Aircraft Movement Simulation on the Location, Number, and Angle of Exit Taxiways at Juanda International Airport to Increase Runway Capacity

Wulan A. Rahayuningtyas and Ervina Ahyudanari

Departement of Civil Engineering, Institut Teknologi Sepuluh Nopember (ITS)
Corresponding Author: ervina@ce.its.ac.id

ARTICLE INFO

Artikel Information

Article Entry: 19-08-20

Revised Article: 20-09-22

Article Accepted: 20-09-22

Keywords

Exit Taxiway, Juanda, Runway, Number and Location of Exit, Geometric, Air Side, ROT.

ABSTRACT

There are several runway performance evaluation analyses with various exit taxiway angles at Juanda Airport. This analysis was carried out when Juanda Airport only had one operating terminal and five exit taxiways. Current conditions show that Juanda Airport has two operating terminals with eleven exit taxiways. Analytically, it shows that the simulation value is greater than the field performance. Geometry evaluation of the exit taxiway angles indicates a discrepancy between the angles on the ground and the theoretical angles. This discrepancy will also affect the runway performance. From the three studies, it can be assumed that the location and number of exit taxiways affect runway performance.Aircraft movement simulation on location, number, and angle of exit taxiway aimed to determine whether the existing conditions can facilitate aircraft movement at both terminals. In the initial process, the aircraft movement data were collected from 2013 to 2019 to forecast aircraft movements in 2025. From the forecasting I result, it was obtained that the number of aircraft movements during peak hours was 46 movements/hour. While from the forecasting II result, it was obtained that the number of aircraft movements during peak hours was 35 movements/hour. The forecasting results were used as maximum aircraft movement data in the simulation. In the second stage, the Runway Occupancy Time (ROT) that occurred at Juanda Airport for each type of aircraft was calculated to be compared with the theoretical ROT. The comparison results showed that the actual ROT value was more significant than the theoretical ROT. The forecasting results of aircraft movements and the ROT calculation used in carrying out the simulation showed that the runway could not facilitate the forecasting results of aircraft movement going to Terminal 2. Furthermore, it combined these simulation results with the analysis results of runway end use used in the planning process of the new exit taxiway location. The planning results obtained a distance of 1,800 m and 2,140 m, measured from each end of the runway to Terminal 2. This analysis also concluded that it will need an additional runway to facilitate aircraft movement in 2025.

INTRODUCTION

Juanda Airport is an international airport located on Ir. Juanda Street No. 1, Sedati, Sidoarjo, East Java. Juanda Airport is the largest airport in East Java and the second busiest airport after Soekarno–Hatta Airport. This airport serves not only domestic flights but is also capable of serving international flights, such as flights on the Surabaya-Madinah route, which facilitate Umrah pilgrims. In addition, it also serves international flights on the Surabaya (SUB)–Singapore (SIN) and Surabaya (SUB)–Kuala Lumpur (KUL) routes. Therefore, it cannot deny that Juanda Airport is a transportation facility that the East Java people need and are proud of.

The number of passenger movements departing and arriving at Juanda Airport increases yearly. Passenger movements can be seen as shown in Figure 1.

With the increase in passengers yearly, the flights served at Juanda Airport have also increased. Meanwhile, Juanda Airport has only one double-sided runway with a length of three thousand meters and a width of forty-five meters, which is used for Terminals (T1) and (T2). This condition needs to be reviewed, considering that the aircraft traffic in and out of Juanda Airport is currently hectic.

In 2015, it was planned to build terminal three (T3) Juanda Airport, but the construction process had not yet

Figure 1. Graph of Passenger Movement in 1999 – 2016

started until 2019. According to Baskoro (2017), the construction of T3 at Juanda Airport, which was originally expected to begin in 2018, was postponed until an undetermined deadline. Therefore, Juanda Airport can only maximize the performance of the existing runway.

