The Capacity of Runway of Ngurah Rai International Airport Bali Based on The Doratask Method

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Abstract

This research aims to know the runway capacity at Ngurah Rai International Airport Denpasar Bali using the Doratask Method. Doratask Method is the method of calculating the capacity of runway adopted from the ICAO project 2009, which is also used to analyze the size of a runway in several ICAO country members in the South America Region (SAM Region). Observation, documentation, interview, and literature study are carried out to obtain the data of runway capacity at Ngurah Rai Airport Bali. The sample in this study is the data of aircraft movements for about 12 hours of flight during peak hours. Direct observation is done for seven full days on runway 09 and runway 27. The research finds the value of runway capacity at Ngurah Rai Airport Bali as many as 18 aircraft movements. The condition of Ngurah Rai Airport when the survey is done is that it can accommodate around 15 changes. It means the runway capacity at Ngurah Rai Airport Bali has been overcapacity. The use of Doratask Method to calculate runway capacity is considered most suitable to be implemented at Ngurah Rai Airport Bali because the value is close to the real condition in the field in line with the philosophy of runway capacity, that is the capability of runway to accommodate the aircraft movements for take-off and landing with no delay

Keywords: Air Transportation, Airport, Runway, Over Capacity, Doratask Method.

1. INTRODUCTION

The growing number of aircraft movements at Ngurah Rai International Airport Denpasar Bali shows significant increases based on the data during the period of 2011-2015, i.e.: in 2011 as many as 122,192; in 2012 (122,640); in 2013 (124,755); in 2014 (130,363); and in 2015 (126,769) (Perum LPPNPI Denpasar Branch, 2016). However, in the next three years, the data of aircraft movements at Ngurah Rai Airport shows significant increases to be 139,100 in 2016; 146,413 in 2017, and 162,623 in 2018. The increasing demand for flight services requires

Indonesia to assure the provided services fulfill the standards of security, safety, and efficiency. In the case of Ngurah Rai Airport Bali in 2014, there was a significant increase in demand as many as 5,608 aircraft movements compared to 2013. It becomes a significant problem of Ngurah Rai Airport at that time concerning the limited capacity of the runway. To overcome this problem, the airport authority makes some efforts to optimize the airport capacity, such as: (1) Constructing a new apron in the southern side of the airport, (2) Reducing some flights, for example Singapore Airlines reduced the frequency of its scheduled flight for the route of Singapore-Denpasar; Batik Air which previously opened the road with destination to Denpasar has no operation there at all; Jet Star replaced the aircraft type for efficiency reasons, for example replacing A320 aircraft with B787 aircraft to be able to accommodate more passengers, (3) performing inspection once in two days.

After the measures mentioned above have been taking, the result can see in 2015: a decrease in the flight traffic to be 126,769 movements or decreasing as many as 3,594 changes from 2014. The Internasional Civil Aviation Organization (ICAO), through ICAO document number 9426-AN/924, has emphasized the virtue of managing safety factors, accelerating and maintaining the regularity of aircraft movement as well as efficiently taking advantage of airspace or airport, in this case, *runway*. In line with this international flight regulation, the Government of the Republic of Indonesia via the Directorate General Civil Aviation Ministry of Transportation quickly responds to it by issuing Regulation No. SKEP/25/II/2009 dated February 13, 2009, concerning Advisory Circular 170.02 Manual of Air Traffic Services Operational Procedures, which explains in general that capacity is an uncompromised safety baseline.

Besides, Transportation Ministerial Decree No.4/2009 on CASR Part 170 Air Traffic Rules explains that air traffic flow management must be implemented to anticipate the increasing air movement (demand) and declare capacity must be determined by the Air Traffic Service (ATS) of the related unit. Furthermore, explained that the agreement must be implemented in the procedure to support the air traffic flow management and also the system to determine the capacity therein.

However, the existing condition is that there has not been any regulation containing guidance for analyzing the capacity of the runway. Some airports in Indonesia calculate the size of the track using different methods. For example, Soekarno-Hatta International Airport Jakarta uses the method issued by Federation Aviation Administration (FAA), the aviation authority of the USA as the reference and adding separation given by air traffic controller as an element of capacity calculation. Ngurah Rai Airport Bali so far uses the method established by IATA. Meanwhile, Adisucipto Airport Yogyakarta is developing a calculation of runway capacity using the Doratask method.

