

Evaluation and Projection of Airport Landing Movement Areas based on Statistical Analyses, ICAO 2013 Manuals and KM 44, 2002 Regulation

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Abstract

This article demonstrated how to calculate an airport landing movement in systematic five main stages encompassing; (i) data collection (including passengers data, aircraft movements, population, GDP, per capita income, cargos movement, temperatures, ground elevation, slope surface, wind speed, and aircraft characteristics), (ii) forecasting the future traffic demands, (iii) calculating aerodrome reference field length (ARFL), (iv) define aerodrome reference code (ARF), and (v) calculate runway dimensions, taxiways, and apron areas. This article has selected Hang Nadim International Airport (HIA) as a case study. It was identified that the aircraft movements in this airport have increased by an average of 7.30% every year in the periods of 2007 to 2016. This Airport has an existing apron with a capacity of 13 aircraft, while the apron currently has to accommodate 19 aircraft. Therefore, to anticipate future demand. This research evaluated and forecasted the requirements standard for the airport landing movement areas in 2026. Based on the International Civil Aviation Organization (ICAO) 2013 manuals and KM 44, 2002 regulation concerning the National Airport Regulation. This article recommended that the existing runway and taxiways would be adequate to facilitate future aircraft movements up to 2026. However, the apron requires to be expanded to 1,600 m x 150 m (which a capacity of 31 aircraft) for accommodating the apron requirements standard in 2026.

Keywords: airport, landing movements, runway, taxiways, apron, ICAO

1. Introduction

It was acknowledged that the constant growth in the air traffic movements in the airport in Indonesia over the past decade has increased the requirement for the development of the airport facilities and infrastructures [1]. It was identified that there were 7 airports which accounted for the highest cargo loads in Indonesia such as; Soekarno-Hatta International Airport, Sultan Hasanuddin International Airport, Kuala Namu

International Airport, Hang Nadim International Airport, Juanda International Airport, Sentani Airport, and Sultan Aji Muhammad Sulaiman Airport [1]. In fact, from 2007 to 2016 the Hang Nadim International aircraft movements increased by an average of 7.30% every year [2].

The capacity of an airport depends on the capacities of its landside and airside components in accommodating passenger movements, cargo and aircraft takeoff, and airport landing movements [3]. Based on Laplacea, et al. (2016),

the population growth, GDP, and the fluctuation of the per capita incomes in a specific region may affect airport traffic movements [4].

An airport configuration may encompass various landing movement facilities such as runway, taxiway, and apron [5]. A runway is a rectangular area on the airport surface that is prepared to accommodate the takeoff and landing of aircraft. Taxiways are defined paths on the airfield surface which are established for the taxiing of aircraft. Taxiways are also intended to provide a linkage between one part of the airfield to another one. The apron is defined as an area for facilitating the aircraft to park, to check its instrument and engine prior to takeoff [5, 6, 7].

Hang Nadim International Airport is located in Batam City, Indonesia. In 2016, the Hang Nadim Airport has a single runway (with the existing dimensions of 4015 m x 45 m), 2 exit taxiways (150m x 23 m), and 2 rapid exit taxiways (300m x 23m). The existing apron has dimensions of 690.5 m x 76.8 m and 240 m x 150 m with the capacity of 13 aircraft. The largest type of operating aircraft that can be operated on this runway and apron were Boeing 737-900. It was projected that the apron of this airport may accommodate 19 aircraft in 2020 [2]. Therefore, the existing apron is in a need to be expanded.

2. Materials and Methods

The Hang Nadim International Airport (coordinates of 01 '07 '15 "NL and 04°06'50" EL) is located in Batam City, Kepulauan Riau Province, Indonesia. The location of this airport is ± 7 km from the downtown of Batam City (Figure 1).



Figure 1. Hang Nadim International Airport (HIA)

This article calculated airport landing movement areas in the five main stages such as; (i) collecting data (previous passengers' data, aircraft movements, population, GDP, per capita income, cargo, temperatures, elevation, gradient, wind speed, and aircraft characteristics), (ii) forecasting the future traffic demands, (iii) calculate aerodrome reference field length (ARFL), (iv) defines aerodrome reference code (ARF), and (v) calculate runway dimensions, taxiways, and apron areas. This article has chosen a Hang Nadim International Airport (HIA) as a case study as this airport is considered one of the largest airports in Sumatra Island.