One way to optimize runway performance is to review the location of the exit taxiway. This review aims to determine whether the existing exit taxiway has helped aircraft use the runway more quickly. If the aircraft can use and leave the runway more quickly, then the waiting time for the following aircraft will be faster too. Inaccurate placement, angle, and number of exit taxiways can result in additional runway usage time on aircraft. This additional use of time affects the runway performance. The longer the use of the runway, the fewer aircraft can be facilitated by the runaway. A good runway is a runway that can facilitate all aircraft movements with a waiting time that is close to zero or equal to zero second. The time used by aircraft to use the runway is called Runway Occupancy Time (ROT). In an analysis aimed at optimizing runway performance, it is also necessary to pay attention to which end of the runway is frequently used. In addition, it is also necessary to pay attention to the classification of airline groups using Terminal 1 and those using Terminal 2. The distribution of the use of the runway ends, and the classification of the use of the Juanda Airport terminal will later influence the design of the exit taxiway.

A similar analysis was carried out at Juanda Airport by Devi [1]. However, this analysis was carried out when Juanda Airport only had one operating terminal and five exit taxiways. Therefore, it is necessary to re-analyze the runway performance of Juanda Airport, which nowadays already has two terminals with a greater number of exit taxiways.

Determination of the number of exit taxiways was carried out by Pangnguriseng [2] by evaluating five exit taxiways that serve two terminals at Juanda Airport. This evaluation generated that it was necessary to add an exit taxiway to increase runway capacity during peak hours.

Analytical runway performance was carried out by Wilogo [3] by simulating the number and composition of aircraft on two parallel runways. The results showed that the simulation value was greater than the field performance.

Another study related to exit taxiways was also conducted by Simanjuntak [4]. Simanjuntak [4] evaluated the geometry of the exit taxiway angles. The evaluation results showed that there was a discrepancy between the angles in the field and the theoretical angles. This discrepancy will also affect the runway performance.

Based on these four studies, it can be assumed that the position and number of exit taxiways affect runway performance. These current conditions have yet to carry out aircraft movement simulations on the location and number of exit taxiways to determine whether the existing conditions can facilitate aircraft movements at both terminals or not. Therefore, a Study of Aircraft Movement Simulation on the Location, Number, and Angle of Exit Taxiways at Juanda International Airport to Increase Runway Capacity is still relevant.

METHODOLOGY

The method used to evaluate the exit taxiway's location at Juanda Airport refers to several literatures. It is hoped that the evaluation used can approach the reality on the ground, which will answer the formulated problems in CHAPTER I. The method used consisted of several stages: a preliminary survey (problem identification), literature study, data collection, data analysis, and the results obtained from the evaluation in the form of conclusions and suggestions. The following are the stages in the evaluation process.

A. *Field Observation*

Field observations were carried out to find out and identify the problems that exist in the object of study. It was also carried out to determine the existing condition of the field. This field observation was carried out at Juanda Airport in Surabaya.

B. *Literature Study*

A literature study is carried out to obtain references to methods and stages appropriate to the problems at the study location from books, journals, and other relevant reference sources that can support the study. The literature study was carried out on the runway, taxiway, and exit taxiway systems, air traffic volume forecasting methods,

Table 1. Estimated Aircraft Movements in 2025.

Period	Forecasting I	Forecasting II
Aircraft Movements	201.774	153.211

Table 2. Estimated Aircraft Movements in 2025.

No	Aircraft Type	Aircraft Movement Percentage
1	A320	34.36%
2	B739	5.41%
3	B738	36.95%
4	ATR-72	6.12%
5	B735	1.39%
6	CRJ1000	0.66%
7	A333	3.08%
8	B744	0.40%
9	etc	11.63%
	Total	100%

Table 3. Estimated Aircraft Movements in 2025.

No	Calculation	Forecasting I	Forecasting II
1	*Peak month ratio*	0.09148	
2	*Peak month movement*	18.459*	14.016*
3	*Peak day ratio*	0.03434	
4	*Peak day movement*	634*	482*
5	*Peak hour ratio*	0.07143	
6	*Peak hour movement*	46*	35*

*) *Peak hour movement*

Table 4. Distribution of the Use of Runway Ends in 2013-2019.