According to the authority of Ngurah Rai Airport, in 2016, domestic and international aircraft movements at Ngurah Rai Airport must fulfill the procedures and the flight's level of On-Time Performance (OTP), where 11% of flights still need to be evaluated due to delay. One of the factors that affect the delay is aircraft movement or traffic movement, which is very crowded at peak hours, so the aircraft which will take off or land shall queue up and be a delay.

Some problems experienced by Ngurah Rai Airport Bali include: (1) The increased demand for the use of airline services at Ngurah Rai Airport Bali from year to year for the last three years; (2) Fight delay at Ngurah Rai Airport Bali due to long queue of aircrafts which will use the *runway*

both for departure (take-off) and landing; (3) The increased aircraft movements at Ngurah Rai Airport Bali which exceed the existing capacity (overcapacity); (4) Traffic density amasses at certain hours and its not evenly distributed; (5) Unavailability of standard and uniform legal guidance as a tool aid to analyze the capacity of runway; and (6) The increased workload of traffic guide due to the increase of flight traffic.

2. LITERATURE REVIEW

2.1. Airport Capacity

According to Horonjeff, McKelvey, Sproule, and Young (2010), airport capacity is the ability to process in a service facility in a certain period. Capacity is an important measurement to know the effectiveness level of an airport. For airport planning, capacity can be defined as the number of aircraft operations in a certain period of time-related to the level of an average acceptable delay. Capacity can also be defined as the maximum number of aircraft operations that can be performed in an airport in a certain period when there is a demand for sustainable services. This demand for sustainable services means there are always aircraft ready for take-off or landing.

According to Harsha (2009), there are two ways to overcome the problem of a crowded airport, namely, by increasing the capacity of the airport and using the technique of demand management. Increasing airport capacity can be done in several ways, such as adding runways and constructing new terminals.

Airport capacity is affected by various types of aircraft in operation (mix aircraft), implemented flight rules, navigation devices utilized, and the configuration and use of runway for a landing strip. In an airport having no separated landing strip, then track with a single setting can serve only ten aircraft movements in one hour, but with a parallel taxiway for aircraft take-off and landing, the service capacity increases to become 40 movements per hour (Poole Jr, 2013).

Senguttuvan (2006) mentions five things affecting the capacity, namely air traffic management, runway system, weather, wind, and noise. Besides, there are some other indicators to be taken into account too, such as taxiway, apron, and gate (Transportation Research Board, 2012), check-in, security screening, and waiting room (Zografos, Andreatta, Eenige, & Madas, 2013), curbside dan baggage claim (Correia & Wirasinghe, 2013).

2.2. Runway Capacity

ICAO (2009a) concerning *Aerodrome* explains that runway is a piece of land used by aircraft for take-off or landing, which can be asphalt or grass. The configuration or pattern of track depends on the volume of air traffic handled, direction, duration, and wind intensity. There are many configurations of the road. They are mostly a combination of several basic settings: single track, parallel runway, intersect track and open V runway. Runway capacity means the ability of the runway to accommodate aircraft measured using a unit of many aircraft movements, which consist of departure and arrival (Norman, Saleh, & Paul, 2011). Capacity depends on the existing conditions at an airport, such as weather conditions, air traffic control, mix index, and type of operation.

According to Horonjeff et al. (2010), the factors affecting the capacity of runway include: (1)

Configuration, number, distance and orientation of the runway system; (2) Configuration, name and position of landing strip and rapid exit taxiway; (3) Composition, size, and number of gates in apron; (4) Time to utilize runway for both arriving and departing aircraft; (5) Size and mix of aircraft using those facilities; (6) Weather, especially visibility and cloud height, because the air traffic regulations for good weather are different from those of bad one; (7) The wind condition that can impede the use of all the existing runways by all aircraft; (8) The procedure of noise reduction that can limit the types and operation time of the current track; (9) with the obstacles of wind and noise reduction, the strategy chosen by controllers is operating a runway system; (10) The number of arrivals relative to the number of departures; (11) the number and percentage of touch and go; (12) The existence and frequency of turbulence which needs greater distance if a light aircraft exists behind a heavy one rather than if a heavy aircraft exists behind a light one; (13) The existence and capability of navigation tool aid; (14) The availability and structure of air space to determine the routes of departure and arrival; (15) The ability of air traffic control facility.

