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Passenger Queue Simulation Analysis and Optimization at The Check-in Counter of Yogyakarta International Airport

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ABSTRACT

Air transportation has a role in providing services to deliver people and goods in a relatively shorter time. Queues will increase due to the relatively low quality and quantity of service. This can happen at the Yogyakarta International Airport check-in counter. This research uses a comparison method between the queuing system and arena software. The queuing system used is a single channel-single phase. The airlines that will be studied are Lion Air and Super Air Jet. The samples used respectively were 65 passengers and 61 passengers from Lion Air and Super Air Jet airlines. Data collection was carried out during peak hours. With this passenger movement simulation model, it is possible to determine the length of queue experienced by passengers at each check-in counter, the time to be served, and the check-in counter staff that must be provided. The length of time queuing for passengers for each airline is that for Lion Air the length of time queuing at the check-in counter is 18,6 minutes with an additional 1 officer from before and for Super Air Jet it is 28,5 minutes with an additional 1 officer from the previous check-in counter.

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1. INTRODUCTION

The Unitary State of the Republic of Indonesia is separated by vast water, which makes one of the important aspects as a link between islands is transportation. Currently, humans have many choices in choosing the mode of transportation they want to use, one of which is air transportation. Air transportation has a role in providing services for the transportation of people and goods from one airport to another in a relatively shorter time.

Under certain conditions, there will be limitations in resources and efforts in the economic system, causing people, goods, and components to have to wait to be served. Queues are waiting situations where many entities (entrants) try to get service from limited facilities (service providers), so that immigrants must queue for a certain period before getting their turn to receive service [1]. Queues occur because of an imbalance between those being served and their services [2]. This can happen in different places and times, one of which is at the check-in counter at Yogyakarta International Airport.

This research discusses the movement of domestic passengers in the check-in counter area and optimization for check-in counter officers at the Yogyakarta International Airport terminal. In serving passengers, there is a reference in the service standards of an airport as stated in the Regulation of the Minister of Transportation of the Republic of Indonesia Number 185 of 2015. For the check-in process, there is a time limit for opening check-in services, which is no later than two hours before the departure schedule. Prospective passengers can check-in a maximum of thirty minutes before the departure schedule. In terms of ticket and baggage services at the check-in counter, passengers wait for approximately 10 minutes for economy class and approximately 3 minutes for executive and business classes. And for the service process time provided to passengers at the check-in counter according to applicable regulations, a maximum of 2 (two) minutes 30 (thirty) seconds per passenger [3].

Yogyakarta International Airport experienced 104% increase in passengers compared to the 2021 when it was Christmas holiday. This increase was because in 2021 there was still a travel ban. So that in 2022 there was a significant increase [4] that had an impact on the accumulation of passengers during the process before the departure of air transportation service users. Several parameters are needed to determine the existing conditions and these parameters include: the number of passengers in the system, the number of passengers in the queue, the length of passengers in the system and the length of passengers in the queue. The way to solve the analysis problem in the queue case that needs to be done is to know the level of service intensity, probability, time between arrivals, passenger service time in the system or the reality is assumed to be a Poisson distribution using the single channel-single phase queue method and later it will be compared with the results of the queue simulation.

2. RESEARCH METHOD

2.1. Queue Structure

The queue structure is divided into four basic models [5], including:

a. Single Channel-Single Phase
Single channel shows that there is only one entry point service system and only one service facility, and can be seen in Figure 1 below:

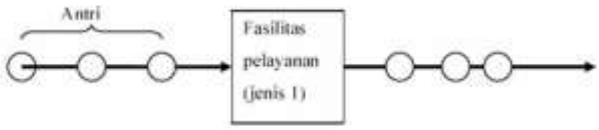


Figure 1. *Single Channel-Single Phase*

b. Single Channel-Multi Phase
This system shows that there is only one entry point service system and there are two service facilities in series on the route.

