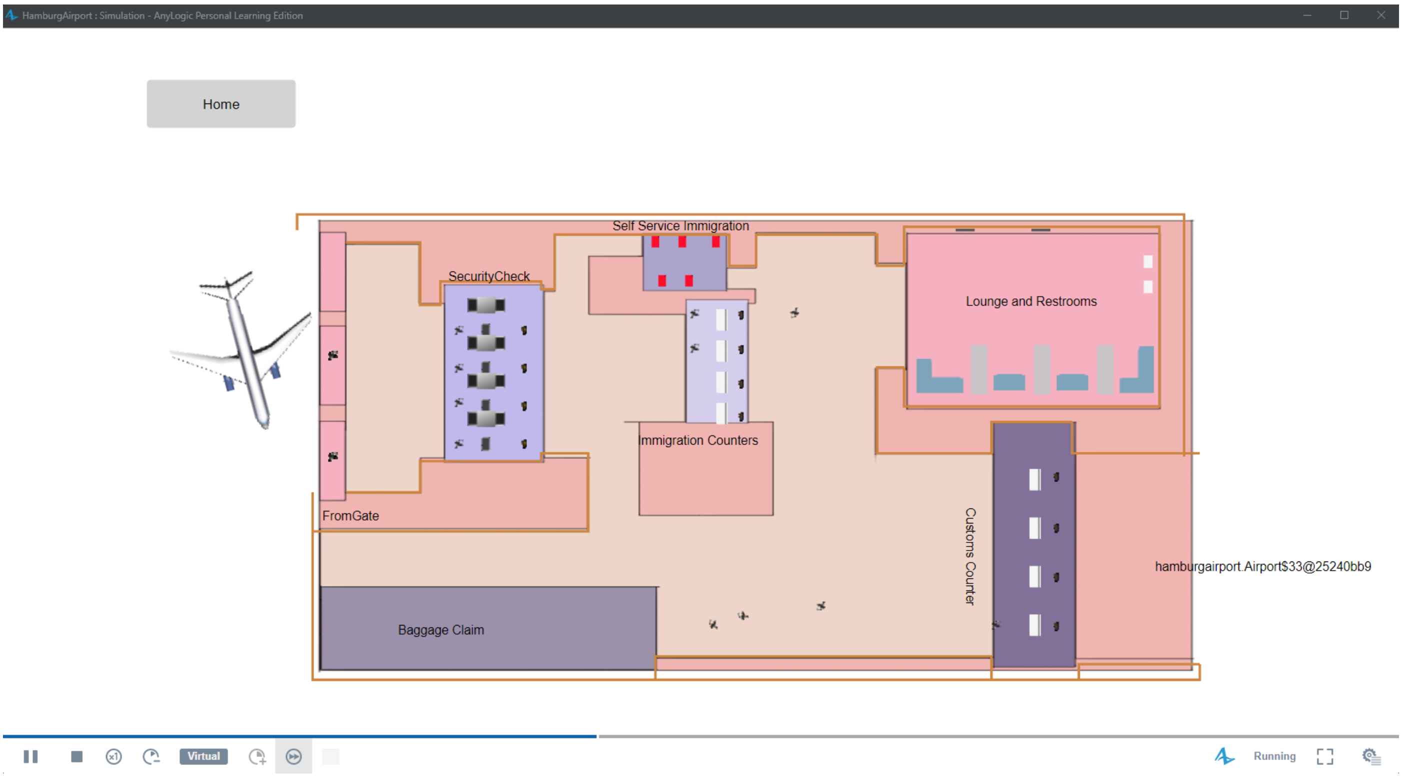

Figure 2.2 The 2D view of the model simulation

3. Experimentation

In Any Logic, there are two types of experiments that can be performed: optimization experiments and parameter variation experiments.

Optimization experiments involve finding the optimal values for a set of input parameters, with the objective of maximizing or minimizing a certain output (anylogic.help, n.d.). These experiments are typically used when there are several input parameters that can affect the performance of a system, and the goal is to find the combination of parameter values that yield the best results. For optimization experiments for the model, the built-in optimization engine was used. The staff utilization was set as the objective function which is to be minimized to find the feasible parameters.

Parameter variation experiments, on the other hand, involve varying the values of one or more input parameters to see how they affect the output of the system (anylogic.help, n.d.). These experiments are useful for exploring the sensitivity of the system to different input values, and for identifying which parameters have the greatest impact on system performance. In the model, parameter variation experiments is performed using the Parameter Variation experiment type, which allows users to define the input parameters to vary, the range of values to test, and the output measures to be monitored. The number of flights per day, the number of dedicated app users per flight and the number of staff at each service was used as parameters for the experiment.

