SIMULATION OF PASSENGER FLOW FOR INTERNATIONAL DEPARTURE USING WITNESS HORIZON

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LIST OF ABBREVIATIONS

ADPI	Aeroport de Paris Ingenierie
AI	Artificial Intelligence
CAI	Cairo International Airport
DES	Discrete Event Simulation
HCIA	Henri Coandă International Airport
IATA	International Air Transport Association
ITC	International Air Carrier Association
KXP	Kulim International Airport
LoS	Level of Service
MAHB	Malaysia Airports Holdings Berhad
mppa	Million passengers per annum
MRO	Maintenance, Repair and Operating
pax	number of passengers
PC	Personal computer

ABSTRAK

Tumpuan kertas kerja adalah untuk menyiasat aliran penumpang di terminal lapangan terbang di Lapangan Terbang Antarabangsa Kulim (KXP). Terdapat beberapa proses yang terlibat dalam pelepasan antarabangsa di terminal lapangan terbang seperti profil daftar masuk, pemeriksaan keselamatan penumpang dan bagasi, dan pemeriksaan pasport berlepas. Objektif kertas kerja adalah untuk menyiasat bilangan mesin dan buruh yang diperlukan melalui simulasi WITNESS pada waktu puncak pada hari bekerja, hujung minggu dan musim cuti. Penyelidikan ini dicadangkan berdasarkan projek Lapangan Terbang Antarabangsa Kulim (KXP) yang kini dalam peringkat perancangan. Terdapat tiga model berbeza yang mensimulasikan aliran penumpang di kawasan daftar masuk, pemeriksaan keselamatan dan pemeriksaan pasport dalam tiga senario berbeza. Ketidakbahagiaan penumpang adalah parameter untuk mengukur sama ada model itu sesuai untuk dilaksanakan dalam kehidupan sebenar. Rasa tidak puas hati penumpang adalah berdasarkan masa menunggu yang diperlukan di setiap bahagian. Masa menunggu yang lama boleh menyebabkan kesesakan dan kelewatan penerbangan. Hasil simulasi adalah berdasarkan ketidakpuasan hati penumpang dan penyelesaian yang lebih baik diperlukan apabila ketidakpuasan melebihi 10%. Keputusan setiap model dianalisis berdasarkan prestasi mesin, penimbal dan buruh. Setiap bahagian kemudiannya dibandingkan berdasarkan peratusan sibuk, peratusan terbiar, bilangan operasi, purata masa menunggu dan lain-lain. Model optimum dicipta apabila ketidakpuasan penumpang melebihi 10%. Susun atur simulasi yang dicadangkan dibandingkan dengan susun atur semasa dengan prestasi yang lebih baik dalam mengurangkan masa menunggu penumpang di terminal lapangan terbang.

ABSTRACT

The focus of the paper is to investigate the passenger flow in airport terminal in Kulim International Airport (KXP). There are some processes involved in the international departure in airport terminal such as check-in profile, security screening of passengers and baggage, and departure passport check. The objective of the paper is to investigate the number of machines and labours required through WITNESS simulation during peak hours in weekdays, weekends and holiday season. This research was proposed based on Kulim International Airport (KXP) project that is currently in planning stage. There are three different models that simulate the passenger flow in the check-in area, security screening and passport check in three different scenarios. The unhappiness of passenger is the parameter to measure whether the model is suitable to implement in real life. Unhappiness of passengers is based on the waiting time required in each section. Long waiting time may cause congestion and flight delays. The simulation result is based on unhappiness of passengers and an improved solution is needed when the unhappiness is more than 10%. The result of each model is analysed based on machines, buffers and labors performance. Each section is then compared based on percentage of busy, percentage of idle, number of operations, average waiting time and others. An optimum model is created when the unhappiness of passengers exceeds 10%. The proposed simulation layout is compared with the current layout with a better performance in reduce passengers' waiting time in airport terminal.

Chapter 1 INTRODUCTION

The aviation business has seen a considerable growth in travellers in recent years, nearly tripling from 2000 to over 4.5 billion in 2019. The determination of air industry organisations to maintain the freedom to travel safely and securely has resulted in an increase in worldwide travel. Since then, the pandemic has altered the aviation sector, resulting in travel restrictions in nearly every country. Covid-19's emergence has a direct impact on travel and hospitality, as it affects border and health standards to protect customers' health. (IATA Annual Review 2021). Hygiene and safety requirements will be tightened to reduce customer health hazards and digitalization will continue to alter the travel experience. To keep track of travellers' health, mobile apps were introduced to save their immunisation certificates and Covid-19 test results.

Since the pandemic getting better and better nowadays with the introduction of vaccines, many countries had reopened their borders to welcome travellers abroad. The airline sector will welcome more travellers to travel abroad after a couple of years. The airport will handle two types of passengers' flow systems which are departure passenger flow and arrival passenger flow (Alodhaibi, et al., 2017). From the problem stated from other studies, passengers seem to have a long waiting time in the departure operations in the airport terminal. Most of the reason that causes long processing time are long queue, flight delay and congestion. The departure flow of the passenger system is more important in the operation of passenger terminals as service to transit passengers in the departure process requires a significantly longer time than the arrival process. The figure below shows the overall passenger flows procedure of international departure and arrival for Kulim International Airport (KXP).