Year	*Runway* R10	*Runway* R28	TOTAL	Percentage R10	Percentage R28
2013	128377	10369	138746	92.53%	7.47%
2014	116672	19042	135714	85.97%	14.03%
2015	123.836	13.010	136.846	90.49%	9.51%
2016	130.253	18.343	148.596	87.66%	12.34%
2017	141.434	7.431	148.865	95.01%	4.99%
2018	156.519	0	156.519	100.00%	0.00%
2019	118411	11415	129.826	91.21%	8.79%

Table 5. Simulation Results

Runway	Terminal	Forecast	Results	Results II	Control
R10	T1	I	61.06	61.06	Necessary
		II	46.04	46.04	Unnecessary
	T2	I	80.25	96.31	Necessary
		II	62.16	73.25	Necessary
	T1 and T2	I	77.24	94.63	Necessary
		II	60.65	71.68	Necessary
R28	T1	I	72.26	79.47	Necessary
		II	52.06	53.80	Unnecessary
	T2	I	79.85	94.32	Necessary
		II	61.48	73.98	Necessary
	T1 and T2	I	76.24	76.24	Necessary
		II	60.22	60.22	Necessary

peak hour determination methods, runway performance evaluation, and the location determination of exit taxiways at airports.

C. *Data Collection*

In this study, the data needed was secondary data (data obtained from other parties) in the form of:

1. Juanda Airport aircraft movements in 2013-2019,
2. Movement of each type of aircraft operating at Juanda International Airport in 2013-2019,
3. Juanda Airport flight schedule,
4. *Landing distance*,
5. Existing exit taxiway distance,
6. Aircraft landing speed,
7. Turning speed and deceleration rate, and
8. The use distribution of the runway end.

D. *Data Analysis and Calculation*

Furthermore, the obtained supporting data will be analyzed. The stages can be seen as follows:

1) Forecasting Aircraft Movements

Forecasting aircraft movement was carried out to determine the number of aircraft movements in 2025, both as a whole and for each type of aircraft movement. Furthermore, forecasting aircraft movements in 2025 were used in the process of forecasting aircraft movements per type in 2025 and forecasting peak hours in 2025. The following are the stages in the process of forecasting aircraft movements.

a) Forecasting air traffic growth (demand) for the next five years

Forecasting needs to be conducted to evaluate runway performance due to forecasting of increase in the total number of aircraft movements on the runway. The data used in the forecasting process was aircraft movement data from 2013-2019. Forecasting used the ARIMA method with Minitab and SPPS assistance programs.

b) Forecasting the growth for each type of aircraft

Forecasting the growth for each type of aircraft operating in the air for the next five years. It was conducted to evaluate the movement composition of each type of aircraft in 2025. This composition was used in the simulation process. Forecasting used the Microsoft Excel program with the help of the Trendline feature.

c) Aircraft movement calculations during peak hours

Aircraft movement calculations during peak hours aimed to predict aircraft movements during peak hours in 2025. The steps for calculating aircraft movements during this peak hour can be seen as follows:

i. Peak month ratio

$$R_{month} = \frac{N_{month}}{N_{year}}$$

Description:

R_{month} = *peak month ratio*
N_{month} = the number of aircraft movements in one month
N_{year} = the number of aircraft movement in one year

ii. Peak month movement

Calculation of *peak month movement*
$= R_{month} \times$ aircraft movement in 1 year

iii. Peak day ratio

$$R_{day} = \frac{N_{day}}{N_{month}}$$

Description:

R_{day} = peak day ratio
N_{month} = the number of aircraft movements in one month
N_{day} = the number of aircraft movement in one day

iv. Peak day movement

Calculation of *peak day movement*
$=R_{day} \times$ *peak month movement*

v. Peak hour ratio

$$R_{hour} = \frac{N_{hour}}{N_{day}}$$

Table 6. Location Details of Distance and Angle of New Exit Taxiway.

Runway	Terminal	Exit Taxiway	Angle	Distance
10	T1	N1	-	-
		N2	-	-
		N3	90	1620
		N5	30	1940
		N6	30	2340
		N7	90	2860
	T2	S1	-	-
		S2	-	-
		S3	-	-
		S4	30	1800
		S5	30	2140
		S6	90	2860
28	T1	N1	90	2900
		N2	30	1920
		N3	90	1240
		N5	-	-
		N6	-	-
		N7	-	-
	T2	S5	-	-
		S4	-	-
		S3	30	1800
		S2	30	2140
		S1	90	2900

Table 7. New ROT for Each Type of Aircraft from R10 to T2.

No	Aircraft Type	From runway 10 to T2	ROT (dt)	Theoretical ROT (dt)	ROT Differences (dt)
1	A320	S4	31.06	27.38	4
2	A333	S5	34.66	27.89	7
3	ATR-72	S4	41.08	24.51	17
4	B735	S4	27.26	25.86	2
5	B738	S4	34.27	29.08	6
6	B739	S5	40.15	29.58	11
7	CRJ1000	S4	30.34	27,04	4
8	B744	S6	84.88	37.54	48

Tabel 8. New ROT for Each Type of Aircraft from R28 to T2.