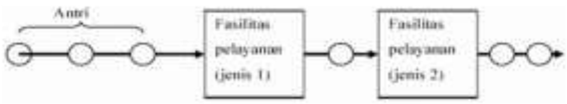


Figure 2. *Single Channel-Multi Phase*

c. Multi-Channel-Single Phase
This system occurs at any time and consists of two or more service facilities fed by a single queue.

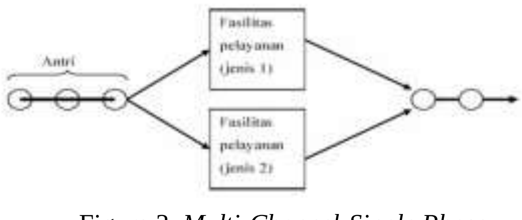


Figure 3. *Multi-Channel-Single Phase*

d. Multi-Channel-Multi Phase
Each system has multiple service facilities at each stage, so that more than one individual can be served at a time.

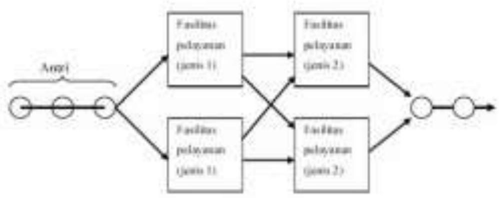


Figure 4. *Multi-Channel-Multi Phase*

2.2. Single Channel-Single Phase Queue Calculation Model

The equation used in analyzing queues for the single channel-single phase queue model shown Formula (1) to Formula (8).

a. Average arrival rate

$$\lambda = \frac{1}{\bar{x}} x60 \text{ minutes} \tag{1}$$

b. Average service level

$$\mu = \frac{1}{\bar{x}} x60 \text{ minutes} \tag{2}$$

c. Average number of passengers in the queue

$$L_q = \frac{\lambda^2}{\mu(\mu-\lambda)} \tag{3}$$

d. Average number of passengers in the system

$$L_s = \frac{\lambda}{\mu-\lambda} \tag{4}$$

e. Average waiting time for passengers in line

$$W_q = \frac{\lambda}{\mu(\mu-\lambda)} \tag{5}$$

f. Average waiting time for passengers in the system

$$W_s = \frac{1}{\mu-\lambda} \tag{6}$$

g. Level of intensity of service facilities

$$\rho = \frac{\lambda}{\mu} \tag{7}$$

h. Probability

$$P0 = 100\% - \rho \tag{8}$$

Where,

ρ = Level of service facility intensity
λ = Average arrival rate
μ = Average service level
L_s = Number of passengers in the system
L_q = Number of passengers in the queue
W_s = Length of waiting time in the system
W_q = Length of waiting time in the queue

2.3. Arena Software Simulation Model

There are basic modules in the use of arena software. Where, the basic module is used to create a real simulation block [6]. Arena offers animation for the entities used, to visualize the process flow well. In addition, various statistical data can be recorded and displayed directly during the simulation and as a report after the simulation ends [7]. The following are the basic modules used for simulation, including:

a. Create
   This module is used to generate entity arrivals into the simulation.
b. Dispose
   This module is used to remove entities from the system.
c. Process
   This module is used to process entities in simulation.
d. Decide
   This module is used to determine decisions in the process, including several options for making decisions based on 1 or several options.

2.4. Optimization Methods

This method is very relevant to use in repetitive and short work cycles. The measurement method with stopwatch time study is an objective measurement method because in this case the time is determined based on the facts that occur and not just subjective estimates [8]. The known data is then processed in Formula (9) to Formula (10) for the calculation of the stopwatch time study method.

a. Cycle Time

$$W_s = \frac{\Sigma x}{N} \quad \text{.....(9)}$$

b. Normal Time

$$W_n = W_s \; x \; p \quad \text{..... (10)}$$

c. Standard Time

$$W_b = W_n \; x \; \frac{100\%}{100\% - allowance} \quad \text{..... (11)}$$

d. Optimum Officer

$$N' = \frac{P \; x \; W_b}{DE} \quad \text{..... (12)}$$

Where,

Σx	= Total service time
N	= Total data
p	= Performance rating
$allowance$	= Field condition assessment
P	= Total output
DE	= Effective time