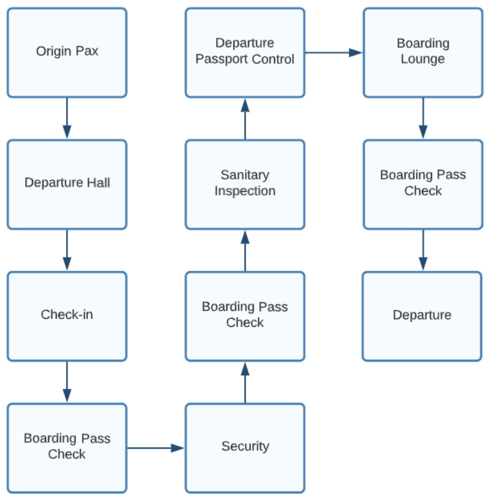

Figure 1.1: Passenger flows in international departures

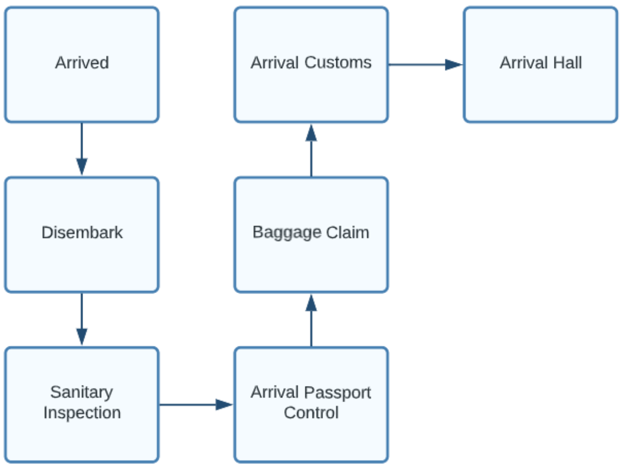

Figure 1.2: Passenger flows in international arrivals

To deal with a variety of passenger arrival patterns, a deeper examination of each checkpoint is required such as check-in, baggage security and passport check was computed using several inputs of passenger arrival behaviour, flight schedules, aircraft capacity, load factors and transfer rates. The appropriate number of machines to operate at different passenger arrival rates are determined using three different scenarios of passenger departure rate: weekdays, weekends, and holiday season. Congestion is easily built up during peak hours, hence congestion-based staffing is utilised to limit the length of queues at counters. If the queue reaches a certain size, for example, more servers are added. By setting proper thresholds, the queue length can be kept within a specified range (Nikoue, et al., 2015).

The procedure that influences passenger flows is the airport terminal's limited infrastructure, which only allows for a limited number of check-in counters (Alodhaibi, et al., 2017). The goal of the project is to improve the passenger experience in the airport terminal when departing. Passengers will be more satisfied because the time-consuming leaving process will take less time.

Discrete Event Simulation (DES), a computer simulation of discrete occurrences, is quickly becoming an indispensable tool for improving the efficiency of manufacturing processes. This is caused by a number of factors, including its capacity to mimic and monitor the stochastic and dynamic characteristics of specific processes, enabling it to predict their behaviour. Researchers can analyse complex systems that are challenging to represent using conventional mathematical and statistical methods utilising computer simulation, a widely utilised analytical tool. The condition of particular controllable system inputs that will result in the best possible system outputs can be identified using this simulation. An effective technique for analysing the behaviour of a variety of business processes, from production layouts to the operation of contemporary call centres, from the management of patient influx in emergency rooms to the processing of online questions, simulation optimization is used. In service stations like airports, contact centres, supermarkets, in industrial production lines, in rail and road traffic, and in logistical tasks like storage and distribution, discrete event simulation is frequently utilised. At each level where a real-world decision is made, the author of a simulation model merely establishes the necessary real-world rules. The model then plays out the scenario, picking one of these options at a time. In terms of throughput, service levels, resource utilisation, profitability, and other factors, this offers a plethora of information on the system's performance. A discrete event simulation model can be used to conduct experiments that show the ranges of current and anticipated outcomes without the requirement for expensive pilot schemes that interfere with the current operation. (Bronislav, 2013).

The world-class WITNESS simulation environment from the British Lanner Group is one of the most effective platforms for simulating logistical, manufacturing, and queuing processes. Both discrete (such as part-based) and continuous (such as fluids and high-volume fast-moving items) features can be modelled by the WITNESS simulation software. Depending on the type of element, it may be in one of several "states." Some of these conditions are idleness (waiting), busyness (processing), blockage, in-setup, broken down, and waiting labour (cycle/setup/repair).Template elements are used to create WITNESS models. By modifying and merging them into module elements and templates, these can be put to new uses. The most fundamental components of a discrete modelling model are parts, buffers, machines, and conveyors. Discrete modelling components include a variety of rail and vehicle types, labour, carriers, shifts, variables, and part attributes. Each element's behaviour in the WITNESS user interface is specified in a tabbed detail form.

Simulation is not an optimization technique in and of itself, but rather a tool for modelling and comparing alternative possibilities. Because a model's number of variable elements can be vast, Lanner Group offers the WITNESS Optimizer plug-in module, which can intelligently evaluate multiple combinations of modifications inside a model and identify the "best" model using an objective function specified by the model designer. The optimization's goal is quantified by this objective function. Furthermore, users supply information on any system limitations, such as the elements inside the model that can vary and their range of fluctuation. The user can additionally specify the length of the model and the number of replications. More sophisticated users can select from a variety of search strategies to swiftly arrive at the best solution. The WITNESS Optimizer offers a variety of optimization approaches, from simply running all possible combinations to more complicated algorithms. In a variety of simulation studies, the WITNESS environment is used to optimise manufacturing, logistics, and queuing systems. WITNESS was used to conduct a process analysis of a firm's lens manufacturing process flow to discover improvement-prone areas and propose improvement alternative options. Other study shows how WITNESS computer simulation was used to develop the creation of a snow-melting module manufacturing company. The following analysis explains the production design process and compares the new design's performance to that of the previous system. The WITNESS environment was also used to simulate the ophthalmology service at Regional Military and University Hospital of Oran in Algeria and to analyse the ideal layout for an industrial plant. The outcomes of using WITNESS Optimizer to solve a manufacturing problem with seven decision factors are reported in. The use of WITNESS in the deployment of simulation solutions has been demonstrated.