The most important factor affecting the capacity of the runway is the distance between the aircraft flying in sequence. This distance depends on the appropriate air traffic rules, weather conditions, and the type of aircraft.
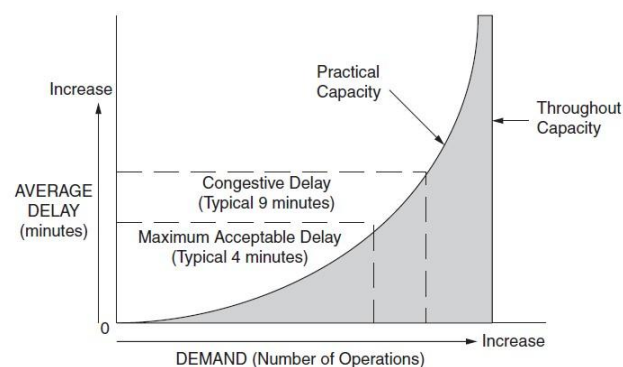

Fig 1. Practical and throughput capacity

In the airport planning, capacity can define in two ways, i.e., actual size and throughput capacity (see Fig 1). Actual capacity can describe as the number of flight operations for a specified period, which corresponds to an acceptable average level of delay. Throughput capacity is the maximum number of aircraft operations that can be done at an airport for a certain period when there is a demand for sustainable services. Such a request for sustainable services means that there are always aircraft ready to take off or land. Fig. 1 explains the direct correlation between demand, delay, and capacity. The primary relationship of those three components is that when demand approaches the capacity value of a runway, then the suspension will happen and will increase exponentially with the capacity of a track. In a condition, demand mix aircraft affects the flight speed, size, and characteristics as well as the capability of pilot to operate the aircraft. The arrangement of mix aircraft, which is increasingly diverse, will force ATC to add separations so the runway occupancy time will increase and influence the capacity value of a runway. The factors affecting delay and capacity among others, are airport characteristics, air space characteristics, air traffic control, meteorological conditions, and the characteristics of demand.

Declared capacity is the capacity per hour used to determine the availability for coordinating the slot time, usually taking around 80% - 90% of the analyzed runway capacity. Several factors affecting runway capacity are: (a) number of active runways; (b) separation used (lateral, longitudinal); (3) weather (visibility, etc.); (4) wind direction and speed; (5) type of aircraft; (6) quality and capability of Air Traffic Services system (including human factor, pilot and ATC); and (7) location of runway exit.

Runway capacity is an amount that indicates the capability of the runway to provide aircraft movement services with acceptable conditions. Runway capacity defined as a quantity that is usually displayed in the movements per hour, indicating the capability of a runway to accommodate the take-off and landing movements. There are two formulas of runway capacity calculation that have beeing developed, namely:

1. Using queuing theory. This theory has a principle of "first come first served" or "the first contact first served." This theory may be ideal to use if an airport has different runways for take-off operation and landing. For the airport which has only one track for both take-off and landing operations, the departure is calculated using Poisson distribution, whereas the landing process tends to use queuing theory. It was formulating if the schedule of departure and arrival in an airport is surely and accurately known.

2. They are using the space-time concept. This concept has a principle of safe distance, where it is impossible to serve two aircraft at the same time, either for take-off or for landing, and landing will be prioritized rather than take-off. So, the calculation used is the concept of necessary safe distance stated in traveling time. The time needed for the operation of each aircraft will calculating so that how many aircraft operations a runway can serve in a specified unit of time is known. This concept needs real-time data; calculation by not directly seeing the process in the field is almost impossible to do.

2.3. Traffic Services

Air Traffic Controller (ATC) is the service provider that controls the air traffic, mainly to prevent an aircraft from being too close to another and to avoid a collision. In principle, ATC services are delivered to make secure, smooth, well-organized, and efficient flight operations.

According to Civil Aviation and Safety Regulation (CASR) and ICAO (2009a), there are five goals of air traffic services, namely: (a) to prevent collision among aircrafts on the air, (b) to avoid the plane crash in the movement area with other obstacles, (c) maintain the regularity and smoothness of flight traffic, (d) give recommendation and information useful for flight safety and efficiency, (e) inform the agency related to the aircraft which need help from SAR (*Search and Rescue*) unit and assists that agency if required.

The services provided by the officer of air traffic controller consist of three services, namely: (1) air traffic control service, (2) flight information service, and (3) emergency services (alerting service)

2.4. Relevant Researches

Some previous researches concerning the calculation of runway capacity, among others, are as follows:

1. Wicaksana, Effendi, and Warsito (2018) states that the size of the runway and gate can

be developed as optimal, so it can help reduce the delay both on the ground and air. The runway optimization is doing by calculating the charge of using runway, taxiway and mix aircraft.

2. Kolos-Lakatos (2013) states that increase the runway capacity, the factor significantly affecting is taxiway and mix aircraft.