2.5. Data Validation

Validation conducted in this research was using the Paired T-test. Paired T-test is a statistical procedure conducted to compare the average of two data measurements taken from individuals, objects or others [9]. The hypotheses built in this study are as follows:

$\boldsymbol{H_0}$ = There is no significant difference between the simulation output and the real system output
$\boldsymbol{H_1}$ = There is a difference between the simulation output and the real system output

To answer the hypothesis, T-$_{count}$ is confirmed with the T$_{tabel}$ value (5%; N-1). When the value -T$_{table}$ ≤ T-$_{count}$ ≤ T$_{tabel}$ then the hypothesis H_0 can be accepted. If otherwise then the hypothesis H_0 is rejected and the hypothesis H_1 is accepted. To determine Tcount the known data is entered into equations (13) and (14).

$$S_{\bar{x}} = \frac{S}{\sqrt{n}} \quad \text{..... (13)}$$

$$t = \frac{\bar{x}_{diff}}{S_{\bar{x}}} \quad \text{..... (14)}$$

Where,

$\bar{x}_{diff}$	= mean sample difference
n	= sample size (number of observations)
S	= standard deviation of sample differences
$S_{\bar{x}}$	= estimated standard error of the mean

2.6. *Research Flowchart*

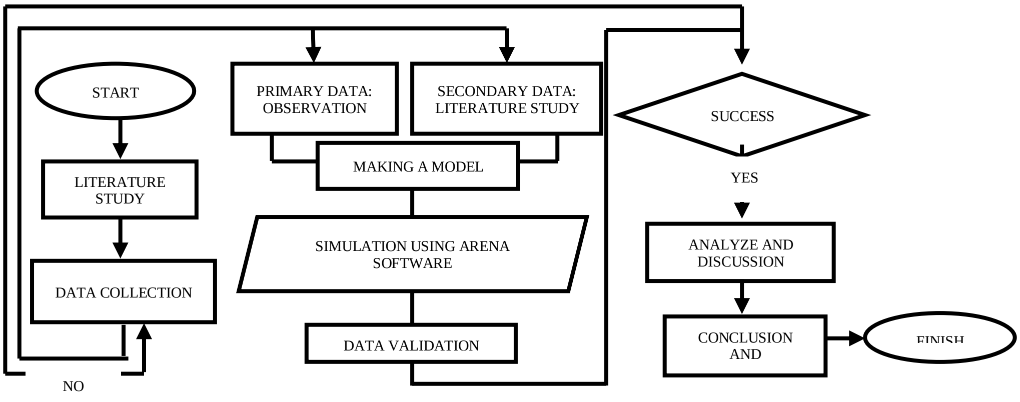


Figure 1. Research Flowchart

Based on the research flowchart (Figure 5), data processing can be carried out with stages as explained below:

a. Research Begins
b. Literature Study
   Literature study is conducted with the aim of obtaining an overview and basis for thinking in solving the problems being studied
c. Data Collection
   Data collection is obtained from primary data and secondary data.
   a) Primary data is data obtained directly from respondents (research objects). For example: questionnaires and interviews with informants.
   b) Secondary data is data obtained through data that has been researched and collected by other parties related to the research problem. For example: Literature study
d. Then simulated using Arena Software V.16.0
e. Data Validation
f. Data Processing and Discussion
   It is the result obtained from the analysis of the research subject, which discusses the understanding and issues raised.
g. Conclusion and Suggestions
   This is the final stage of the research process, which includes answering the research objectives that have been set and analyzing the main topics processed from the existing data, including conclusions and constructive suggestions, in order to add completeness to the writing of this thesis.

3. RESULT AND DISCUSSION

For this research, passenger departure data was obtained during peak hours and passenger service times at each airline check-in counter. In this research, 2 airlines were used, namely Lion Air and Super Air Jet.

