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Development of a Model for International Traveler's Check-In Process Using Arena Software Tool

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Abstract

The increasing demand for airline services amidst limited resources results in passenger dissatisfaction and dwindling revenue for airports and airlines. The dynamics of service demand and resource supply results in check-in issues for the stakeholders in the commercial aviation industry. This has the effect of impacting negatively on service performance, cost of operations, customer satisfaction, and overall throughput. Hence, this paper modelled the travelers' check-in process at the "D Wing" of the Departure Section of Murtala Muhammed International Airport (MMIA), Ikeja, using Arena Software Tool. The work was carried out by determining the parameters of the queues at designated service points in the check-in process. The primary data required to develop the model were acquired by direct observation of passenger flow and oral interview. Thus, the average check-in time was determined. Thereafter, a model of the international check-in system of the MMIA was developed using Arena software in combination with Microsoft Office tools. The data collected were therefore inputted into the model and simulated; the real result was compared with the simulation result of 133 completions and there was no significant difference. The result showed that the model is a representation of the real system under study. Further work will be tailored towards simulation (*i.e.* the model will be subjected to experimentation in order to have different scenario).

Keywords

Modelling, Check-In Process, Arrival Rate, Service Rate, Average Check-In Time, Server Configuration

1. Introduction

Airports and airlines face a lot of challenges in the conduct of their operations.

These include maintaining ground equipment and infrastructure, keeping the airplanes in good and serviceable conditions to engender airworthiness and equipment safety, complying with current operational guidelines as specified by both national and international regulators of the industry, while also ensuring the safety and security of passengers and staff. A common but vital facility in all airports is the terminal. An airport terminal is a building where passengers transfer between ground transportation and the facilities that allow them to board and disembark from an airplane.

In order to undertake any commercial flight with passengers, airlines critically concentrate their efforts on the verification and confirmation of the identity of outbound passengers. This service, which is referred to as the check-in process, is usually carried out at the departure hall of the airport terminal. The check-in process is an enormous task involving many stakeholders, some of who are not staff of the airlines and are therefore not under their control. The task has become even more challenging following the stringent security measures incorporated in the air transport industry following the tragic event of September 11, 2001 in the United States of America [1] where some travelers who were checked-in as normal passengers later turned out not to be.

An international airport such as the Murtala Muhammed International Airport (MMIA) Ikeja, handles high passenger traffic. Usually, the high human traffic is as a result of air passengers who seek the services of both the airport and airlines to enable them embark on their scheduled flights. In a typical international airport, check-in processing takes place at the departure hall. Check-in processing is characterized by various activities, major of which is the initial security screening, identification, verification and confirmation of travelers' identities as contained in the travel documents, as well as the identification, weighing and acceptance of travelers' baggage and freight. The process of identifying, verifying, confirming travelers' identities, and their baggage by both the airport and airline staff, as well as other governmental security agencies is time consuming.

However, by design, airlines have an average time estimated to service a particular passenger at the counter and check-in counter staff always attempt to adhere to this timing. Usually, passengers arrive the departure hall for check-in activities at random, and for most times, the arrival rate is greater than the estimated service rate. At the commencement of the check-in process, passengers' arrival rate is usually lower than the estimated service rate. However, as the scheduled departure time approaches, the arrival rate of travelers increases exponentially in a highly-random manner, and becoming much higher than the estimated service rate. Since travelers' arrival rate is random and therefore unpredictable, this leads to a build-up of a queue of passengers waiting to be served. When passengers' queue build-up, the problem of prolonged waiting on the queue arises. At this point, travelers' start becoming agitated for fear of missing their flights as this has various consequences. As the situation continues, it sometimes leads to delayed flights with the associated consequences on airlines, passengers and airport management. Eventually, the series of delays result to problems for both the airlines and their esteemed travelers, leading to loss of revenues, travel time and passenger dissatisfaction.

Recognizing the existence of queues and its impact on organizations, various researchers have sought ways to address the queue problem. A major effort in this regard was proposed by Agner Krarup Erlang, a Danish engineer who worked for the Copenhagen Telephone Exchange [2]. Queueing theory is further described as a branch of mathematics that studies and models the act of waiting in lines [3]. Similarly, [4], described queueing theory as the theory behind what happens when you have lots of jobs, scarce resources, and subsequently, long queues and delays. This results in customer dissatisfaction, wastage of scarce resources and most times, unexecuted businesses.