3. Ioannis and John-Paul (2002) state that the flight traffic density, which also causes delay, can be reduced by arranging the runway operation or Runway Operation Planning.

4. Gelhausen, Berster, and Wilken (2013) states that consumer demand for air transportation services will increase by 6%-15% in 2016. Therefore, a correct calculation of airport capacity is needed to prevent the problem that may exist due to overcapacity.

5. Bonnefoy (2008) states that traffic growth is increasing from year to year. Based on the research prediction, in the next years, the aviation system is not able anymore to adjust the need for air transportation services. The key is increasing capacity, so the demand for air transportation services can be appropriately accommodated.

6. Arca (2009) states that overcapacity happens in a specific time, and the factors affecting the capacity calculation, among others, are the ratio of demand increase, workload, and flight schedule.

7. Pitfield and Jerrard (1999) state that to increase the capacity of the runway from 80 aircraft movements per hour to 84 aircraft movements per hour, such measures as utilizing runway to the maximum and regulating the path of the aircraft which will take off and the aircraft which will land.

3. RESEARCH METHOD

Various kinds of methods can be used to analyze the capacity of the runway, such as a method of FAA (Federal Aviation Administration), Doratask, Steady-State Queuing Theory (mathematical theory), and Time-Space Concept. Up to now, there have not been regulations and manuals of calculation as the legal and uniform standard guidance in Indonesia to analyze the capacity of the runway, so the count temporarily done in the field uses different methods.

In this research, the authors will focus on the use of the Doratask method. The Doratask process is the method of calculating runway capacity adopted from the ICAO (2009b), which is also used to analyze the size of the runway in several country members of ICAO in the South America Region (SAM Region). Ngurah Rai Airport Bali, as one of the airports with high traffic density and various types of aircraft operating therein, needs the most appropriate method to calculate the capacity of the runway.

This research takes place at Ngurah Rai International Airport Denpasar Bali Indonesia and in the head office of Indonesian Air Navigation. The survey is doing in six months, from May to October 2016. As an illustration, Ngurah Rai Airport Bali now (at the time the survey was performed in 2016) serves around 70 aircraft movement per day with 22 routes of domestic flights and 28 routes of international flights. Ngurah Rai Airport Bali also serves some unscheduled flights such as tour flights, medical evacuations, and military flights.

Various airline companies opening flight from and to Bali consist of 12 domestic airlines, 21

international airlines, and 23 local and international airlines with no flight schedule. Today the flight traffic at Ngurah Rai Airport serves flight with various types of the airport, starting from fixed-wing aircrafts category A to D and rotary-wing aircraft.

Ngurah Rai Airport Bali has a single runway with a length of 3000 m and the end of the track directly adjacent to the beach. There are seven taxiways available, and seven apron taxiways with 38 parking stand for commercial flights, one apron for military aviation, and a helipad for rotary-wing aircraft.

The population of this research is the data of runway operation for about two weeks of flight. The sample of this research is data of aircraft movements for about 12 hours of flying at peak hours. The peak hours used are daily peak hours. Data collecting is done through observation, documentation, interview, and literature study to obtain the data of the runway capacity of Ngurah Rai Airport Bali. Data collecting in the Doratask method is done to receive the following data:

1. Runway Occupation Time Takeoff

Survey data of Runway Occupancy Time Take-Off, where the calculation is done when the aircraft enter the runway up to cleared track; the recording is in second.

2. Runway Occupation Time Landing

Survey data of Runway Occupancy Time Landing, where the calculation is done when the aircraft passes through the threshold and exits from the runway (evacuate runway); the recording is also in second.

3. Flight time between Outer Marker and Threshold

Data collection survey to obtain the flight time between outer marker and threshold is done at the Approach Control unit, wherefrom the monitor screen of the identified aircraft, we can record the time needed by each aircraft to fly passing through the outer Marker until the threshold runway. Besides, interview with some guiding officers concerning the average time usually required by each aircraft is also done.

3.1. Runway Physical Capacity Calculation

The calculation of runway capacity using Doratask Method is done in three phases through 16 steps, namely:

Step 1. Collecting the data on Runway Occupancy Time (ROT) when take-off and landing. The column "Remarks" can be filled in with additional information on the taxiway used or how long the preparation by pilot takes time when he has got permission from the ATC officer to take off. The data is obtained from the survey on aircraft movement at the Aerodrome ATS unit or control tower.