1.1 Project Background

The study of this project is to identify the main factors that affect the passenger flows in an airport during the international departure process. The international airport chosen is the newly develop and establish to be called as Kulim International Airport (KXP). Kulim International Airport was built as part of a government attempt to improve access to Malaysia's northern regions. The project will expand Malaysia's economic potential and add value to current industries by focusing on the transformation and expansion of the region's agriculture, manufacturing, tourism, and logistics sectors. To reduce travel distance and eliminate superfluous construction, the passenger terminal area is intended to be built near the aircraft's runway. The construction of Kulim International Airport is expected to finish in 2026 that on that time Penang International Airport will beyond its maximum load of 12 million passengers per annum (mppa). A future forecast of the KXP will start to serve about 800,000 passengers in 2026 then steadily grow to 1.4mppa and 9,1mppa in 2044. The passenger terminal area is projected to have 16.2mppa in 2054 and the construction of the passenger terminal area is targeted to satisfy the capacity of 20 million passengers (Kulim airport to focus on passengers, The Star, 23th August 2021).

The simulation of passenger flows in Kulim International Airport is by using WITNESS software. In a virtual, risk-free environment, WITNESS simulation may create feature-rich models and predictive digital twins, enable test processes, and validate decisions. WITNESS' technical capabilities for transforming data into a rich and entertaining simulation environment that can seamlessly move between 2D and 3D. The use of WITNESS simulation can characterise different flows of entities and bottlenecks at the Kulim International Airport. The software platform is included to test multiple management options once the airport terminal is built and operational. The simulation data was derived from historical data from another international airport. The study of a particular area, such as the check-in area, security screening area, and passport check area, was the focus of airport simulation models. The multimodal station, terminal building, and platform are all modelled in the microscopic simulation environment. The creation of terminal simulation models can provide a thorough analysis of the traffic patterns inside the terminal structure. In order to improve the passenger flows in the airport terminal, the simulation programme can identify the cause of the prolonged waiting times during the departure process and simulate the best outcomes. Simulation is extremely useful to understand and evaluate the flow of passengers through the departure processes of an airport. One of the fundamental drawbacks of simulation in the past was that it was not an optimization approach. An analyst would test a few various system configurations, then pick the one that appeared to deliver the best outcomes. However, faster computers and improved heuristic optimization search methods (such as tabbed search, simulated annealing, and evolution strategies) are significant signs of the new union between optimization and simulation in practise. Nowadays, almost all commercial discrete-event simulation software packages come with a module that performs some kind of "optimization," as opposed to a simple statistical estimate. The goal of an "optimization" package is to coordinate the simulation of a number of different system configurations to find an optimal or nearly optimal configuration. Additionally, it is thought that this "optimal" solution can be discovered by modelling just a small portion of the various configurations that would be required through exhaustive enumeration. In commercial simulation software, most optimization engines (packages) are evolutionary in nature. (WITNESS Simulation Modeling Software, Lanner).

1.2 Problem Statement

The optimisation of the departure and arrival procedures in the airport terminals is to solve the passenger flow problems. The main passenger flows problems are due to long waiting times, flight delays and congestion in the departure process especially in holiday season. These time-consuming procedures have decreased passengers' airport experience and give a negative impact. The simulation of passenger arrival rates in three different situation which are weekdays, weekends and holiday season. A simulation model using WITNESS is to analyse and identify the suitable number of machines to be opened in different scenario and improve it through the simulation result.

1.3 Objectives

- To investigate the waiting time of passengers during departure in check-in area, security screening area and passport check area in different passenger arrival rate

- To simulate the passenger flow in peak hours with around 3 hours in check-in area, security screening area and passport check area using WITNESS
- To optimise the current service rate to meet up the arrival rate of passengers

1.4 Scope of Work

The scope of the field study will focus on analysis of passenger waiting time in airport terminal for international departure. Airport terminal sections such as check-in area, security screening area and immigration area are the factors contribute to long waiting time. Simulation using WITNESS based on secondary data from other airport is used to identify the major problem of long waiting time and provide a solution to solve it. A simulation model is built based on the proposed solution of the current number of machines required whether enough to deal with the passenger arrival rate in three different situations which are weekdays, weekends and holiday season. The aim of the simulation is to optimise the process in these three departure processes and reduce passengers' waiting time.

1.5 Thesis Outline

This thesis is divided into 5 main chapters. Chapter 1 is the introduction to the study. It includes project background, the problem statement, the study objectives, and the study scope. In Chapter 2, a review of published information related to passenger flow and process flow in airport from the past studies are discussed. The related articles are explored from the issues encountered and limitation in the draft layout of the simulation model. In Chapter 3, the methodology of the entire research study is explained. This chapter explains the sequential processes flow beginning from the dataset used followed by draft simulation process flow in build a simulation model and data verification stages. The methods and techniques applied in this study are discussed. Chapter 4 presents the results generated from simulation the process flow in airport in different sectors. An optimisation solution is used to improve the current layout to handle a higher passenger flow. Last but not least, Chapter 5 concludes the study by providing an overall view of the passenger flow in the airport between current and proposed layout. The chapter also outlines how the objectives of this study were achieved, contributions of this study as well as suggestions for the future work.

Chapter 2 LITERATURE REVIEW

2.1 Kulim International Airport (KXP)

Kulim International Airport (KXP) is a proposed airport for the Malaysian city of Kulim, which is in the state of Kedah and borders the state of Penang. The state government of Kedah filed a request to the country's Prime Minister for approval to establish Kulim International Airport. Due to growing capacity constraints at Kulim's nearest international airport, Penang, the state government plans to develop a new airport. Alor Setar and Langkawi International Airport are the two current airports in Kedah State. The airport will be built on a 1700-hectare property and will be able to handle 15 million passengers per year once completed. The airport is planned to be ready by 2026.

These projects will help to boost e-commerce growth not only in the region, but also in Southern Thailand. It will also help high-tech companies like the Maintenance, Repair, and Operating Supplies (MRO) subsector advance faster. The capacity to connect marine, air, and surface transportation modalities is one of KXP's primary advantages over many other airports. KXP can facilitate sea-to-air transfer at half the cost and in half the time thanks to its proximity to Penang Port on Pulau Pinang. Furthermore, KXP has easily available acreage that will allow it to expand for the next 20 to 50 years. The 3,982 hectares of land for KXP Aerotropolis and development has been gazetted for public use under the Land Acquisition Act 1960. (*Kedah Aerotropolis - Northern Corridor Economic Region (NCER) Malaysia*).