2.1 Forecasting

Forecasting is a process of predicting future events [8,9]. In the planning and decision-making processes, the prediction of future events is very crucial in making logical and rational decisions [10,11,12]. Therefore, forecasting is essential for making the appropriate decision in the development of airport landing movement areas. Prior to forecast airport landing movement areas (encompassing runway, taxiways, and apron) some of the following data such as passengers' data, aircraft movements, population, GDP, per capita income, and cargo should be obtained (Table 1).

Table 1. Data of Hang Nadim Int. Airport and Batam City

Years	Passenger (people)	Aircraft Movements (unit)	Population (people)	GDP (Rp)	Percapita Income (Rp)	Cargo (Kg)	Aircraft in Peak Hours (unit)
2007	2.835.662	27.367	695.739	47.297.634,49	34.556.694,01	22.961.924,00	9
2008	2.682.181	25.823	824.964	52.624.417,00	36.836.279,69	24.535.161,00	9
2009	2.910.554	25.380	885.503	57.645.949,75	40.588.181,66	22.584.306,00	9
2010	3.358.369	26.089	954.450	63.640.191,41	42.379.608,73	24.693.029,92	9
2011	3.385.628	27.414	1.000.661	74.181.300,30	44.171.035,79	25.831.274,00	10
2012	3.918.427	32.838	1.047.534	83.751.112,92	46.266.613,81	31.296.794,21	12
2013	4.361.504	37.367	1.094.623	96.661.045,01	49.548.888,22	32.547.984,59	14
2014	4.944.291	41.554	1.141.816	107.219.525,72	52.588.078,64	29.778.905,00	16
2015	5.199.019	43.184	1.188.985	121.168.686,28	55.034.822,60	36.265.619,00	17
2016	6.299.699	50.290	1.236.399	130.734.768,94	59.892.929,89	40.360.336,00	20

The passengers and aircraft movement in 2026 is projected with the multi-linear and linear regression approaches. It was identified that in 10 years the number of passengers increased 300 times, aircraft movements increased by 200% as well as cargo one. The number of aircraft in peak hours have been also increased by 200%.

2.1.1 Linear Regression

Linear regression analysis is one of the most commonly used statistical methods for modeling cross-section data [10, 11]. In regression

modeling, there are two kinds of variables, dependent variable (variables that are influenced or value depend on other variables) and independent variable (which is suspected to affect the dependent variable) [10, 11]. The linear regression is formulated as follows:

$$Y = A + BX \tag{1}$$

Where:

Y = dependent variable

A = constant (the intersection of the curve to the Y axis)

B = regression coefficient

X = independent variable

2.1.2 Multi-linear regression

Regression models with one dependent variable and more than one independent variable are called multilinear regression [10-12]. Multilinear regression is formulated as follows:

$$Y = A + B_1X_1 + B_2X_2 + \dots + B_ZX_Z \tag{2}$$

Where:

Y = dependent variable

X_i ... X_Z = independent variable

A = constant

B_i ... B_Z = regression coefficient

2.2 Airport Configurations for Landing Movement Area

The airport configurations for landing movement areas have an important role in the airport operation and maintenance purposes. These landing movements may encompass 2 major elements such as airport airside and airport landside areas. Both areas have been designed based on the operating characteristics of the operating aircraft. On the airside, the representative aircraft will determine the runway of taxiways [6,7,12,13,14]. The regulations applied for evaluation and design of runway and taxiways utilized the International Civil Aviation Organization (ICAO) 2013 manuals and KM 44, 2002 regulation concerning the National Airport Regulation.

2.2.1 Runway

A runway was designed based on the operating aircraft standards which normally utilized the longest Aeroplane Reference Field Length (ARFL). The length of the minimum runway is affected by the local conditions of the airport, such as temperature, elevation, and slope.

$$Lro = ARFL \times Ft \times Fe \times Fs \tag{3}$$

Where:

Lro = corrected Runway Length (m)

Ft = temperature correction factor

Fe = elevation correction factor

Fs = slope correction factor

2.2.2 Taxiway

The major function of taxiways is to provide landside access for aircraft to travel from the runways to other areas of the airport such as from runways to the apron, runway to another runway, etc. The widths of taxiways are designed according to the type of the operated aircraft. Specifically the wingspan of the designated aircraft [7,12,13,14].