Step 2. Calculating the average arithmetical time of ROT based on aircraft category (*Arithmetical Mean Runway Occupancy Time/AMROT*).

$$\text{MROTL} = \frac{\sum ROTL_{CATX}}{n\,ACFT_{CATX}} \qquad \text{MROTT} = \frac{\sum ROTT_{CATX}}{n\,ACFT_{CATX}} \qquad \begin{aligned} &AMROT \\ &= \frac{MROTL_{CATX} + MROTL_{CATX}}{2} \end{aligned}$$

Step 3. Data of aircraft movement for one week can be used to calculate the percentage

of runway usage based on aircraft category.

$$MIX = \frac{\sum \%ACFT_{CATX}}{n\ Days}$$

Step 4. Valuing the Runway Occupancy Times of each aircraft category (step 2) and then multiplying with Mix Index of each aircraft category (step 3) and put in the equation 4.4 so that the mean Runway Occupancy Time (MROT) will be obtained.

$$MROT = \frac{\sum (AMROT_{CATX} \times MIX_{CATX})}{100}$$

Step 5. Calculating the Physical Capacity of Runway (PCR) for one hour, which is converted to second, then calculating with the following equation:

$$PCR = \frac{3600}{MROT}$$

Step 6. Data on aircraft movement for one year is needed to calculate the Aerodrome Physical Capacity (APC). The weighing percentage is calculated on each runway, although at the end of the calculation, it will be analyzed to become one value of track.

$$APC = \frac{\sum (PCR_{RWYX} \times \%UP_{RWYZ})}{100}$$

3.2. *Theoretical Runway Capacity Calculation*

Theoretical Runway Capacity Calculation is done in the range of 60 minutes (3600 seconds) based on the average runway occupancy time, which is added with the prevailing separation of safe distance at the ATS unit of Ngurah Rai Airport. The separation of safe distance is surely based on the provisions of traffic services and standard local procedures. It can be observed in the services provided by the officers wherewith the proper traffic planning, and the runway capacity can be utilized maximally.

The average runway occupancy times, aircraft mix, percentage of runway utilization, as obtained in Step 1 to 6, will be used to calculate Theoretical Runway Capacity Calculation.

Step 7. Collecting data and calculating the average flight time of each aircraft category between the outer marker and Threshold (Mean Flight Time/MT). Recording starts when the aircraft passes through the Outer Marker until passing through the threshold. If there is no Outer Marker, the calculation can begin when the aircraft starts final approach segment until passing through a limit or a reference point when the aircraft performs final approach where the end makes impossible for the aircraft going to take-off to enter the runway when the aircraft going to the land passes that point.

Step 8. Calculating the speed of the aircraft approach between the Outer marker and threshold (AV). The data obtained in Step 7 is used to calculate the average time for each aircraft category to pass through the outer marker until the limit in each runway.

Step 9. Calculating the average speed of aircraft approach between OM dan THR (Mean speed in the final approach/MV).

$$MV = \frac{(MIX_A \times AV_A) + (MIX_B \times AV_B) + \cdots (MIX_E \times AV_e)}{100}$$

Step 10. Determining the safe distance (Safety separation/SS). *Safety separation* is a safe distance to permit one aircraft to take-off between 2 consecutive landings without breaking safe separation distance.

$$SS = MV \times MROT$$

Step 11. Determining the total safe distance between 2 successive arrivals (complete separation between 2 consecutive landings/TS). The value is obtained from the calculation of safe distance plus aircraft safe distance when the first aircraft on the runway starts rolling for take-off, and the second aircraft is on the comprehensive final approach at the airport.

$$TS = SS \times RSM$$

Step 12. Calculating the time between 2 consecutive landings (weighted time between 2 vertical landings/MTTS). It is done to calculate the total separation between 2 successive arrivals which is obtained from dividing the total safe distance (Step 11) with the average speed of each aircraft category and is calculated for every threshold on each runway.

$$MTTS = \frac{TS}{MV}$$

Step 13. Determining the number of aircraft that can land in one hour *(Number of Landings in a One-hour Interval/P)*. The result obtained in Step 12 is used as the divider to calculate how many aircraft are possible to land if the safe separation time needed is as obtained.

$$P = \frac{3600}{MTTS}$$

Step 14. Determining the number of aircraft that can take off in one hour (Number of take-offs in a one-hour interval/D). Based on the total separation time obtained, it is possible for one aircraft to take-off between 2 consecutive landings by taking time between the two aircraft landings. Then from the number of landing aircraft, the number of aircraft that can take-off between those aircraft landings can be obtained through the equation:

$$D = P - 1$$

Step 15. Determining the *Theoretical Runway Capacity* (TRC).

$$TRC = D + P$$

3.3. Runway Declared Capacity Calculation

The percentage of runway utilization, as in Step 6, is accumulated with the value of theoretical runway capacity and used to calculate the declared capacity.