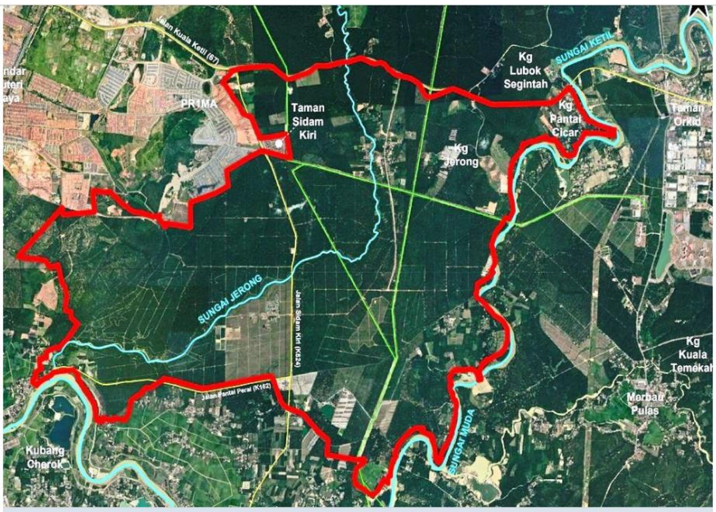

Figure 2.1: Actual location of KXP from Google Maps

2.2 Passenger Flow

There are five main primary procedures that make up the departure process for passengers such as arrival characteristics of passengers, including distribution of arrivals, manner of arrival, number of baggage taken, class of travel, and time of travel. The second is the check-in procedure, which assigns distinct check-in counters for each aircraft and allows for several check-in methods such as kiosk, online, business, and economy. Both secondary screening and the x-ray inspection are part of the security screening process. Smart gate service and a common counter for passport control are all parts of the immigration processing process. The final step is boarding procedures, which include flight capacity, jetway capacity, boarding strategy, and boarding time. The suggested simulation framework and model can be used as a feedback mechanism to refine it before to implementation and to estimate in advance the impact of various flight schedules. These findings collectively imply that integrating the development of aircraft schedules and passenger simulation analysis may be a way to alleviate some concerns with passenger flow in airport terminals, particularly at the two most affected processes, namely security screening and immigration. (Alodhaibi, et al., 2017)

For the study of Liu X, Li L et al. (2018), a case study in Chengdu Shuangliu International Airport, focused on the characteristics of passenger flow of passengers' dwell time and total occupant number in various areas in terminal buildings. The airport received about 46 million in 2016 which is one of the most important hubs in southwest China. Various hall in airport terminal is compared and predicted the total occupant numbers in the departure hall and check-in hall. In addition, a field investigation-based model is proposed and validated to forecast the overall occupant numbers in the departure hall and the check-in hall. When a passenger enters the check-in area, they have the option of checking in at a counter or using self-service. The passenger will then go through the security checkpoint. Before boarding for the aircraft, the traveller can choose to visit a restaurant, a mall, or a rest place. Before exiting the terminal buildings, passengers must pass through the arrival hall, luggage claim area, and arrival corridor for the arrival process. According to the real flight schedule, the departure process has a rush hour from 6 am to 9 am. From 9:00 am to 11:00 pm for the departure procedure and 9:00 am to 2:00 am for the arrival process, at a largely consistent level. Parameter used to measure passenger flows in the airport terminal are:

Table 2.1: Parameter used in measure of passenger flow

Parameter	Description
Dwell time	- Refers to time that passengers will spend in a specific hall - Affected by the characteristics of different halls such as floor areas and service counters - Used to determine passengers' activity level based on setting values of indoor environment
Total occupant number	- Refers to number of people in a specific hall - Influence the operation models in specific areas
Occupant density	- Refers to the number of people per unit area in a specific zone - Determine the design and operation of terminal unit

Based on the information from field investigations and questionnaires, surveys are done to analyse dwell duration and the overall number of occupants in various halls based on the Table 2.1. A table is created based on the number of passengers, dwell time, normal activities, building information, and indoor atmosphere, as well as the amount of time spent by passengers in various areas.

Table 2.2: Comparison between various areas

	Departure Process		**Arrival Process**			
	Check-in hall	**Departure hall**	**Arrival passage**	**Baggage claim area**	**Arrival hall**	**Transfer hall**
Inner height (m)	15–25	10–15	3–5	5–8	5–8	3–5
Floor area (m^2)	32600	73300	20063	16930	7668	6117

Average dwell time of passengers (min)	34	132	<10	5–18	<5	<5
Maximum number of people	4647	8715	495	495	500–600	<100
Typical activities of passengers	walk/stand with baggage	various activities (sit, stand, shop, eat etc.)	walk	walk/stand with baggage	walk/stand with baggage	walk/stand with baggage

From the Table 2.2 above, the dwell time in the departure process is longer than the arrival process. The departure hall has the longest average dwell time, at 132 minutes. The departure hall is a typical enclosed indoor room with little activity where travellers will spend a lot of time. The inside atmosphere is therefore significantly impacted by the outdoor environmental conditions in the check-in hall, arrival hall, and transfer hall due to the numerous regularly opened gates that connect to the external locations. Despite the enclosed spaces in the arrival route and the baggage claim area, travellers will move through them fast. By adjusting the dwell probability distribution's parameters in accordance with the actual flight schedule, this field investigation-based model can be used to terminal operations.

From Senay S, et al. (2009), suggested that the airport terminal capacity planning problem is the main issue. In this case, a derive time function is used to estimate the maximum delays in the processing areas and hallways of an airport terminal. Create a multistage stochastic programming model based on a multi-commodity flow network representation of the entire airport terminal using these delay functions. The study's findings are transferable to all comparable queuing networks, including those seen in different kinds of passenger terminals. The study concludes that free-flow walking speeds in airport terminals have a mean of 80.5 m/s and a standard deviation of 15.9

m/s, which is normally distributed. For flows up to 4000 people per hour, and even for higher flows, the estimation of delay as flow rate increases is correct.