3.1. Queue Calculation Results Using Single Channel-Single Phase

From the known data, it is then processed using equations (1) to (6) to obtain the results from the two airlines. The calculation results using the single channel-single phase queue model will be included in Table 1.

Table 1 Single Channel-Single Phase Model Calculation Results

	Lion Air	Super Air Jet
λ	34 passenger/hour	38 passenger/hour
μ	37 passenger/hour	40 passenger/hour
L_q	10 *pax*	18 *pax*
L_s	11 pax	19 *pax*
W_q	18,6 minutes	28,5 minutes
W_s	19,8 minutes	30 minutes

Thus, the data above that corresponds to Table 1 is the result of the calculation of the single channel-single phase model queue. Furthermore, from the arrival rate data and the level of passenger service time, the level of service intensity and the probability of leniency for each check-in officer can be calculated. In calculating this, it is adjusted to equations (7) and (8) and the results will be included in Table 2.

Table 2 Probability Calculation Results

	Lion Air	Super Air Jet
ρ	91,8%	94,7%
$P0$	8,2%	5,3%

Table 2 shows that the level of service intensity and the probability of leniency from check-in officers does not reach 10%, therefore officers carry out their duties with a busyness of over 90%.

3.2. Arena Simulation Model Results

At this stage, it will create a simulation block in the arena software to apply real conditions in the check-in counter process. The following is a queue simulation for the check-in process at Yogyakarta International Airport using Arena 16.0 software.

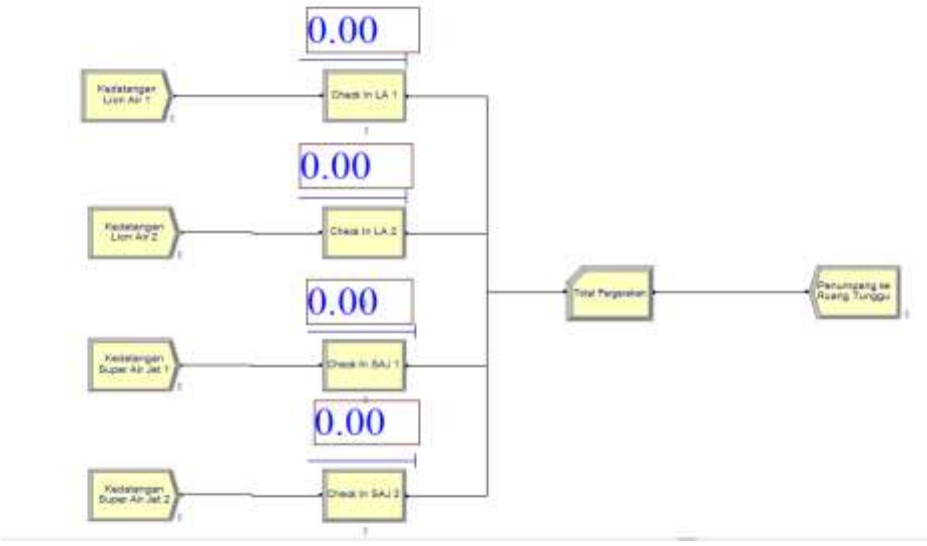


Figure 2. Arena Simulation Model

The following are the stages of creating a simulation of the check-in queue system conditions using Arena 16.0 software:

a. Arrival Module
The passenger arrival module is created with create. Passengers who will queue to print boarding passes are entities. The number of entities per arrival is assumed to be 1 with a maximum passenger arrival of 61-65 people.
b. Service Module
The process module is a check-in counter service by officers. The workforce is filled with 1 person and the type of service is filled with expression according to the type of distribution data.
c. Record Module
The record module is a module that records passenger movements after the process module.
d. Finish the Module
Dispose is the end point of the entity in the simulation model design. Entities that have completed the simulation model can be calculated with record data.