Step 16. The total *Declared Capacity of Runway* (DCR) is the value of full capacity based on the percentage of utilization of each runway, which is operationally correct.

$$DCR \frac{(UP_A \times TRC_A) + (UP_B \times TRC_B) + \cdots (UP_E \times TRC_E)}{UP_A + UP_B + \cdots UP_E}$$

The citation in Doc. 9426 explains that the ATS unit cannot operate with maximum capacity because, in a specific time, there will be several variables that can reduce the ability, so it is recommended to take the value between 80% and 90% of the total declared capacity. It gives them more flexible capacity value and within the ideal interval for the safety of flight operation.

4. RESULTS AND DISCUSSION

4.1. Results

With the condition of flight traffic at Ngurah Rai Airport Bali at the time of analysis using Doratask Method it is obtained as follows:

Step 1. Collecting data, a survey on Runway Occupancy Time Take-Offs and Landings.

Step 2. Calculating the average Runway Occupancy Time *(Arithmetical Mean Runway Occupancy Time)* of each aircraft category as in Table 1.

Tab. 1. Arithmetical Mean Runway Occupancy Time (AMROT)

CAT	AMROTT		AMROTL		AMROTTT	
	RWY 09	RWY 27	RWY 09	RWY 27	RWY 09	RWY 27
A	67,5	172	41	0	54,25	86
B	121,182	121,227	67,679	73,333	94,431	97,28
C	114,302	119,365	71,833	74,275	93,068	96,82
D	127,027	111,575	69,175	80,058	98,101	95,817
Total	430,011	524,167	249,687	227,666	339,849	375,917

Step 3. Calculating mix index runway 09 and 27, the detail is summarized in Table 2.

Tab. 2. Mix Index Runway 09 and 27

Cat	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7	Mix
	acft	acft	acft	acft	acft	acft	Acft	(%)
A	1	0	0	1	1	0	1	1%
B	15	9	13	15	14	14	9	17%
C	43	35	35	34	25	37	27	46%
D	19	29	28	24	36	19	33	36%
Total	78	73	76	74	76	70	70	100%

Step 4. Calculating the average *Runway Occupancy Time (Mean Runway Occupancy Time/MROT)* of each runway, as explained in Table 3 and Table 4.

Tab. 3. Mean Runway Occupancy Time Runway 09

AMROT			MIX			MROT
Cat	Time (sec)		Cat	Aircraft (%)		(sec)
A	54,25	×	A	1%	=	0,42
B	94,431		B	17%		16,256
C	93,068		C	46%		42,483
D	98,101		D	36%		35,673

∑ Time (sec) = 94,832

Tab. 4. Mean Runway Occupancy Time Runway 27

AMROT			MIX			MROT
Cat	Time (sec)		Cat	Aircraft (%)		(sec)
A	86	×	A	1%	=	0,665
B	97,28		B	17%		16,746
C	96,82		C	46%		44,196
D	95,817		D	36%		34,842

∑ Time(sec) = 96,451

Step 5. Calculating the Physical Capacity Runway (PCR)

Runway 09

$$PCR = \frac{3600}{MROT} = \frac{3600}{94,832} = 37,962$$

Runway 27

$$PCR = \frac{3600}{MROT} = \frac{3600}{96,451} = 37,325$$

Step 6. Calculating Aerodrome Physical Capacity (APC) and the percentage of runway utilization.

Tab. 5. Runway Utilization Percentage (UP)

Month	09	27	Monthly Movement
August	4820	5775	10595
September	11064	144	11208
October	10765	61	10826
November	10259	409	10668
December	11501	6	11507
January	10030	777	10807
February	8664	2211	10875

March	7521	2962	10483
April	1536	9744	11280
May	199	10450	10649
June	2418	7299	9717
July	4004	5965	9969
Total	82781	45803	128584
% Utilization (UP)	**64%**	**36%**	

RWY	PCR		% Utilization (UP)	
		×		
9	37,962		64	2429,568
27	37,325		36	502,68

APC = 37,73

Step 7. Calculating the flight time of each aircraft category from *Outer-Marker* passing through Threshold (*Flight Time*) as in Table 6.