No	Aircraft Type	From runway 28 to T2	ROT (dt)	Theoretical ROT (dt)	ROT Differences (dt)
1	A320	S3	34.06	30.38	4
2	A333	S2	37.66	30.89	7
3	ATR-72	S3	44.08	27.51	17
4	B735	S3	30.26	28.86	2
5	B738	S3	37.27	32.08	6
6	B739	S2	43.15	32.58	11
7	CRJ1000	S3	33.34	30.04	4
8	B744	S1	90.06	37.54	53

vi. *Peak hour movement*

$$R_{hour} \times peak\ hour\ movement$$

vii. *Operating Aircraft Composition*

Operating Aircraft Composition
= peak hour movement x aircraft movement percentage

2) *The Analysis of Field Runway Occupancy Time (ROT) Values*

ROT calculations were carried out to determine how much time it takes for the runway to facilitate current aircraft movements. In ROT calculation, what needed to be done was to calculate the landing distance, then proceed with the distribution of the use of exit taxiways. From these two processes' results, it proceeds with ROT calculation. The ROT calculation results were used in the ROT evaluation process. The stages in the ROT calculation process can be seen as follows.

a) Landing distance calculation

Landing distance calculation was required for the analysis process of the use of exit taxiways. Before being used in the analysis process of the use of exit taxiways, the landing distance needs to be corrected first. Following are the corrected exit taxiway calculation steps:

i. *Correction factor due to elevation (fe)*

The runway length was extended by 7% for each additional height of three meters from the mean sea level (msl).

$$Fe = 1 + 0{,}07\left(\frac{h}{300}\right)$$

Where :
Fe = Elevation correction factor
h = Height (m)

ii. *Correction factor due to temperature (ft)*

At higher temperatures, a longer runaway was required. It is because the air desinty level will be low at high temperatures, resulting in a low aircraft thrust output. As a high temperature standard, the temperature above sea level of 59° F = 15°C was chosen, with the following calculation:

$$Ft = 1 + 0{,}01(T - (15 - 0{,}0065\,h))$$

Where:
Ft = Temperature correction factor
h = Height (m)
T = *Aerodrome reference* temperature (°C)

iii. *Correction factor due to gradent (runaway gradient) (fg)*

The upward slope required a longer runway than a flat or descending runway. The airport planning criteria limited the runway slope to 1.5%. The slope correction factor (Fs) was 10% for every 1% slope, applicable for take-off conditions.

$$Fg = 1 + (0{,}1\,S)$$

Where :
Fg = Gradient correction factor
S = Runaway slope (%)

iv. *Landing distance after correction*

Landing distance
= Landing distance before correction x Fe x Ft x Fg

b) Distribution of the Exit Taxiway Usage

The distribution of the exit taxiway usage was obtained by plotting where the aircraft would turn by paying attention to the corrected landing distance compared to the distance of the exit taxiway from each end of the runway. It was intended with the assumption that the aircraft would turn and use the nearest exit taxiway from the end of the landing distance. This process was carried out for each direction of runway movement at both terminals.

c) Runway Occupancy Time (ROT) Calculation

Runway Occupancy Time (ROT) calculation was conducted for each direction of runway movement for both terminals. The basic concepts in the ROT calculation are as follows:

Table 9. ROT of Each Aircraft Type on R10.

Terminal	Forecast	Simulation Results I	Simulation Results I		Control
			BB	BA	
T1	I	63.62	53.04	63.62	Need
	II	48.75	39.74	48.75	Ok
T2	I	94.68	53.76	63.36	Need
	II	72.09	40.02	49.77	Ok
T1 and T2	I	92.73	53.29	63.14	Need
	II	70.60	48.21	41.03	Ok
T1	I	74.36	56.44	74.36	Need
	II	53.15	40.95	52.71	Ok
T2	I	91.98	53.06	62.00	Need
	II	72.77	40.10	50.06	Ok
T1 and T2	I	75.70	54.00	64.82	Need
	II	61.19	40.82	49.56	Ok

i. Calculating the time to touchdown deceleration in the air, a1 = 0.76 m/s2. The touchdown speed has a difference of 5 knots – 8 knots from the landing speed;

ii. Furthermore, adding 3 seconds, as the time that the wheels take to touch the runway pavement;

iii. Calculating braking time, with the deceleration on the ground a_2 = 1,52 m/s^2;

iv. Time required to turn onto the exit taxiway, t=10s.