2.2.3 Apron

An apron area will accommodate several aircraft to a board and un-board depends on the aircraft types during peak hours [7]. The planning of the apron depends on the wingspan and the length of each type of aircraft referring to ICAO Annex 14, 2013[7, 15].

3. Results and Discussions

The results will be discussed in 3 subsections, such as forecasting results, evaluation, and projection of the movement area, and pavement

3.1 Forecasting results

The forecasting result is shown in the table below:

Table 2. Forecasting result of Hang Nadim International Airport and Batam City

Years	Passenger (people)	Aircraft Movements (unit)	Population (people)	GDP (Rp)	Percapita Income (Rp)	Cargo (Kg)	Aircrafts in Peak Hours (unit)
2017	6.073.036	48.663	1312503	136.400.608	60.820.273	39.346.342	20
2018	6.451.855	51.378	1368036	146.020.270	63.480.993	41.212.557	21
2019	6.830.674	54.093	1423570	155.639.933	66.141.713	43.078.772	22
2020	7.209.493	56.807	1479103	165.259.596	68.802.433	44.944.986	24
2021	7.588.311	59.522	1534637	174.879.259	71.463.153	46.811.201	25
2022	7.967.130	62.237	1590171	184.498.921	74.123.874	48.677.416	26
2023	8.345.949	64.952	1645704	194.118.584	76.784.594	50.543.630	27
2024	8.724.767	67.667	1701238	203.738.247	79.445.314	52.409.844	29
2025	9.103.586	70.382	1756771	213.357.909	82.106.034	54.276.059	30
2026	9.482.405	73.097	1812305	222.977.572	84.766.754	56.142.273	31

The increase in the number of passengers and aircraft movements by 150% to 200% in 10 years period (2017-2026) indicated that the existing air-side facilities require to be developed. It was forecasted that in 2026 there would be more than 9.48 million passengers utilized this airport, with 73 thousand aircrafts movement, 56 tons of cargo, and 31 aircraft will park in apron per hour. Hence, at the average 150% increase in traffic demand and the number of aircraft in peak hours in 10 years (2017-2026). Thus, there would be necessary to calculate the future requirement of runway, taxiways, and apron to meet the increase of the traffic demand within this airport

3.2 Movement Area

Movement area is the part of an aerodrome to be used for the take-off, landing, and taxiing of aircraft, consisting of the maneuvering areas (runway and taxiways), and the apron [7,15]. The characteristics of the operating aircraft within Hang Nadim International Airport are shown in the table 3.

Table 3. The characteristics of operating aircraft at Hang Nadim International Airport

Number	Type of Aircraft	REF CODE	Characteristics			
			ARFL (m)	Wingspan (m)	OMGWS (m)	Length (m)
1	A 320	3C	2090	34,1	8,70	37,6
2	ATR 725	3C	1220	27,0	4,78	27,2
3	B 737-200	4C	1990	28,4	5,91	30,53
4	B 737-300	4C	1940	28,9	5,91	33,4
5	B 737-500	4C	1830	28,9	6,40	31
6	B 737-800	4C	2256	34,3	6,40	39,5
7	B 737-900	4C	2240	34,3	6,40	42,1
8	B 737-900 ER	4C	2240	34,3	6,40	42,1
9	CRJ-1000 ER	4C	2079	26,2	5,25	39,1

3.2.1 Runway

The analysis of the runway is performed based on two types of aircraft. First, the operating aircraft which has the longest airplane reference field length (ARFL), namely B 737 – 800 (2256 m). Second, B 747 – 300, the largest aircraft operated in 2026 with ARFL of 3320 m (future planning). Based on the existing local conditions, it was identified that the calculation result of corrected Runway Length, was as follow:

elevation correction factor (Fe) = 1,0091;
 temperature correction factor (Ft) = 1,153;
 slope correction factor (Fs) = 1,004.