3.2.1. Input Analyzer Software Arena

Input Analyzer is part of Arena software. This tool is used to determine the probability distribution function of input data. It can also be used to match specific functions of file data distributions and compare distribution functions or to display the effects of parameter changes for the same distribution. Input Analyzer displays the random input data which can then be analyzed using the 21 fitting distribution software feature to find the distribution shape that best describes the data.

a. Interarrival Time Analyzer Input Results

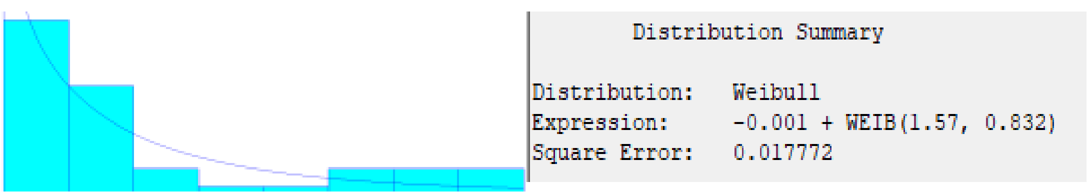


Figure 3. Lion Air Arrival and Departure Times

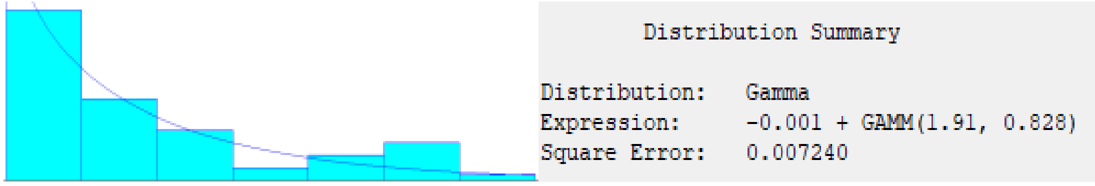


Figure 4. Super Air Jet Arrival Interval Time

Figure 7 shows that the distribution used in the software is the Weibull distribution. This distribution has an important role, especially in reliability and maintainability issues. The Weibull distribution is often used as an approach to determine the characteristics of the damage function because changes in value will cause the Weibull distribution to have certain properties or be equivalent to a certain distribution [10]. While Figure 8 shows an approach to the distribution of time between passenger arrivals using the gamma distribution because the distribution function is dense and broad [11].

b. Service Time Analyzer Input Results

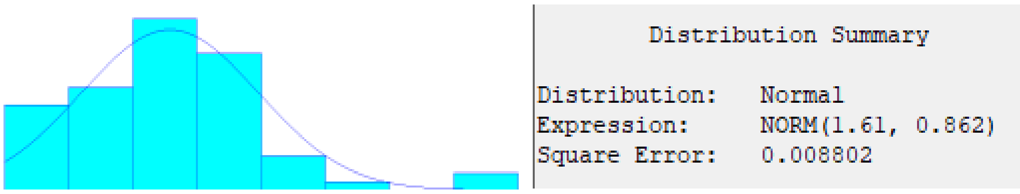


Figure 5 Lion Air Service Hours

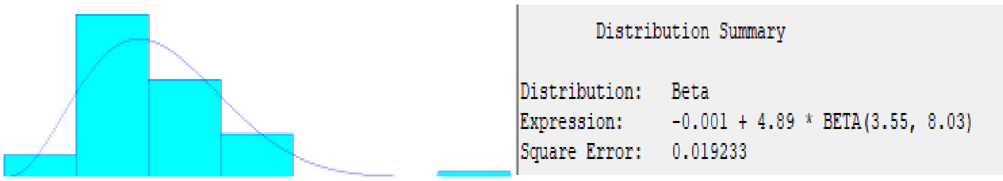


Figure 6. Super Air Jet Service Hours

Figure 9 shows that the service time of Lion Air airline uses the Normal Distribution. The normal distribution is the most important distribution in statistics. Many phenomena that appear in nature, industry, and research can be well described by the normal distribution curve. This normal distribution curve is shaped like a bell or gong, and its equation was first discovered in 1733 by Abraham DeMoivre. This distribution is also called the Gauss distribution [12].