[5] was of the opinion that doubling service demand in queue situations does not necessarily require resources increase to achieve better performance. Furthermore, [6] investigated the number of critical resources at the first two phases of the airport departure operations and found that most passengers are not satisfied with the services received at the airport check-in process. Also, [7], applied the Discrete Event Simulation (DES) model to evaluate how arrival patterns of passengers to the airport departure hall affect international terminal operations such as check-in, security screening and immigration control. The researcher found that arrival pattern is a major factor responsible for overcrowding at the check-in section of airports.

[8] analyzed the airport check-in counter allocation problem that has been a concern to the scheduled air transport industry for decades. Their work was motivated by the high demand for scheduled air transport following the hosting of the 2014 FIFA Soccer World Cup (an international event) in Brazil. Their study proposed a methodology to optimize Airport Check-in Counter Allocation Problem which will minimize operators' costs while at the same time match demand with service supply. Using the Kuwait International Airport (KIA) as case study, [9] opined that given the unique and important services offered to passengers by airport operators and airlines, and the relatively high cost paid for the services, passengers deserve to be satisfied. Al-Sultan's research therefore dwelled on customer satisfaction and cost effectiveness. At the end of analysis of the results, the researcher proposed the use of deterministic (integer programming) and stochastic (simulation) approaches to address the problem. Integer programming was to be used to optimize service resources while simulation was to be used to model the airport system to study the effects of various parameters such as the number of passengers on a flight and the check-in counter time of operation.

Both [10] and [11] shared the same view with [5] that modelling and simulation is the modern approach to study airport/airline check-in system problem. During his study, [10] built a simulation model (SM) using SimEvents tool box on MATLAB to implement the analytical model (AM). From the study, the researcher found that SM exhibited stochastic behavior which actually depicts reality and hence, produced more results. The study was based on Manchester and Leeds-Bradford airports in Europe. Similarly, [11] used Simquick Process Simulation software to analyze the operation of passengers' check-in desks of Nok Air at the Nakhon Thamarat Airport in Thailand. Findings from the study showed that the approach used demonstrated the efficient allocation of check-in resources which resulted in the resolution of operational issues that could prevent ultimate outcomes. The study also found that queuing theory and simulation are useful in the airline industry. [10] and [11] were of the opinion that applying queuing theory and simulation to the airport check-in problem would provide helpful information regarding the required capacity so that passengers are not subjected to endless waiting on the queue.

[12] supported the views expressed by [5] [10] and [11] on the need to deploy modelling and simulation tools provided by modern technology to study check-in system problem in airports. In his study, [12] evaluated various scenarios for the check-in procedure for Kuwait Airways at Kuwait International Airport (KIA). The researcher used simulation model to study the queuing processes and also to evaluate and improve operational and personnel planning in order to minimize the staffing cost, and at the same time, meet an appreciable level of service. The researcher used the Arena software to apply the simulation model and also used Expertfit and Input Analyzer to come up with the appropriate data distributions. The research, however found that the time the customer spends waiting on the queue is directly related to their satisfaction level.

[13], investigated the traveler's flow process in both the MMIA and Nnamdi Azikiwe International Airport, Abuja (NAIA) and recommended multiple server multiple queue structure to address airport check-in problem at the check-in counter sub-section as a way of addressing passenger dissatisfaction. [14], adopted the Spearman Rank correlation method using weighted average and Gap analysis to examine the relationship between passengers' satisfaction and service quality in MMIA. Yet, [1], proposed the integration of a biometric system into the check-in process to enhance the airport operators' performance. The researcher built a model of a medium-sized airport and analyzed it using the Simio simulation environment and used it to evaluate the expected performance of the BST ID. The result of the simulation models reported more than 90% decrease in check-in time from 47.98 minutes for manual check-in passengers to 3.6 minutes for BST ID compliant passengers. This research will model the check-in process at the international terminal of MMIA, Ikeja with a view to proposing an improved model that will address the airport check-in process queue problem as well as effectively handle higher airport passenger traffic using cost effective option.

Although check-in process at the airports is generally seen as activities that take place at the airline check-in counter, the process actually starts at the departure hall entrance and terminates at the airline check-in counter. Thus, this research covers the activities that take place at the four distinct sections of the airport check-in section, which includes departure hall access/security screening gates, baggage weighing sub-section, passenger profiling sub-section, and airline check-in counter sub-section.