Both optimization experiments and parameter variation experiments was used to improve the performance of a system, by identifying the optimal input parameter values that yield the best results, or by identifying the input parameters that have the greatest impact on system performance. The experiment settings for both experiments are shown by Figure 3.1 and 3.2.

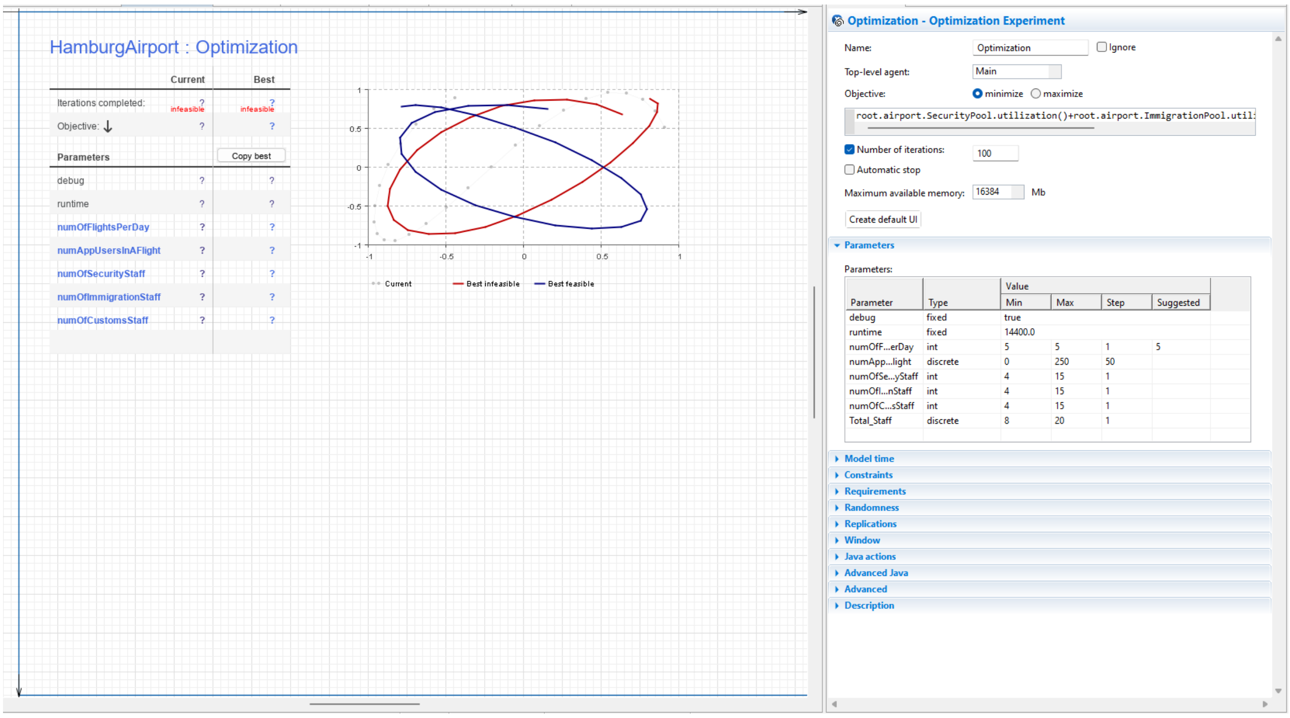

Figure 3.1. Optimization Experiment

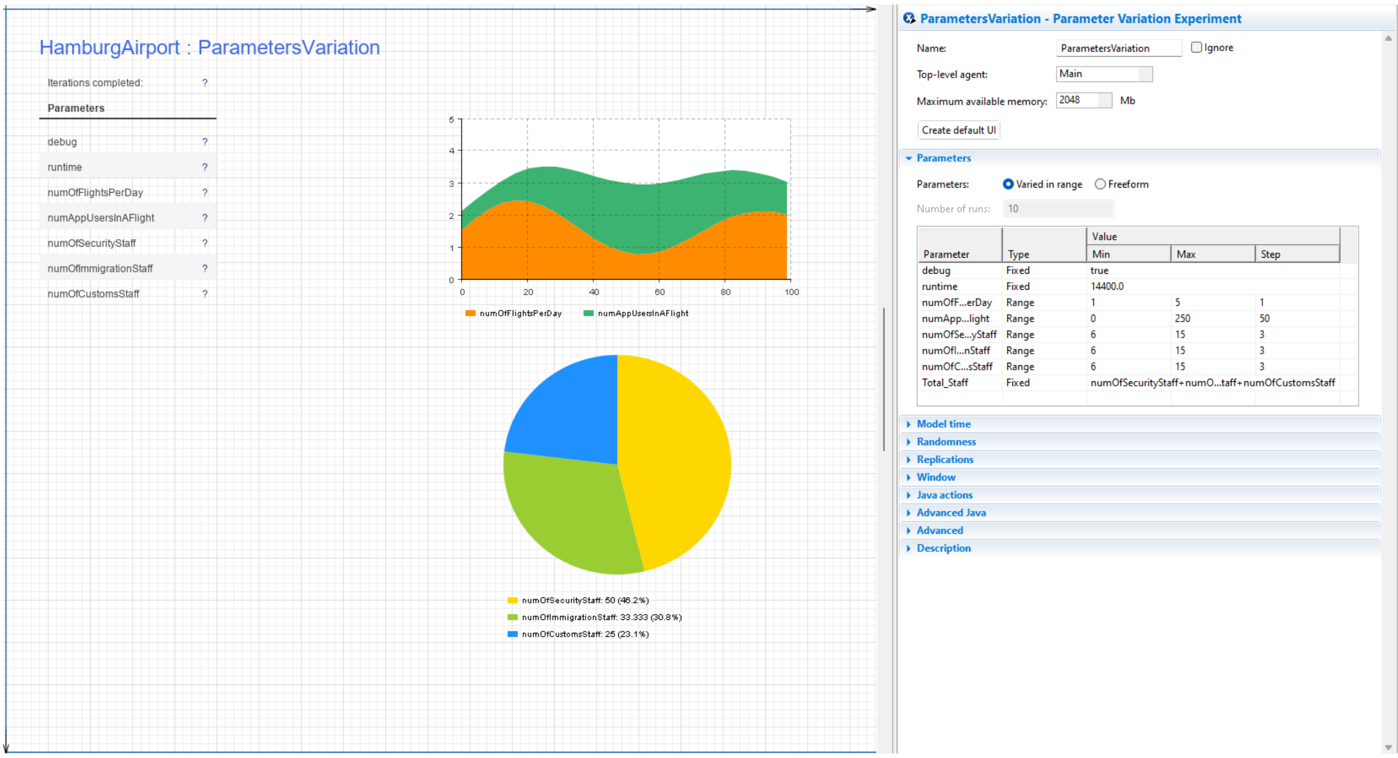

Figure 3.2. Parameter Variation Experiments

4.Results and Conclusion.

With the adoption of smart app there was considerable difference in the time each passenger spent inside the system. There was a time difference if approximately 1 to 1.5 minutes between the time spent by each type of passenger in the system, passenger who uses the smart app having the lesser value. Depending on the staff allocated and the number of smart app users there was considerable decrease in staff utilization noted. These finding were based on assumptions and calculations from historic data but still the findings provide a positive insight on adopting a smart app to optimize the working of Hamburg airport in the future.

References

anylogic.help. (n.d.). *Parameter variation | AnyLogic Help*. [online] Available at: https://anylogic.help/anylogic/experiments/parameter-variation.html.

Bommel P and Müller JP (2008). An Introduction to UML for Modelling in the Human and Social Sciences. In:

Heathrow Airport (2022). Facts and figures | Heathrow. [online] Heathrow Airport. Available at: https://www.heathrow.com/company/about-heathrow/facts-and-figures.

IATA (2021). IATA. [online] www.iata.org. Available at: https://www.iata.org/.

Phan D and Amblard F (Eds.) Agent-based Modelling and Simulation in the Social and Human Sciences. The Bardwell Press. pp. 273-294

Pidd M (1998). Computer Simulation in Management Science. Wiley.

Robinson S (2004). Simulation: The practice of model development and use. Wiley.

Robinson S (2008a). Conceptual modelling for simulation Part I: Definition and requirements, JORS, 59(3):278-290

Robinson S (2008b). Conceptual modelling for simulation Part II: A framework for conceptual modelling,JORS, 59(3):291-304

Robinson S, Brooks R, Kotiadis K, and Van Der Zee D-J (Eds.) (2010). Conceptual Modeling for Discrete-Event