The processing stations, like as security checks and check-in counters, are where airport terminals have the most congestion. This section develops relationships between flow and capacity and the maximum delay at processing stations in airport terminals. This study found that at this station's near-triangular peak demand level of 7242 passengers/hour, when the average processing capacity of the security checkpoints was estimated to be 3690 passengers/hour, a maximum wait of 31 minutes was experienced at security checkpoints.

The model can be set up to estimate whether it would be better to construct a new terminal building rather than extend the current one by including feasibility limitations. In all situations, significant cost savings can be gained by reducing the need for expansion and streamlining airport expansion timetables. Airport terminal peak period estimates can be used for any other traffic flow network or queuing system when steady state cannot be reached, and transient analysis is difficult. The established upper boundary heuristic can also be used to and tested on various capacity expansion models that have been written about.

2.3 Process in check-in area, security and immigration

From the study Khalid Abdul. el at. (2022), key objectives for airport operations are cost effectiveness and customer satisfaction. These two objectives are essential to the passenger departure procedure since they mark the beginning of the passenger trip and serve as the clientele's first point of contact with the airport. The passenger departure process, which includes the following touchpoints starting with check-in, security checks, and immigration, is the subject of this study as a result. Check-in counters are scarce in many airports. During peak hours, there are too few check-in counters to accommodate the whole demand, which causes long queues for passengers. Making effective use of the check-in counter resources available in airport terminals is a top priority for airport administrators and airlines. Check-in counters and personnel usage that is insufficient and inefficient have grown to be significant problems that contribute to passenger congestion and departure delays. The recommended arrival time for passengers on leaving aircraft is two to three hours prior to departure. Normally, the check-in desks are open for two hours before shutting 30 minutes prior to departure.

The airport has built a multitude of security checks to ensure passengers' safety. The greater number of people coming at the security checkpoint increases the likelihood of bottlenecks. Therefore, controlling the traffic jam at the security checkpoint is essential to averting upcoming issues like flight delays. An assessment by Skytrax found that managing immigration lines is challenging, leading to lengthy waiting times of up to 25 minutes. Space restrictions and a lack of queue discipline are two factors that contribute to this unsatisfactory procedure. The boarding gate typically opens 30 to 45 minutes prior to flight departure, and the service counter must handle a large volume of people quickly. As a result, lines form frequently during the boarding process. As a benchmark for present and proposed queue performance, the model will also employ the ideal wait time specified in the Level of Service (LoS) concept of the International Air Transport Association (IATA).

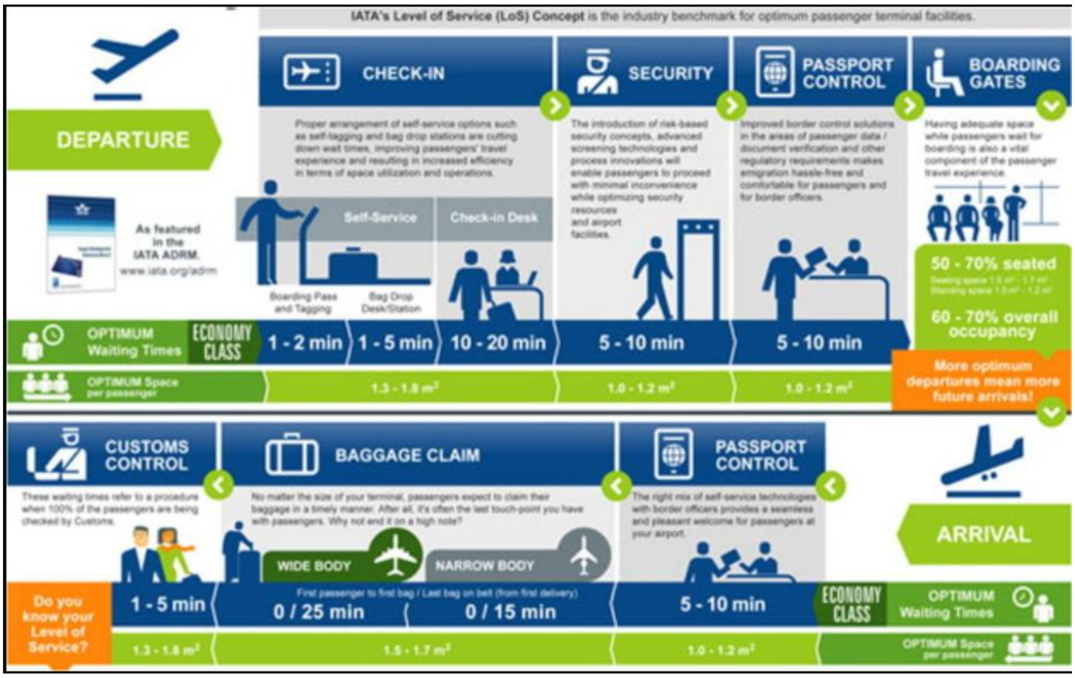

Figure 2.2: The IATA LoS Concept - Wait time

According to Table 2.3, the actual arrival rate at Cairo International Airport (CAI) is anticipated to be 1020 people per hour using a service time of 4.5 minutes each passenger. The service rate is 1067 passengers per hour with a service duration of 4.5 minutes. Despite this, several tourists have observed that fewer than half of the kiosks are consistently staffed, even during busy times of year. Therefore, it will be assumed that four servers per check-in row are available. If the peak period check-in process accommodates 26 flights using four check-in rows, there will be 80 servers. Due to a lack of servers, the system service rate is significantly lower than the arrival rate of passengers. As was already said, the system would not be able to calculate this scenario where the server utilisation value is greater than one. According to the IATA's LoS Concept, the ideal check-in waiting time is one to five minutes. One of the following three scenarios—increasing the number of servers, enhancing the service time, or simultaneously implementing scenarios 1 and 2—occurs when efforts are made to adhere to the IATA-recommended wait time (Refer to Table 2.4).