2. Methodology

2.1. Description of the Case Study

The check-in process reflecting the outbound passenger's activities at the Departure Wing of the largest and the busiest international airport in Nigeria, the Murtala Muhammed International Airport (MMIA), was used as case study for the model development. Specifically, the Emirates check-in section was the focus of the study. The airline handles the highest passenger traffic amongst 27 international airlines operating from the airport [15]. The airline uses two modes of check-in for processing outbound passengers. These include the conventional check-in model that uses the Common Use Terminal Equipment (CUTE) technology and the remote (online) check-in model. **Figure 1** shows the quantitative diagram of the case study check-in flow process while **Figure 2(a)** and **Figure 2(b)** show the flowchart of the check-in activities. The airline utilizes one baggage weighing equipment, one passenger profiling device, and 4 check-in counters to process check-in for Economy Class passengers. Irrespective of the mode of check-in used by a passenger travelling through the airport, all passengers are expected to present themselves physically at any of the check-in counters for identity confirmation, baggage processing, and collection of boarding pass.

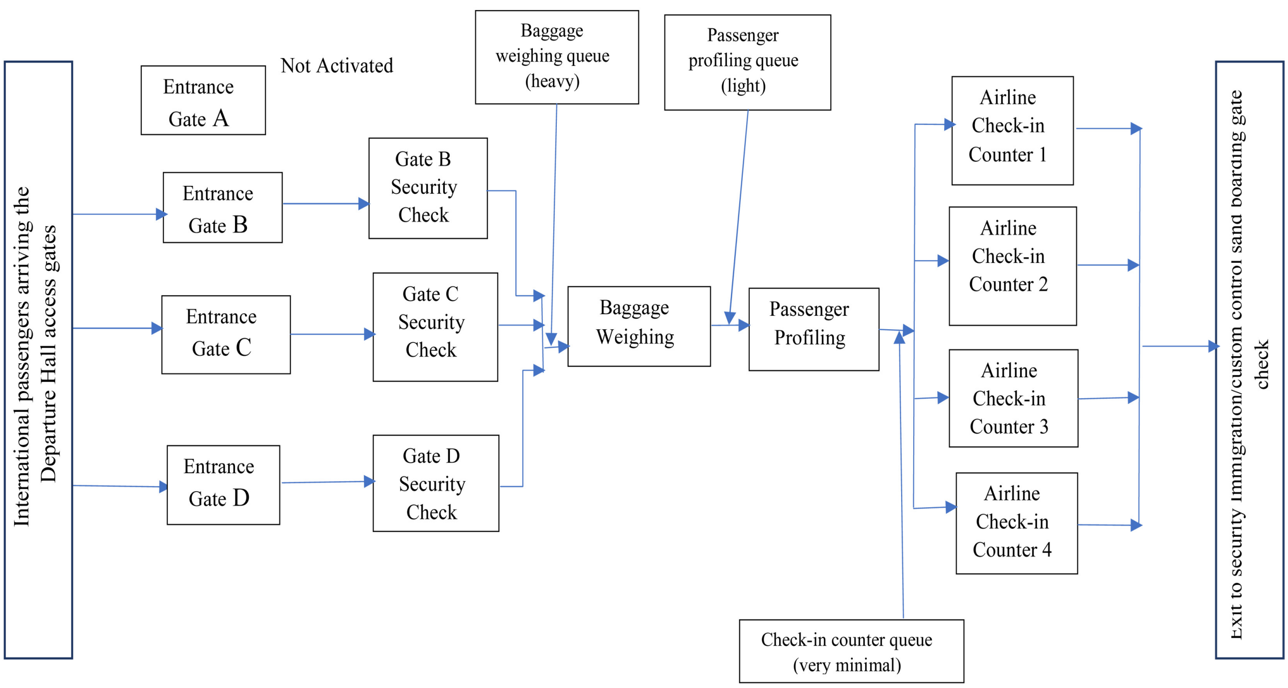
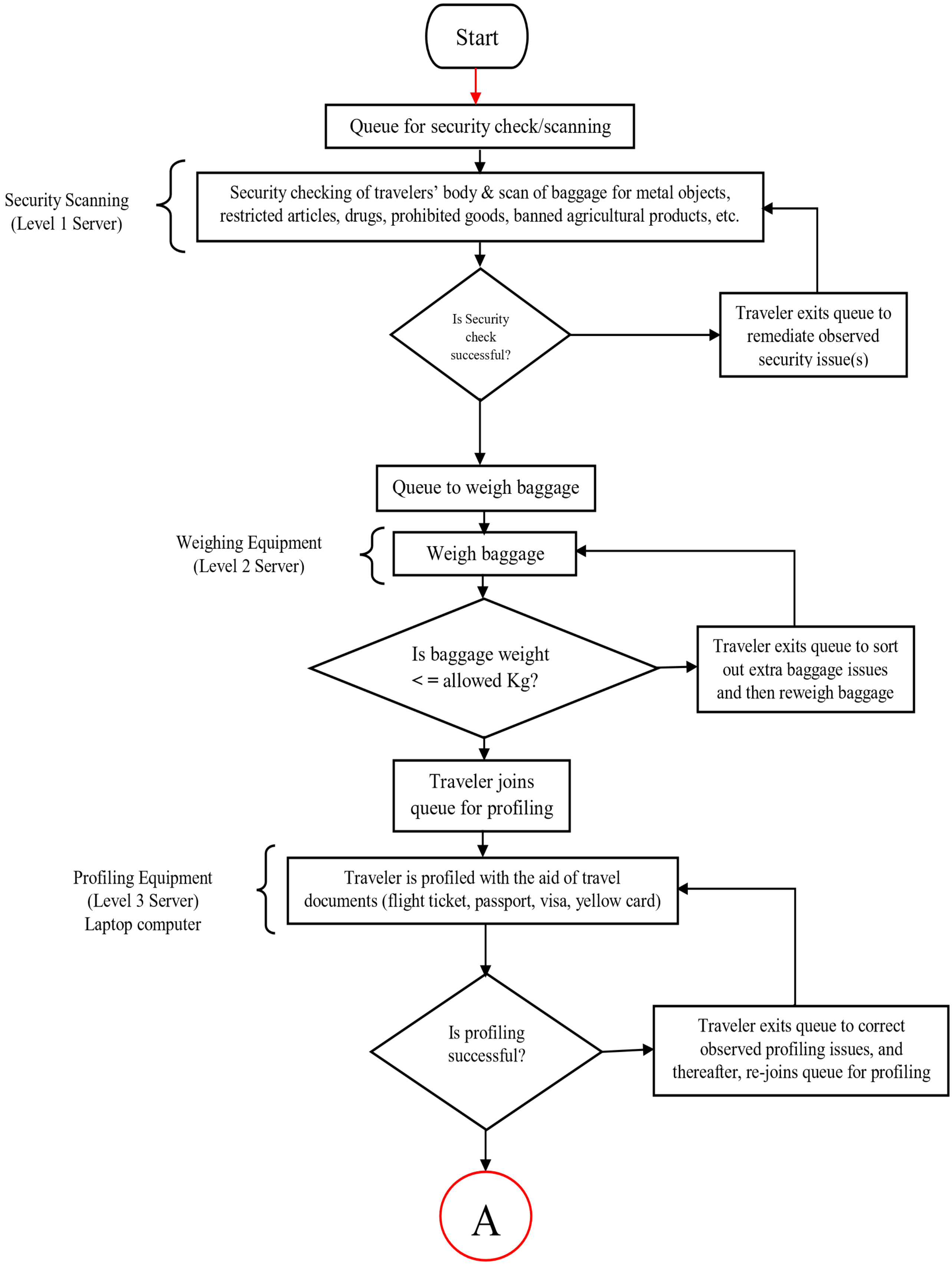
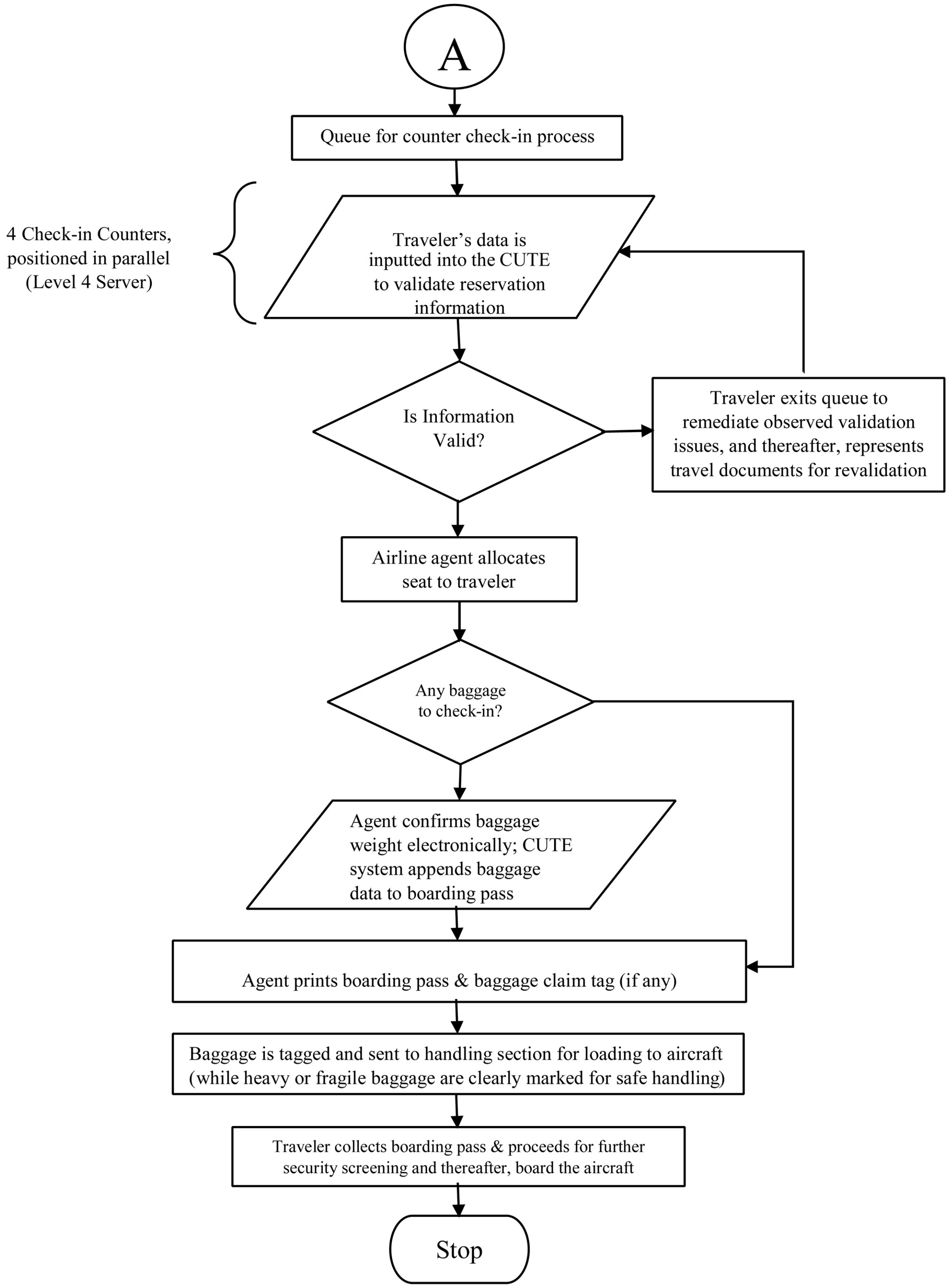