Mathematically, ROT is formulated as follows:

$$ROT = \frac{v_{landing} - v_{touchdown}}{2a_1} + 3 + \frac{v_{touchdown} - v_{turn}}{2a_2} + t$$
$$= \frac{v_{ot} - v_{td}}{2a_1} + 3 + \frac{v_{td} - v_e}{2a_2} + 10$$
$$= \frac{v_{ot} - v_{td}}{2a_1} + \frac{v_{td} - v_e}{2a_2} + 13$$

This formula can be used if the aircraft uses the runway and turns exactly at the landing distance that has been fulfilled. However, the aircraft cannot turn directly on the ground. It needs to wait until the aircraft's turning point. Thus, the time required to use the runway increases. If this happens, the ROT calculation uses the formula below.

$$ROT = \frac{v_{ot} - v_{td}}{2a_1} + \frac{v_{td} - v_e}{2a_2} + 13 + \frac{s_{exit\ taxiway} - landing\ distace}{v_e}$$

With :

v_{ot} = landing speed
v_{td} = touchdown speed
v_e = turning speed
a_1 = deceleration in the air
a_2 = deceleration in the air

d) Runway Occupancy Time (ROT) Calculations

ROT evaluation was carried out to determine the time difference between the existing ROT and the ideal ROT. This evaluation aimed to determine which exit taxiway had the highest ROT difference. This comparison was made for each direction of runway movement for the two terminals.

3) Runway End Usage Analysis

Runway end usage analysis aimed to determine which runway is often used in aircraft operations. The thing that needed to be done in this process was to analyze the data obtained from PT. Angkasa Pura (Persero). The analysis results were used as the basis for the re-planning process of the exit taxiway.

4) Aircraft Movement Simulation

Aircraft movement simulations were conducted to determine how the runway will perform in 2025. The thing required to be done in this process was to do a simulation first. Furthermore, the simulation results were used to evaluate the exit taxiway location. The evaluation results were used as the basis for the re-planning process of the exit taxiway, followed by the ROT calculation on the new exit taxiway. The ROT calculation results were used for re-simulation. The following are the stages in the aircraft movement simulation process.

a) Aircraft Movement Simulation

The aircraft movement simulation required input from the forecasting aircraft movement process and ROT calculations results. The simulation was used to know the runway movement in 2025. The simulation results were used to evaluate the existing exit taxiway.

b) Analysis of the Existing Exit Taxiway Condition

Analysis of the existing exit taxiway condition was carried out to determine the currently existing condition. Then, analyzed the existing exit taxiway performance to know whether aircraft movements in 2025 were maximized or not.

c) Re-Planning Exit Taxiway

Exit taxiways re-planning was to get exit taxiway locations that can accommodate maximum aircraft movements in 2025. It was carried out by considering the existing exit taxiway condition. The result of re-planning exit taxiway was a new exit taxiway design.

d) New ROT calculation

The re-planning results of the new exit taxiway need to be calculated for a new ROT. This process obtained the results of the new ROT calculation and the difference in the new ROT design with the ideal ROT. In addition, this ROT calculation was used as input in the simulation II process.

e) Aircraft movement II simulation

After obtaining a new taxiway design and conducting ROT calculations in the new taxiway, it was necessary to re-simulate the aircraft movement. Re-simulation aimed to determine whether the new exit taxiway design can facilitate aircraft movements in 2025 or not.

E. Conclusions

The conclusion is in the form of evaluation results and the number of exit taxiways on optimizing runway performance at Juanda Airport.

ANALYSIS AND DISCUSSION

A. *Forecasting Aircraft Movement (Demand)*

Forecasting was carried out using a statistical program named Minitab to get the ARIMA model, which will be input into the SPSS program to get appropriate forecasting results with the needs of this forecast. Based on forecasting, it was obtained an estimated annual movement at Juanda Airport in 2025. It can be seen in Table 1.