Table 2.3: Actual Scenario for Check-in Process for Cairo International Airport

Arrival rate (Pax/h)	**Service time (min/pax)**	**Service rate (pax/h)**	**No. of servers**	**Server utilization**
1020	4.5	1067	80	>1 (1.41)

Table 2.4: Proposed solutions for Check-in Process for Cairo International Airport

Scenario	Arrival rate (pax/h)	Service time (min/pax)	Service rate (pax/h)	No. of servers	Server utilisation	Queue length in line	System queue length	Wait time in line (min)	System wait time (min)
1	1020	4.5	1200	90	0.87	2.42	24.93	0.48	4.99
2	1020	2,9	1467	110	0.91	5.93	20.43	1.19	4.09
3	1020	3.5	1714	100	0.92	7.49	25.00	1.50	5.00

Even though Scenario 1 was able to reduce the waiting time in the queue system to 4.99 minutes by increasing the number of servers, the 10 extra workers needed will significantly raise costs. Of the three techniques provided, it also has the lowest server usage rate. This makes the situation unfavourable. The queue system waiting time was the shortest, and the server utilisation rate was at its maximum, in Scenario 2, which also improved service time. The shortest system queue length for each of the three alternatives is also displayed. The service duration must be cut to 2.9 minutes, although this drastic reduction in service time could not be soon feasible. In Scenario 3, it was suggested to add 20 more servers and increase the response time to 3.5 minutes. This turned out to be the airport's most practical and cost-effective solution in the short run. The report advises CAI management to consider Scenario 3 while educating its staff to lengthen service times and improve skills toward Scenario 2's goal.

For the security process computes the arrival rate differently than the check-in process, which uses the output of the preceding queue of the check-in system. As a result, the hourly arrival rate is 350 passengers. When security numbers are derived using the three scenarios indicated in Table 2.5, the suggested waiting time at security is between five and ten minutes, according to IATA. Attempts to meet the IATA's suggested waiting time result in one of three scenarios: Increase the number of servers, enhance service time by increasing the number of servers, and improve service time by maximising the use of the current 35 counters.

Table 2.5: Actual Scenario for Security Process for Cairo International Airport

Arrival rate (Pax/h)	**Service time (min/pax)**	**Service rate (pax/h)**	**No. of servers**	**Server utilization**
350	5	420	35	>1 (2.23)

Table 2.6: Proposed solutions for Security Process for Cairo International Airport

Scenario	Arrival rate (pax/h)	Service time (min/pax)	Service rate (pax/h)	No. of servers	Server utilisation	Queue length in line	System queue length	Wait time in line (min)	System wait time (min)
1	350	5	480	40	0.94	10.89	28.72	3.05	8.05
2	350	4	750	50	0.95	15.4	29.66	4.32	8.32
3	350	3	700	35	0.89	5.05	15.75	1.42	4.42

In Scenario 1, the service time was maintained at five minutes, but there were now 40 servers. Because of this, it was able to lower the system waiting time to 8.05 minutes and raise server utilisation to 0.94 percent. The results of expanding the number of servers to 50 while lowering the service time to 4 minutes are shown in Scenario 2. This helped to achieve the IATA-recommended LoS criterion with a 0.95 server utilisation rate and an average wait time of 8.32 minutes. Similar to Scenario 1, but with a longer waiting time and a queue length of 29.66, this proposed scenario has the same problems as Scenario 1. To make the best use of the current security counters, Scenario 3 reduced the service time to 3 minutes while retaining the number of servers at 35. In this instance, the average queue length and system waiting time were both dramatically shortened to 4.42 minutes and 15.75 minutes, respectively. It is the most economical of the three options, even with a slight decrease in server utilisation compared to the alternatives stated above; if no more employees can be assigned to the security procedure, the airport will incur four more labour costs.

The output of the security process is used to compute the immigration arrival rate. As a result, there are 700 passengers arriving every hour. The true number of servers is probably 60, with an average response time of 5 minutes. Due to the service time, the service rate is 12 passengers per hour. The IATA recommends a 5 to 10 minutes waiting time for passport control. However, the 6.02 minutes that were calculated as the average system wait time fall within the IATA's suggested duration for passport control. The analysis suggests that the current service time should be significantly enhanced. According to the analysis, service time should be cut to 4.5 minutes while keeping the same number of servers (Refer to Table 2.7). By doing so, the system's waiting time would be reduced to 4.91 minutes, which is better than the IATA's recommended wait time.

Table 2.7: Actual and Proposed Scenario for Immigration for Cairo International Airport

Scenario	Arrival rate (pax/h)	Service time (min/pax)	Service rate (pax/h)	No. of servers	Server utilisation	Queue length in line	System queue length	Wait time in line (min)	System wait time (min)
Actual	700	5	13.33	60	0.80	1.64	9.64	1.02	6.02
Proposed	700	4.5	13.33	60	0.72	0.65	7.86	0.41	4.91

According to the study, the LoS idea was created by IATA to motivate airports to raise service standards while preventing over-performance and wasting scarce airport resources. On the other side, the suggested alternative would only call for training for airport staff service, which is already covered in most airport training standards. It would provide the immigration personnel at the airport more time to prepare for the scheduled service time; planning ahead and taking proactive measures are crucial in an airport setting where passenger volume is quickly rising.

2.4 Innovative technologies in passengers processing

The newest technology, including self-service check-in kiosks, self-service bag drop locations, automated border control systems, and "smart" airports with their own intelligent systems, will be completely accessible to air travellers within the next ten years. The image above depicts the steps in the airport's automated passenger processing procedure. As it is clear, a traveller can go right away to passport control and boarding after checking in at the self-service kiosk and dropping off his baggage at the self-service bag drop points, due to the most recent automated technologies. By eliminating lines, these technologies will give passengers ten minutes to complete all airport formalities before their departure.