Tab. 6. Flight Time from OM to THR

CAT	RWY 09 (5 NM)		RWY 27 (5 NM)	
A	127	2,1	0	0
B	137,75	2,29	148	2,46
C	123,786	2	124,08	2
D	126,5	2,1	129,091	2.1

Step 8. Calculating the average flight time from *Outer–Marker* passing through *Threshold* (AV) as seen in Table 7.

Tab. 7. Mean Flight Time between OM and THR (AV)

CAT	RWY 09		RWY 27	
	Speed (kts)	Speed (nm/sec)	Speed (kts)	Speed (nm/sec)
A	141,732	0,039	0	0
B	130,672	0,036	121,622	0,034
C	145,412	0,040	145,068	0,040
D	142,292	0,040	139,437	0,039

Step 9. Calculating the average speed at the *final approach (MV)* on runway 09 and runway 27.

$$MV = \frac{(MIX_a \times AVA) + (MIX_b \times AVB) + (MIX_c \times AVC) + (MIX_d \times AVD)}{100}$$

Table 8. *Mean Speed in the Final Approach* (MV)

RWY	MV			
09	0,039	nm/s	141,712	kt
27	0,038	nm/s	137,861	kt

Step 10.   Determining the *safety separation* (SS) as follows:

Runway 09

$$SS = MV \times MROT = 0{,}039 \times 94{,}832 = 3{,}733 \text{ nm}$$

Runway 27

$$SS = MV \times MROT = 0{,}038 \times 94{,}451 = 3{,}694 \text{ nm}$$

Step 11.   Determining the total separation distance between 2 consecutive landings (TS) as follows:

Runway 09

$$TS = SS \times RSM = 3{,}733 + 8 = 11{,}733 \text{ nm}$$

Runway 27

$$TS = SS \times RSM = 3{,}694 + 8 = 11{,}694 \text{ nm}$$

Step 12.   Calculating the average separation time between 2 consecutive landings (*Mean Total Consecutive Landing Separation/MTTS*)

Runway 09

$$MTTS = \frac{TS}{MV} = \frac{11{,}733}{0{,}039} = 298{,}062 \ s$$

Runway 27

$$MTTS = \frac{TS}{MV} = \frac{11{,}694}{0{,}038} = 305{,}356 \ s$$

Step 13.   Calculating the number of aircraft that can land in 1 hour (P), as follows:

Runway 09

$$P = \frac{3600}{MTTS} = \frac{3600}{298{,}062} = 12{,}078 = 12 \text{ aircraft movement}$$

Runway 27

$$P = \frac{3600}{MTTS} = \frac{3600}{305{,}356} = 11{,}790 = 11 \text{ aircraft movement}$$

Step 14.   Calculating the number of aircraft that can take off in 1 hour as

follows:

Runway 09

D = P – 1 = 12 – 1 = 11 aircraft movements

Runway 27

D = P – 1 = 11 – 1 = 10 aircraft movements

Step 15.   Calculating *Theoretical Runway Capacity* (TRC)

Runway 09

TRC = P + D = 12 + 11 = 23 aircraft movements

Runway 27

TRC = P + D = 11 + 10 = 21 aircraft movements

Step 16.   Calculating the *Declared Runway Capacity* (DCR)

$$DRC = \frac{(23 \times 64) + (21 \times 36)}{(64 + 36)} = 22{,}951 = 22$$

Based on doc. 9426, 80% x 22 = 18

4.2.   *Discussion*

The analysis using the Doratask method is performing through a direct observation for seven days. The first observation is performed at the *Approach Control Unit* to know the value of aircraft *flight time* from the *outer marker/final approach segment* until a *threshold,* and the treatment applied to both runways, namely runway 09 and runway 27. The distance between the *Final Approach Segment* and *Threshold* is 5 NM for both runways.

The second observation is performed at the *Aerodrome Control Tower* unit to obtain the data of the value of *Runway Occupancy Time (ROT)* on both runway 09 and runway 27. The factors taken into account in this analysis using the Doratask method are *aircraft mix*, average *runway occupancy time*, and separation used by the controller. The calculation is aim at knowing the acceptable capacity by Ngurah Rai Airport Bali now following the Doratask method and what factors significantly affecting the increase and decrease of capacity, primarily if implemented at Ngurah Rai Airport Bali.

Based on the result of this analysis, it can be known that the capacity value of a single runway at Ngurah Rai Airport Bali now is: 23 aircraft movements on runway 09 in the condition of IFR and VFR, 21 aircraft movements on runway 27 in the situation of IFR and VFR.