Figure 1. Quantitative diagram of case study check-in flow process.


Start
Queue for security check/scanning
Security Scanning
(Level 1 Server)
Security checking of travelers' body & scan of baggage for metal objects, restricted articles, drugs, prohibited goods, banned agricultural products, etc.
Is Security check successful?
Traveler exits queue to remediate observed security issue(s)
Queue to weigh baggage
Weighing Equipment
(Level 2 Server)
Weigh baggage
Is baggage weight < = allowed Kg?
Traveler exits queue to sort out extra baggage issues and then reweigh baggage
Traveler joins queue for profiling
Profiling Equipment
(Level 3 Server)
Laptop computer
Traveler is profiled with the aid of travel documents (flight ticket, passport, visa, yellow card)
Is profiling successful?
Traveler exits queue to correct observed profiling issues, and thereafter, re-joins queue for profiling
A

(a)



(b)

Figure 2. (a): Flowchart of emirates check-in process model at the MMIA. (b): Flowchart of emirates check-in process model at the MMIA continues.

2.2. Data Collection

Primary data were collected for the study. The data collection methods used include direct observation and oral interview. This entailed monitoring of passenger flow from the departure hall entrance gates up to the airline check-in counters. The data collected included arrival time (AT), service time (ST), delay time (DT), and remediation time (RT). These data were used to determine the time spent at each of the 4 service points in the process; which together sum up to the total check-in time (TCT) for each passenger. These data were collected for 5 international flights spread across 7 days between 8 a.m. and 5 p.m. These variables were used as time inputs for model development, the model comprises 4 timegroups, namely; security check time (SCT), baggage weighing time (BWT), passenger profiling time (PPT), and counter check-in time (CCT) as shown in **Table 1**. From the Table, the average time spent on the system; *i.e.*, average check-in time (ACT) is 76.16 minutes.

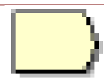
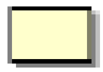
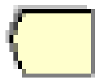
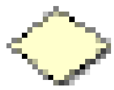
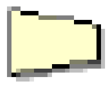
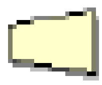
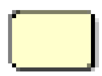
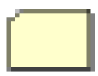
2.3. Development of a Model for Airport Check-in Process

The model for airport check-in process understudy was developed in line with the Unified Modelling Language (UML) concept. The UML is a modern approach to computer modelling and is based on diagrammatic representations of software components. According to [16], "UML belongs to the group of graphical languages". By using graphical representations, it is easier to understand possible flaws or errors in software or business processes. One widely used example of UML is Arena simulation software. Arena is an extendible modelling system that is based on SIMAN Cinema and includes integrated support for input data analysis, model building, interactive execution, animation, and output analysis [17]. Due to its flexibility and ease of use, Arena was used to develop the model for the international traveler's check-in process (ITCP). The software features icons, symbols and command buttons with their embedded function codes. The development process involved dragging and dropping of icons, symbols and other command buttons from the basic process panel into the model development environment. **Table 2** represents the description of the Arena modules. Thereafter, connector lines were used to link the modules together to specify the flow of entities. It is important to state that modules have specific actions relative to entities, flow, and timing [17]. The exact representation of each

Table 1. Data collected.

Activity	1st Flight (minutes)	2nd Flight (minutes)	3rd Flight (minutes)	4th Flight (minutes)	5th Flight (minutes)
SCT	1.15	1.45	1.30	1.53	1.59
BWT	35.45	37.25	36.16	36.66	36.37
PPT	25.15	26.26	23.01	25.00	25.50
CCT	12.32	13.47	13.00	15.09	12.69
ACT	74.47	78.43	73.47	78.28	76.15

Table 2. ARENA flowchart module symbols/description.

Flowchart Module Symbol	Module Name/	Description
	Create	Entities enter the simulation here
	Process	An activity, usually performed by one or more resources and requiring some time to complete
	Accepted/Returned (Dispose)	Entities are removed from the simulation here
	Decide	A branch in entity flow, only one branch is taken
	Batch	Collects a number of entities before they can continue processing
	Separate	Duplicates entities for concurrent or parallel processing, or separating a previously established batch of entities
	Assign	Changes the value of some parameters (during the simulation), such as the entity's type or model variable
	Record	Collects a statistic, such as an entity counter or cycle time

module and entity relative to real-life objects was given great concern during the model development process. The model was developed based on the existing 1 × 1 × 4 server configuration. At the end of the development process, the model was tested for errors using the RUN function; the test result showed no error with an ACT of 79.25 minutes. Figure 3 shows the screen shot of the model for the ITCP. In the development of the model, the following assumptions were made:

1) Passengers arrive the departure hall entrance gates for check-in processing at random.

2) Check-in process starts at the departure hall entrance gate and terminates at the airline check-in counter.

3) Check-in process starts 3hrs ahead of departure time of designated flight.

4) Arrival rate is recorded at the baggage weighing sub-section.

5) The queue discipline adopted was First Come First-Serve (FCFS).