Table 2.8: Newly invented technologies used in airport

Technology	Function
Automatic passenger check-in system	- Self-service bags drop points - Allow uniformly redistribute passengers - Avoid passengers' congestion in separate terminal areas - Able to manage queues, time of airport formalities and optimal usage of terminal areas
Automatic boarding gates	- Decrease time of airport formalities during check-in and boarding operation
Self-service kiosks	- Report about lost baggage

The deployment of self-service check-in kiosks at the researched airport is expected to result in a large rise in the number of passengers processed, according to the calculations' findings. The same number of passengers can be processed by this self-service equipment as by a traditional check-in counter, but four times more quickly.

When self-service check-in systems are employed, the processing time for one passenger at a standard check-in counter can be slashed to as little as 30 seconds, proving the efficiency of these technologies for the airport authority (Ivannikova, V, et al., 2021).

New digital initiatives are continuously being introduced by airports. Airport management must concentrate on strategies to increase airport business and operational efficiency in this cutthroat climate even if safety and security are a top priority for airports. In 2020, spending on digital-based airport improvements will increase by 40% with the aim of enhancing customer satisfaction and operational efficiency. Digital solutions for airport operations include flow monitoring and management, process automation, group decision-making, predictive & preventative solutions, and customer engagement with the goal of increasing commercial and technical efficiency. The study discusses the changes in ITC, education, training, and marketing management, with societal responsibility management serving as a strong pillar. It also gives a general trend on operational management at airports, with a focus on HCIA. Airport managers should soon consider creating a mobile app for travellers that would provide information about airport amenities and layout, directions inside the terminal indicating points of interest or suggestions, real-time flight notifications and airline policies, a parking guide and information about costs, but also intermodal connections and transportation (] Zaharia, S. E., & Pietreanu, C. V., 2018).

Table 2.9: Innovative technologies used in International Henri Coandă Airport

Technology	**Ways to implement**
Airport operations management	- Implement an operations center (APOC) to improve services including ground activities - Help airport develop collaborative decision making and optimise resources - Use analytics based on real-time data inputs to visualise airport operations or AI for decision making
Flow monitoring and capacity management	- Self-services and implementation of automatic baggage handlers

	• For a traditional counter, the present processing time is 2 min/pax, this means 30 pax/hour/counter, or 2400 processed passengers for all 80 counters considered in the hypothesis. At the same time, having 13 self-service counters, 120 passengers will be processed in one hour at one counter, this means 1560 pax/hour for the 13 self-service counters. The optimistic approach on passenger processing time indicates a 41.9% increase in processing capacity in the check-in area following technology deployment (from 2790 to 3960 pax/peak hour/flow). - Security Control • Available of 9 automatic security control gates with modules for curves or straight sections which will ensure optimum flow rate-interface, we will achieve 1811 pax/hour/control point compared to the current 1249 pax/hour/control point. - Boarder Control • The boarding control area consists of 13 traditional checkpoints and 13 biometric passage gates. In this case, an increase of approximately 62.5% (3380 pax/hour) of processing capacity will be obtained by implementing biometric technologies based on facial recognition. - Boarding • The optimistic approach of 400 passengers can be embarked on a flight,

	meaning 3.3 seconds per passenger, or 22 minutes for a flight.
Predictive and preventive solutions	- Human resources education and training • Specific demands and competencies need to be tackled collaboratively by the industry and regulatory authorities • Implying the ability to deal with complex knowledge and problem-solving in ICT. • Education and training strategies must be applied by universities and training institutions for preparing the next generation of aviation employees.

2.5 Summary

Throughout the decades, many methods and techniques have been developed and studied to investigate the passenger flow in airport. Many researchers had suggested that most of time wasted in the process for check-in, security screening and passport check. This cause passengers need to reach the airport 2 hours earlier before the departure. Many passengers wasted a lot of time before the departure of flight. Research for the waiting time of passengers in check-in area, security screening and passport check to find out the main problems that cause the congestion of queue lines. The utilisation of machines, queue lengths and waiting time are the important parameter to take account to proposed solution to improve the passenger flow. Research of innovative technologies that implement in the other airports that improve passengers' experience in the airport terminal. The improved of technologies able to increase the arrival rates of passengers as it shortens the time of departure flight process.

Chapter 3 METHODOLOGY

3.1 Overview

The report aims to develop an improved simulation model that can evaluate how the Kulim International Airport performed. The dataset of passengers' arrival rate was obtained from online open dataset platform and website. The data collected is then simulate using WITNESS horizon. The research was implemented across various stages as shown in the flowchart in Figure 3.1.