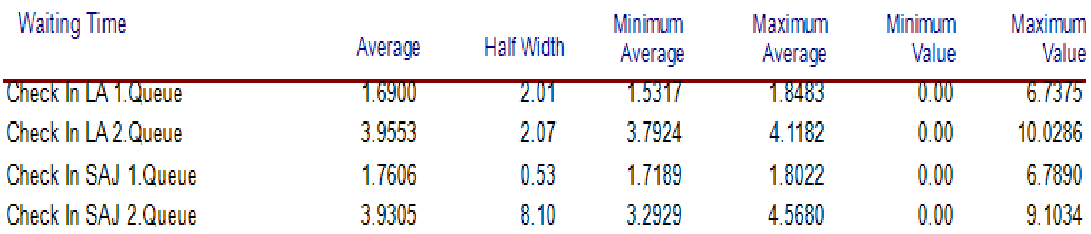
Meanwhile, Figure 10 shows the Super Air Jet service time using Beta Distribution. Beta Distribution is one of the continuous probability distributions defined on the interval [0, 1] and has two positive parameters, denoted by α and β, which act as random variable exponents and control the shape of the Beta distribution [13].

3.2.2. Service Time and Waiting Time Simulation Results

From the previous simulation model, the results obtained for waiting time and service time per passenger are in accordance with Figures 11 and 12.

VA Time Per Entity	Average	Half Width	Minimum Average	Maximum Average	Minimum Value	Maximum Value
Check In LA 1	1.6394	0.88	1.5703	1.7084	0.00	3.9495
Check In LA 2	1.6259	0.06	1.6209	1.6308	0.00	3.9464
Check In SAJ 1	1.4441	0.00	1.4440	1.4442	0.2070	3.5004
Check In SAJ 2	1.4968	1.23	1.3996	1.5939	0.4113	2.8760

Figure 7 Passenger Queue Waiting Time



Waiting Time	Average	Half Width	Minimum Average	Maximum Average	Minimum Value	Maximum Value
Check In LA 1.Queue	1.6900	2.01	1.5317	1.8483	0.00	6.7375
Check In LA 2.Queue	3.9553	2.07	3.7924	4.1182	0.00	10.0286
Check In SAJ 1.Queue	1.7606	0.53	1.7189	1.8022	0.00	6.7890
Check In SAJ 2.Queue	3.9305	8.10	3.2929	4.5680	0.00	9.1034

Figure 8. Passenger Service Hours

Table 3. Comparison of Simulation Results with Actual Results

Airline	Replication	Simulation (X_1)	Actual (X_2)	d= X_1-X_2
Lion Air	1	1,5703	1,61	-0,04
	2	1,7084	1,61	0,09
	Rata-rata beda			0,025
	Standar Deviasi			2,28
Airline	Replication	Simulation (X_1)	Actual (X_2)	d= X_1-X_2
Super Air Jet	1	1,4440	1,49	-0,05
	2	1,4442	1,49	-0,05
	Average difference			-0,05
	Standard Deviation			2,11

3.3. Data Validation

Validation is the process of determining whether what is conceptualized in the simulation is truly an accurate representation of the real system being modeled. The following are the results for the comparison of calculations between simulation and validation: The data in Table 3 is the average service time per passenger at Yogyakarta International Airport on August 16, 19, and 20, 2023. The following is the calculation process according to equations (13) and (14) for each airline:

3.3.1. Lion Air

In the validation test, a calculation process is carried out to determine the accepted hypothesis with a value of T_{table} based on the normal distribution table with the number N = 2 and a confidence level of 80% and a value of a = 0.2 is 1.367 or - 1.367. For the calculation, it is found that the value of T_{count}= 0.02 with a value of T_{table} of 1.367, so the value of T_{count} is still between T_{table} $1.367 \leq 0.02 \leq -1.367$, then the hypothesis H_0 can be accepted, so it can be concluded that the existing simulation model with the real situation is the same (valid)