2.4. Results and Discussions

The report of the simulation runs showed results for 133 completions (passengers) used for analysis. The report grouped the time distributions into five categories. These include average time spent in agency/security checks, average time

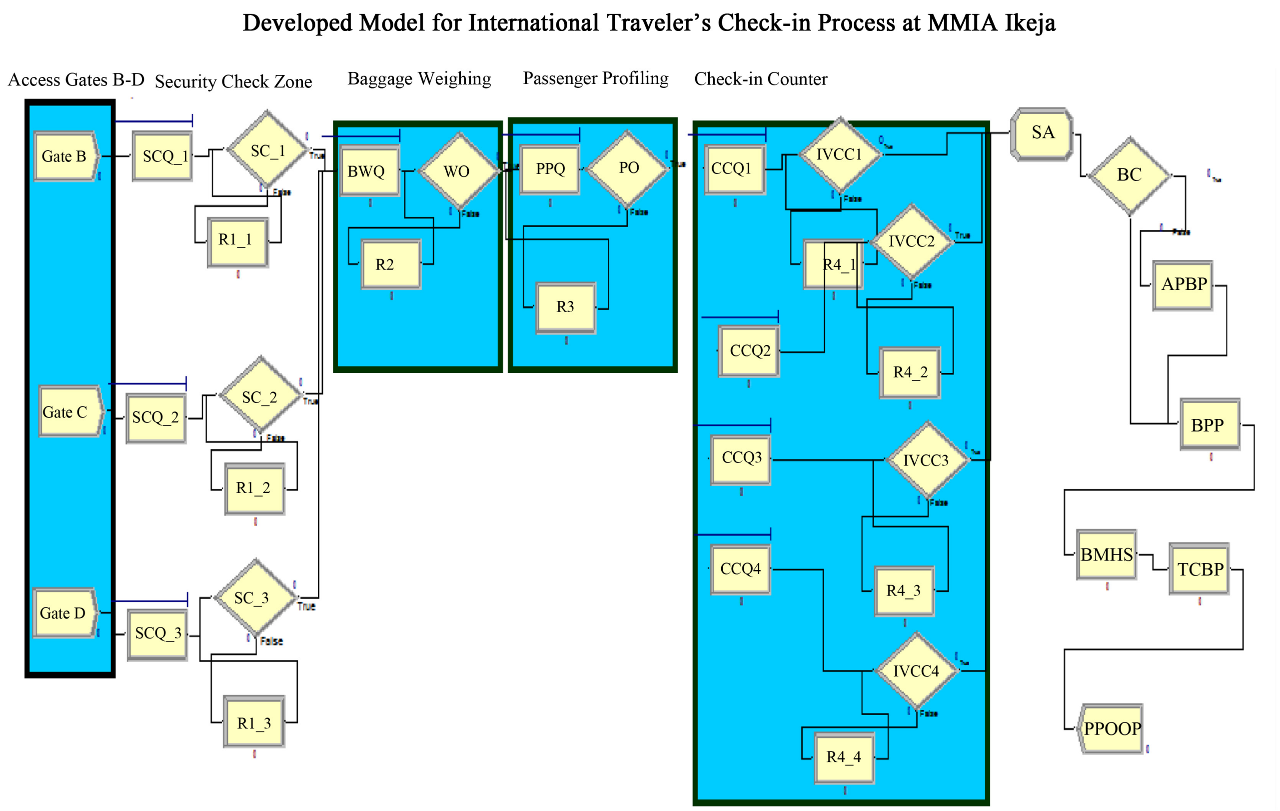


Figure 3. The model of ITCP for MMIA. Legend: SC: Security Check; BW: Baggage Weighing; PP: Passenger Profiling; CC: Check-in Counter; Info: Information.

spent in baggage weighing, average time spent in passenger profiling, average time spent for counter check-in activities and finally, the average time spent in the check-in process system. For brevity in writing, and clarity in discussion and analysis, this simulation model arrived at from the combination of the 3 server categories is abbreviated as 1 × 1 × 4 servers; representing 1 weighing machine (1 WM), 1 profiling device (1 PD) and 4 check-in counters (4 CCs). The simulated result of the real system showed that the average check-in time (ACT) for 133 completions (passengers) is 79.25 minutes. For the purpose of model validation, the two parameters that are considered are: SCT and ACT. The summary statistics of the simulation result based on the two parameters for the 1 × 1 × 4 servers model is shown in Table 3 and the graph is shown in Figure 4. Statistical analysis was carried out on the simulation results and the actual average flow time of passengers for the 5 flights under study by comparing the actual (real) result with the simulated result and it was confirmed that there was no significant difference between the two systems. Thus, the model represents the real system. It can be seen that $p = 0.01$; which is less than the standard 0.05 Alpha level. This implies that there is no significant difference between the real system and the developed model, this is shown in Figure 5. Hence, the developed international traveler's check-in process model is valid and accurately represents the existing airport passenger check-in process under study.

Table 3. The summary statistics of the simulation result for the 1 × 1 × 4 servers model.