B. *Forecasting Each Type of Aircraft Movement*

Forecasting was done by paying attention to the types of aircraft that often operate at Juanda Airport. Each type of aircraft was chosen to represent each type of aircraft. Table 2 shows the results of forecasting aircraft movement in 2025. The results of forecasting aircraft movement will be used as an aircraft composition in the aircraft movement simulation.

C. *Linear Analysis*

Aircraft movement calculation during peak hour was carried out, and the results can be seen in Table 3.

Table 3 shows the total peak hour ratio value and aircraft movement of each type. Forecasting I obtained the results of aircraft movements of 46 movements/hour, and forecasting II obtained 35 movements/hour.

D. *Travel Time and Average Time*

Runway occupancy time is the time used by aircraft in utilizing the runway. The ROT value is very influential in determining the runway capacity. At this stage, an analysis of the calculation and comparison was carried out between the actual rotation value and the theoretical ROT value. From the analysis process that has been carried out, it can be concluded as follows.

1. In the ROT value calculation from Runway 10 to Terminal 1, almost all aircraft types have an actual ROT value close to the theoretical ROT value.
2. In the ROT value calculation from Runaway 10 to Terminal 2, almost all aircraft types have an actual ROT value that is different from the theoretical ROT value. 76% of all aircraft types operating at Juanda Airport experienced an additional ROT value of more than 15 seconds. At least 20 types of aircraft that came out through the exit taxiway experienced a slowdown in ROT values of more than 30 seconds.
3. In the ROT value calculation from Runway 28 to Terminal 1, almost all aircraft types have an actual ROT value that is different from the theoretical ROT value. 50% (15 types) of all aircraft types operating at Juanda Airport experienced an additional ROT value of more than 15 seconds. Eight of them exited through N1, and four others through N3. 47% experienced an increase of less than 10 seconds.
4. In the ROT value calculation from Runway 28 to Terminal 2, almost all aircraft types have an actual ROT value that is different from the theoretical ROT value. 80% of all aircraft types operating at Juanda Airport experienced an additional ROT value of more than 15 seconds.

The biggest addition of ROT value occurs in the exit taxiway that goes to terminal 2. This is caused by the exit taxiway that goes to Terminal 2, which almost all has 90º angle, affecting the aircraft's turning speed. The biggest addition of ROT value is also influenced by the exit taxiway's location, which is further than the landing distance. Thus, it takes more time to reach the turning point.

E. *Road Capacity*

Table 4 is a distribution table for runway ends usage in 2013-2019 (in years).

Table 4 shows that the runway often used is R10, with a usage percentage reaching 82%. One of the efforts to optimize runway capacity is it needs to pay attention to the exit taxiway, which facilitates from the runway 10 direction. The intended exit taxiways are N3, N5, N6, N7 for Terminal 1, and exit taxiways S2, S3, S4, and S5 for terminal 2 of Juanda Airport.

F. *Degree of Road Saturation (DS)*

Simulations were carried out on runways 10 and 28 towards Terminal 1 (T1) and Terminal 2 (T2) twice in each exit direction. The first simulation was carried out using forecasting data I. Then, proceed with using forecasting data II. The final simulation results can be seen in Table 5.

Table 5 shows that the existing runway is currently unable to accommodate aircraft movements in 2025, with a total of 46 movements/hour. This number of aircraft movements used the forecasting I result, namely the forecasting results using data from 2013 to 2018. It shows the need for an exit taxiway design that can accommodate aircraft movements in 2015 from the directions of R10 and R28 towards T2 and T1.

On the other hand, the results of aircraft movement simulations in 2025 with the number of aircraft movements of 35 movements/hour. The number of aircraft movements used the forecasting II result, namely the forecasting result using data from 2013 to 2019. There was a decrease in aircraft movements due to rising flight ticket prices in 2019. The simulation results show that the existing runway and exit taxiway could also not accommodate the movement of aircraft moving from R10 or R28 to T2 or T1 and T2. Meanwhile, from the direction of R28, then towards R10, the runway and existing exit taxiway could still accommodate aircraft movements. It shows the need for an exit taxiway design that can accommodate aircraft movements in 2025 from directions R10 and R28 to T2 and T1.