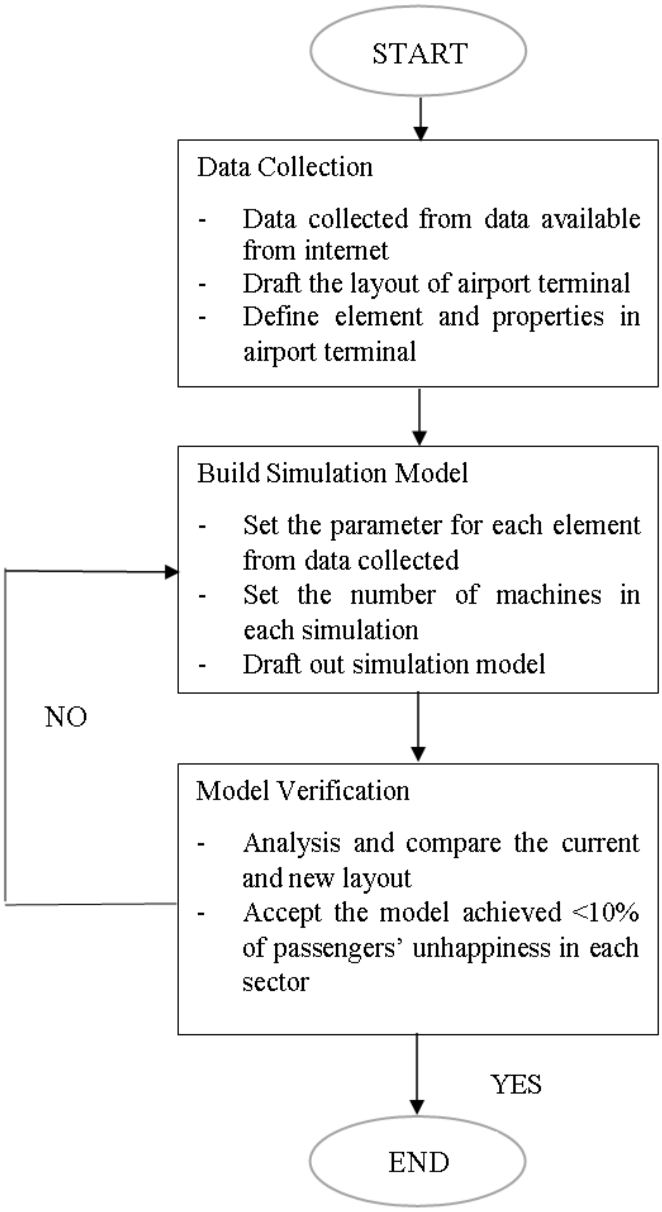

Figure 3.1: Study flowchart

3.2 Data Collection

The data of processing time in each section and parameters are mostly gathered from a report that prepared by Aeroport de Paris (ADP) Ingeniere that hired by KXP AirportCity Holdings Sdn. Bhd. First, the arrival rates of passengers for international departure during weekdays, weekends and holidays are obtained from Malaysia Airports Holdings Berhad (MAHB) reports (2019). The daily arrival rate is chosen the peak hour in the airport which from 6.00am to 9.00am that the number of flights is observed to obtain the number of passengers arrived. The arrival rates are obtained from multiple international airports in Malaysia that passengers departed. The arrival rates of passengers will use to simulate and determine whether the airport terminal able to handle the passenger flow in these situations. The arrival rates of passengers in different scenarios are stated in the table below.

Table 3.1: Arrival rates of passengers for international departure in Malaysia Airport

Scenario	Passengers arrived in peak hour (pax/hr)	Arrival rate (min/pax)
Weekdays	726	0.083
Weekends	952	0.063
Holidays	1163	0.052

The process of passengers' arrival pattern also obtained from journal of Liu X.C. et al. (2018), and the simulation will be carried out based on the process. Firstly, passengers arrived at the airport terminal and went to the check-in counter or self-service kiosk. After finish check-in, passengers will go through security check for baggage checking. Passengers then go through passport check area before departure.

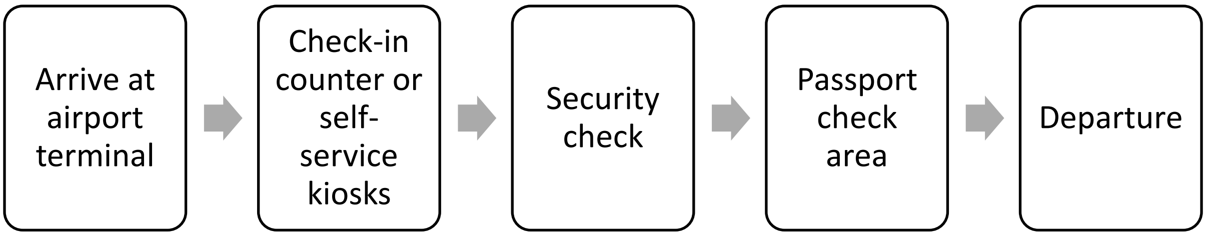

Figure 3.2: Process of passenger flow in the airport terminal

The dataset of daily arrival rate of passengers for international departure in 2019 is used as there is no pandemic that affect individual to travel abroad. The simulation is break into three parts which are check-in area, security check area and passport check area. The waiting time of passenger in each sector are recorded to improve and optimise the performance in the airport. The maximum waiting time of passengers in each sector is tabulate in the Table 3.2 below.

Table 3.2: Maximum waiting time per process

Facility	Standard facility (min)	Fast track (min)
Check-in counters	20	5
Self-service kiosk	8	5
Security	25	18
Passport check	10	5

In the WITNESS Horizon simulation, four main elements involved which are parts, machines, buffer and labor. The elements and its function are described in Table 3.3 below.

Table 3.3: Type of elements and properties in WITNESS simulation

Elements	Properties	Function
Parts	Active profile	Represent discrete items that move around the model such as passengers.
Machines	Single type machine	Represent to take parts from somewhere, processes it and sent to next destination. Machines represent conventional counter and self-service kiosks.
Buffer	-	Store parts and wait parts to pull out by machine. It is used to represent the

		queueing line in the airport terminal.
Labor	-	Represent a resource that is needed for a task to take place. Labor is used in each machine.

3.3 Build Simulation Model

Data is a critical parameter to consider before starting the simulation to guarantee a successful outcome. Most of the data for this study came from old scientific articles or journals. The three types of data that were most likely to be used in a model were according to the categories in Table 3.4. Since the KXP project is currently in the research phase and has not yet started, there were no data on aircraft turnaround available. Therefore, the data collection for this project did not apply to categories 1 and 2. Since there was a dearth of data, the traditional approach to handling Category 3 material involved gathering secondary data and subject-matter experts. However, each assumption needed to be stated clearly.

Table 3.4: Type of data

Category	Data type
Category 1	Available
Category 2	Not available but collectable
Category 3	Not available but not collectable

The sample data from the report included the number of counters opened for each section, passengers' distribution, maximum queueing time and processing time in each counter. The ratio of economy class and business class is 8:2 which 38% of passengers using self-service kiosk while 12% of passengers using conventional counters for business class and 50% of passengers using conventional counters for economy class. These parameters will be used for the check-in area. For security screening area, the passengers' distribution of economy class and business class are involved in the simulation model which the ratio is 8:2 and the average bag carried by passengers is one bag per person. In the passport checking area, the passengers' distribution is