3.3.2. Super Air Jet

In the validation test, a calculation process is carried out to determine the accepted hypothesis with a value of $Ttabel$ based on the normal distribution table with the number N = 2 and a confidence level of 90% and a value of a = 0.1 is 3.078 or - 3.078. For the calculation, it is found that the value of T_{count} = 0.03 with a value of T_{table} of 3.078, so the value of T_{count} is still between $Ttabel$ $3.078 \leq 0.03 \leq -3.078$, then the hypothesis H_0 can be accepted, so it can be concluded that the existing simulation model with the real situation is the same (valid)

3.4. Check-In Officer Optimization

This research conducted an analysis to obtain optimum ground handling officers in the check-in counter area. The following are the calculations carried out in this study according to Formula (9) to Formula (12).

3.4.1. Cycle Time

Cycle time is the average process time in observing a work operation, which in this case is a work operation that is carried out repeatedly. The results of the cycle time calculation can be seen in Table 4.

3.4.2. Normal Time

Normal time is the working time that has taken into account the adjustment factor, namely the average cycle time multiplied by the adjustment factor [14]. The results of the normal time calculation can be seen in Table 4.

Table 4. Cycle Time, Normal Time and Standard Time Results

Airline	Cycle Time (Minutes)	Normal Time (Minutes)	Standard Time (Minutes)
Lion Air	1,61	2,00	2,08
		2,03	2,11
Super Air Jet	1,49	1,92	2,00
		1,91	1,99

3.4.3. Standard Time

Standard time is the time needed to work on or complete an activity or job by reasonable workers in normal situations and conditions [15]. The results of the standard time calculations can be seen in Table 4.

3.4.4. Optimum Officer

a. Lion Air

In calculating the check-in service time is 18 hours and 2 hours of rest. So the total effective time during peak hours with high movement status to carry out the check-in process is 3 hours or 180 minutes. If the number of outputs, available working time and standard work time have been determined, then to determine the number of officers needed in an operational activity, equation (12) can be used as follows:

$$N' = \frac{P\ x\ W_b}{DE} = \frac{164\ pax\ x\ 4{,}19\ minutes}{180\ minutes} = 3\ officers$$

With the current workforce, the optimal number of staff produced is 3,817 staff or equivalently 3 staff.

b. Super Air Jet

If the amount of output, available working time, and standard work time have been determined, then to determine the number of ground handling personnel required for an operational activity, you can use equation (12) as follows:

$$N' = \frac{P\ x\ W_b}{DE} = \frac{156\ pax\ x\ 3{,}99\ minutes}{180\ minutes} = 3\ officers$$

With the current workforce, the optimal number of staff produced is 3,458 staff or equivalently 3 staff.

3.5. Queue Analysis At Check-In

After conducting this simulation study, there is a difference between the queuing method and the arena software simulation [16]. According to Table 1 compared to Figure 11, there is a time difference for the average waiting time for passengers in the system. In Figure 11, the resulting time is the average queue time per passenger, therefore in Table 1 the average waiting time for passengers in the system (Ws) is divided by the average number of passengers in the system (Ls). The results of the calculation per passenger in Table 1 are respectively 1.8 minutes and 1.58 minutes for Lion Air and Super Air Jet airlines. From the results of these calculations compared to the simulation, there is a difference in the average waiting time for Lion Air airlines of 0.11 minutes while Super Air Jet is 0.18 minutes. In this case, the time difference is still within reasonable limits.

4. CONCLUSION

From the calculation results of the queue at the check-in counter, it can be seen how long the queue experienced by passengers of each airline is. For Lion Air, the queue time is 18.6 minutes and for Super Air Jet it is 28.5 minutes. So that the number of ground handling officers in the check-in counter area of each airline can be determined. For Lion Air and Super Air Jet officers, each should add 1 officer. In addition, the amount of check-in service time carried out on each airline. From the simulation results and the manual carried out for the check-in service time, the difference in service time from Lion Air is 0.02 minutes and for Super Air Jet is 0.03 minutes.

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