G. *Road Density (D)*

It was given that the existing exit taxiway had a turning angle of 90º. The exit taxiway turning angle of 90º is the turning angle with the smallest turning speed, so it takes a longer turning time. Thus, it is better if the exit taxiway angle is changed with an exit taxiway that has a turning angle with a higher turning speed. Therefore, it can minimize the aircraft's time and reduce the turn speed. By considering the several things that have been mentioned, the authors plan the exit taxiway angle. It plans to use 30º for the direction coming from R10 with exit taxiway distances of 1800 m and 2140 m measured from the ends of runway R10 and R28. The new design also removes the exit taxiway S3. There is no change in the design for the exit taxiway leading to T1 because the existing exit taxiway is deemed appropriate, considering that T1 still facilitates the small aircraft movement that does not operate on T2. The conclusion for the location of the distance details and angle of the new exit taxiway can be seen in Table 6.

H. Travel Expenses

After getting the location and the new exit taxiway data, the ROT will change. The following is the ROT calculation on Runway 10 with the exit taxiway direction to Terminal 2.

The ROT calculation with the new exit taxiway design shows that all aircraft heading to terminal 2 has an actual ROT, which tends to be almost the same as the theoretical ROT value. These results indicate that the location of the exit taxiway design is appropriate for facilitating the types of aircraft that will operate at Juanda Airport in 2025. Table 8 is the ROT calculation on Runway 28 with the exit taxiway direction to Terminal 2.

The ROT calculation with the new exit taxiway design shows that all aircraft heading to terminal 2 has an actual ROT, which tends to be almost the same as the theoretical ROT value. These results indicate that the location of the exit taxiway design is appropriate for facilitating the types of aircraft that will operate at Juanda Airport in 2025.

I. Aircraft Movement Simulation Results

After redesigning, the runway accommodated aircraft movements in 2025 with 46 aircraft movements/hour. The number of aircraft movements used the forecasting I result, namely the forecasting result using data from 2013 to 2018. It shows that after redesigning, the runway cannot facilitate aircraft movements in 2025. In the simulation, it is also known that the runway can still be used if arrangements are made with a particular composition. Thus the runway can accommodate aircraft movements in 2025.

On the other hand, the results of aircraft movement simulations in 2025 with the number of aircraft movements was 35 movements/hour. The number of aircraft movements used the forecasting II result, namely the forecasting result using data from 2013 to 2019. There was a decrease in aircraft movements due to rising flight ticket prices in 2019. After re-planning the angle, location, and number of exit taxiways, the results show that the exit taxiways can accommodate aircraft movements in 2025 from directions R10 and R28 to T2 and T1.

CONCLUSIONS AND SUGGESTIONS

A. Conclusions

Based on the results of the calculation analysis in this study, several conclusions can be drawn as follows:

1. Forecasting aircraft movements using the ARIMA method. Forecasting generated aircraft movements in 2025. Forecasting was conducted twice using the Minitab and SPSS programs. Each forecast generated the conclusion as follows:
a) The first forecasting used 2013-2018 in-sample data and 2019 out-sample data. The first forecasting obtained the best ARIMA model (0,1,1) $(0,1,1)^{12}$. The error rate using 4.23% of MAPE criteria. The forecasting aircraft movement plot experienced an upward trend. Forecasting results produced comparisons by producing a more than 15% comparison ratio throughout 2019. The results of forecasting aircraft movements in 2025 were 201.774 movements.
b) The second forecasting used 2013-2019 in-sample data without out-sample data. The second forecast obtained the best ARIMA model (1,2,1) (1,0,1)12. The error rate using 4.83% of MAPE criteria. The forecasting aircraft movement plot experienced an upward trend but was less significant than the first forecasting result. Forecasting results produced more than 15% comparison ratio in March-May 2019. The results of forecasting aircraft movements in 2025 were 153.211 movements.
c) Forecasting aircraft movements for each type in 2025 found that the most operational aircraft data was the B738 type at 36.95%. In addition, it was almost the same as the A320 at 34.36%.
d) The results of forecasting aircraft movement were used to find the total peak hour ratio value and aircraft movement for each type. Forecasting I obtained the aircraft movement results were 46 movements/hour, and forecasting II obtained 35 movements/hour.
2. The current Runway Occupancy Time (ROT) calculation results are as follows:
a) ROT calculation on runway 10 to terminal 1 mathematically was 67% (20 types) of all aircraft types operating at Juanda Airport experienced an additional ROT of less than 15 seconds. There were 10 types of aircraft leaving through the exit taxiway experienced a ROT deceleration of more than 30 seconds.
b) ROT calculation on runway 10 to terminal 2 mathematically was 77% (23 types) of all aircraft types operating at Juanda Airport, experiencing an additional ROT of more than 15 seconds. At least 20 types of aircraft leaving through the exit taxiway experienced a ROT deceleration of more than 30 seconds.
c) ROT calculation on runway 28 to T1 mathematically was 50% (15 types) of all aircraft types operating at Juanda Airport experienced an additional ROT of more than 15 seconds. Eight of them left through N1, and the other four through N3. In addition, 47% experienced an additional of less than or equal to 10 seconds.
d) ROT calculation on runway 28 to terminal 2 mathematically was 80% (24 types) of all aircraft types operating at Juanda Airport, experiencing an additional ROT of more than 15 seconds.
3. The distribution of the runaway ends usage showed that the runway that tended to be used from 2013 to 2019 was runway 10, especially during the dry season (May-October). In the rainy season (November-April), especially in January and February 2014, Juanda Airport was more tend to use runway 28. Whereas