To determine the declared capacity, the lowest calculated capacity of both runways is taken. It is done considering safety factors following Doc. 9426 Air Traffic Service Planning Manual. Thus, the capacity of runway 09 and runway 27 at Ngurah Rai Airport Bali according to the Doratask method, is 18 movements. The value is obtained by considering several things as follows:

1. In the existing analysis of traffic conditions, the percentage of aircraft in category A is 1%, in category B 17%, in category C 46%, and in category D 36% taken into account in

the calculation of Mix Index percentage.

2.   The separation used by the controller, following Standard Operational Procedures (SOP) at Ngurah Rai Airport Bali, is 8 nm.

3.   There is no separated calculation for each runway. In this case, the weather conditions, both visual and instrument, do not affect the quantity of the calculated value.

4.   The utilization value of runway 09 is more prominent than of runway 27. It indicates that the utilization of runway 09 tends to be more frequent than that of runway 27.

5.   All the data used to calculate the capacity using the Doratask method is obtained through direct observation.

Tab 9. Results of Analysis Using Doratask Method

	Mix Index	Runway Occupancy Time (ROT)	Utilization Percentage (UP)	Landing Capacity	Take-off Capacity	TRC	80%
09 IFR and VFR	A = 1% B = 17%	93,832	64%	12	11	23	
27 IFR and VFR	C = 46% D = 36%	96,451	36%	11	10	21	18%

Tab. 10. Results of Analysis Using Doratask Method

	Mix Index	Runway Occupancy Time (ROT)	Utilization Percentage (UP)	Landing Capacity	Take-off Capacity	TRC	80%
09 IFR and VFR	A = 1% B = 17%	93,832	64%	12	11	23	
27 IFR and VFR	C = 46% D = 36%	96,451	36%	11	10	21	18%

Tab 11. Results of Analysis Using Doratask Method

Time	Number of Movements	Doratask Method
06.01-07.00	26	overcapacity
07.01-08.00	19	overcapacity
08.01-09.00	32	overcapacity
09.01-10.00	20	overcapacity
10.01-11.00	23	overcapacity

11.01-12.00	24	overcapacity
12.01-13.00	20	overcapacity
13.01-14 00	22	over capacity
14.01-15.00	11	in capacity
15.01-16.00	21	overcapacity
16.01-17.00	12	in capacity
17.01-18.00	13	in capacity
18.01-19.00	6	in capacity
19.01-20.00	0	in capacity
21.01-22.00	0	in capacity
22.01-23.00	3	incapacity
23.01-00.00	23	overcapacity
00.01-01.00	14	in capacity
01.01.02.00	23	overcapacity
02.01-03.00	25	overcapacity
03.01-04.00	24	overcapacity
04.01-05.00	19	in capacity
05.01-06.00	26	overcapacity

In the calculation using the Doratask Method with that number of movements, the aircraft movement has exceeded the runway capacity at Ngurah Rai Airport Bali. Based on the field data, the analysis results, and the theoretical basics as explained before, the utilization of single runway—not parallel runway—and apron taxiway, Ngurah Rai Airport now can only accommodate around 15 movements per hour. Based on the calculation and the theory, the result is close to the real condition at Ngurah Rai Airport Bali. Analysis using Doratask Method shows that the capacity of the runway at Ngurah Rai Airport Bali has been overcapacity.

Several essential things related to runway capacity that need to be paid attention are the addition and reduction of total aircraft movements at certain hours. This is due to the existence of unscheduled extra flight, a commercial flight that breaks its schedule thus entering the slot for next flight, military aircraft, tourist aircraft with an unclear timing of departure

5. CONCLUSION

Based on the results of research and discussion, the following conclusions can be made:

1. The value of runway capacity at Ngurah Rai Airport Bali analyzed by using Doratask Method is as many as 18 aircraft movements

2. The use of Doratask Method to calculate runway capacity is considered most suitable to be implemented at Ngurah Rai Airport Bali because the value is close to the real condition in the field in line with the philosophy of runway capacity, that is the capability of runway to accommodate the aircraft movements for take-off and landing with no delay

3. Increasing the size of Ngurah Rai Airport Bali can be done through developing the

existing facilities, constructing new facilities, improving demand management or administration, building further coordination with all parties, as well as considering the aspects of social, economy, culture and flight safety.

4.   We recommended for the government, in this case, the Ministry of Transportation as the regulator, to make legal reference concerning the method and parameter to be used for increasing the capacity of both landside and airside.

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