Activity	Average Time (minutes)
SCT	1.45
ACT	79.25

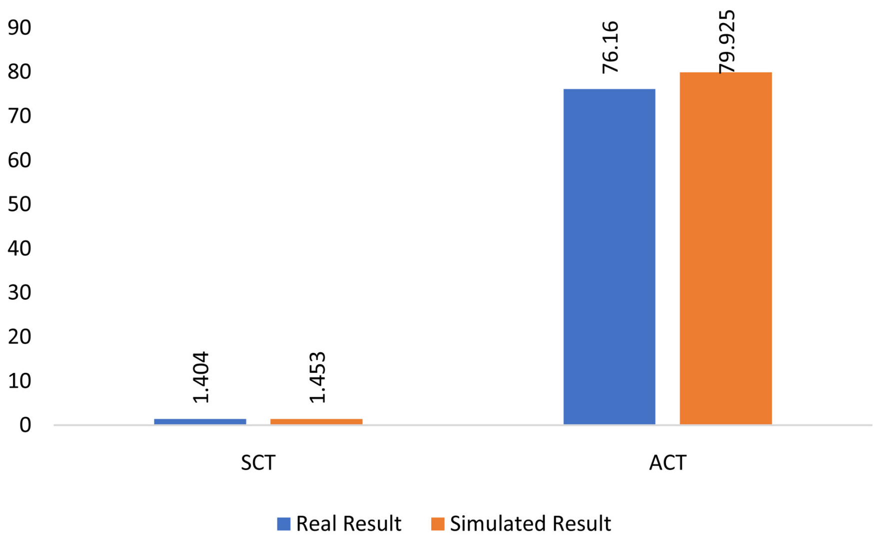


Figure 4. Graph comparing the real results with the simulated result.

t-test results - assuming homogenous variances

**Note: the probabilities in the two tables below are highlighted if <= 0.05 two-tail. If using the Bonferroni adjusted alpha, these may no longer be "significant"*

Bonferroni Adjusted alpha = *0.010000*

Test Description	Mean 1	Mean 2	T-calc	Deg F	Probability	Cohen-d	eta sq
Security Check	76.16	79.925	0.0777	8	0.94000	0.055	0.001
Baggage Weighing	76.16	79.925	0.1458	8	0.88766	0.103	0.003
Passenger Profiling	76.16	79.925	0.1133	8	0.91257	0.080	0.002
Counter Check-in	76.16	79.925	0.0925	8	0.92860	0.065	0.001
Average Check-in Time	76.16	79.925	3.0515	8	0.01579*	2.158	0.538

t-test results - unequal variances - Welch-Satterthwaite Adjustment

Test Description	Mean 1	Mean 2	T-calc	Deg F	Probability	Cohen-d	eta sq
Security Check	76.16	79.925	0.0777	7.9812	0.94000	0.055	0.001
Baggage Weighing	76.16	79.925	0.1458	7.9766	0.88767	0.103	0.003
Passenger Profiling	76.16	79.925	0.1133	7.9797	0.91257	0.080	0.002
Counter Check-in	76.16	79.925	0.0925	7.9824	0.92860	0.065	0.001
Average Check-in Time	76.16	79.925	3.0515	7.9888	0.01581*	2.159	0.538

Figure 5. Screen short of t-test showing p-values to be less than 0.05.

3. Conclusions, Recommendation and Future Work

In this work, a model for international traveler's check-in process was developed for the international terminal of the MMIA, Ikeja.

The developed model yielded an ACT of 76.16 minutes. The developed model represents the real system under study based on the result of the statistical analysis, which shows that there were no significant differences between the simulated and the measured ACT at 5% level. Thus, the simulation results give a confirmation of the developed model's efficacy to correctly describe the check-in process of MMIA under consideration. The experimental result showed that the developed model is valid and is therefore useful for airline decision makers to manage passengers' check-in problem as a way of boosting revenue, improving the quality of service, reducing passengers' waiting time and enhancing customer experience.

Following the positive result from the simulation model, further work will be on simulation experiments by varying the resources at the baggage weighing and passenger profiling sub-sections. This will be used to determine the best combination of resources that would give the smallest ACT for passengers. Also, future work on the airport check-in process problem may look into a system that will ensure that arrival of passengers to the airport is not at random; which ultimately will discourage overcrowding at the check-in section.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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