throughout 2019, the runway used was runway 10, except in January 2019. In January, the runway used was runway 28.

4. Aircraft movement simulations were carried out to determine whether the runway could facilitate the maximum movement per hour. The simulation was carried out using the concept of time-space diagrams. A simulation calculation was carried out using the percentage of aircraft composition obtained to determine whether the runway could facilitate aircraft movements in 2025. After using the time-space diagram method, it proceeded by conducting an Air Traffic Separation analysis. The results of the aircraft movement simulation showed that in 2025 the existing exit taxiway could no longer accommodate the aircraft movement operating at Juanda Airport in Surabaya, and it is necessary to re-model the exit taxiway.
5. Re-planning exit taxiway and re-analyzing with new exit taxiway planning.

a) The result of the new exit taxiway design planning was to eliminate the exit taxiway S3 and add two exit taxiways placed 1800 from each runaway end with a turning angle of 30º. Furthermore, changed the angle of exit taxiways S2 and S4 to 30º. Because it eliminates one existing exit taxiway and adds two exit taxiways, there were six exit taxiways at Juanda Airport facilitating T2. Due to the number of exit taxiways changing, the naming will also change.

b) The simulation was repeated with the existing aircraft composition with a new exit taxiway design. The results of the aircraft movement simulation show that the exit taxiway design can accommodate 35 movements/hour in 2025. For 46 movements/hour, the existing runway was unable to accommodate movement. Thus, it is necessary to add a runway to accommodate aircraft movements in 2025.

B. Suggestion.

The authors provide suggestions for further discussion.

1. For further forecasting aircraft movement, it is better to use several models. Thus, it can obtain various results and search for the alternative model to find the forecast closest to the actual.
2. Rescheduling flights so aircraft activity during peak hours can be distributed evenly and reduce activity during peak hours.
3. Adding an exit taxiway should be done gradually by adding the exit taxiway S4 first. This is because the exit taxiway S4 will facilitate a more frequently used runway.
4. Planning additional new runways to assist the existing runways in facilitating future aircraft movements.
5. Accelerating the construction process of Terminal 3, which PT. Angkasa Pura (Persero) has planned.

REFERENCES

[1] S. Devi, “Evaluasi Kinerja Runway dnegan Berbagai Sudut Exit taxiway (Studi Kasus Bandara Internasional Juanda Surabaya),” Institut Teknologi Sepuluh Nopember, Surabaya, 2004.

[2] Z. Panguriseng, “Penentuan Jumlah Exit taxiway Berdasarkan Variasi Jenis Pesawat Dan Kerapatan Jadwal Penerbangan Pada Bandara Internasional Juanda Surabaya ,” Institut Teknologi Sepuluh Nopember, Surabaya, 2010.

[3] S. R. Wilogo, “Simulasi Penentuan Jumlah Dan Komposisi Pesawat Maksimum Pada Dua Paralell Runway ,” Institut Teknologi Sepuluh Nopember, Surabaya, 2014.

[4] S. Simanjutak, “Evaluasi Desain Geometrik Fasilitas Sisi Udara dengan Memperhatikan Pergerakan Kedua Sisi Runway di Bandar Udara Internasional Surabaya,” Institut Teknologi Sepuluh Nopember, Surabaya, 2016.