1. For B 737-800, it was calculated that Lro =
 $Lro = ARFL \times Fe \times Ft \times Fs$
 $= 2256 \times 1,009 \times 1,153 \times 1,004$
 $= 2636 \text{ m}$

2. For B 747-300, it was calculated that Lro =
 $Lro = ARFL \times Fe \times Ft \times Fs$
 $= 3320 \times 1,009 \times 1,153 \times 1,004 = 3878 \text{ m}$

The existing runway of Hang Nadim Airport is 4025 m (>3878 m). Therefore, the existing runway is no need to be expanded until 2026.

The aim of this aerodrome reference code (ARC) is as a simple method for interrelating the number of aerodrome specifications to its requirement facilities suitable to accommodate the operated airplanes. The ARC contains 3 main elements such as; code number, code element 1 (the airplane performance characteristics (ARFL), and code element 2 (dimensions of wingspan and outer main wheel gear).

Table 4. Aerodrome Reference Code (ARC)

Code number (1)	Code element 1		Code element 2	
	Aeroplane reference field length (2)	Code letter (3)	Wing span (4)	Outer main gear wheel span ^a (5)
1	Less than 800 m	A	Up to but not including 15 m	Up to but not including 4.5 m
2	800 m up to but not including 1 200 m	B	15 m up to but not including 24 m	4.5 m up to but not including 6 m
3	1 200 m up to but not including 1 800 m	C	24 m up to but not including 36 m	6 m up to but not including 9 m
4	1 800 m and over	D	36 m up to but not including 52 m	9 m up to but not including 14 m
		E	52 m up to but not including 65 m	9 m up to but not including 14 m
		F	65 m up to but not including 80 m	14 m up to but not including 16 m

a. Distance between the outside edges of the main gear wheels.

Based on table 4 the type of this Hang Nadim Airport runway is 4 E as the runway length > 1800 m and B 747 – 300, wingspan = 59,6 m (wingspan <65), .and length = 56,30 m

3.2.2 Taxiway

Based on Annex 14 2013, the evaluation of the existing taxiway is no need to be expanded until 2026. The existing taxiways are 2 exit taxiways with dimensions of 150 m x 23 m and 2 rapid exit taxiways with dimensions of 300 m x 23 m. The following table was the taxiway’s dimensions as on Table 5 below.

Table 5. Dimensions of taxiway

Code	Classification	Width of taxiway (m)
A	I	7,5
B	II	10,5
C	III	15 ^a
		18 ^b
D	IV	18 ^c
		23 ^d
E	VI	23
F	VI	25

As the taxiways and runway are no need to be expanded, the current condition of these landing movements is no need to be re-designed up to 2026.

3.2.3 Apron

The existing Hang Nadim Airport has an apron area with the capacities for accommodating 13 aircrafts such as B747-SP, B737-900, dan F27. In fact, in 2016 (when this research was conducted), the apron has to be able to accommodate 19 aircraft. The calculation of existing apron requirements in 2016 was shown in the table below:

Table 6. Calculation of existing apron requirements in 2016

a. Clearances	4.5m
b. The distances between parallel aircraft at apron w. other buildings	10m
c. The clearances between parked aircraft with aircraft in the taxi lane and other obstructions	10m
d. Distances between aircraft to the terminal building	9 m
Category I (B747-SP) wingspan = 59,6 m and length = 56,30 m	
Length of the apron (wingspan + a)	74,6m
Width (aircraft length+d+wingspan+c)	134,90m
Category II (B737-900) wingspan = 34,3 m and length = 42,1 m	
Length of the apron (wingspan + a)	38,8 m
Width (aircraft length+d+wingspan+c)	92,90m
Category III (F27) wingspan = 29,00 m and length = 25,1 m	
Length of the apron (wingspan + a)	33,50 m
Width (aircraft length + d + wingspan + c)	70,6 m
Existing Apron Requirements (19 aircraft)	
Length of Apron = (4 x category I) + (12 x category II) + (3 x category III) + (2xc) = (4 x 74,60) + (12 x 38,80) + (3 x 33,50) + (2 x 10) = 884,50 m Width of Apron = 134,90 m Area of Apron = 119.319,05 m ²	
In fact based on the data provided by Angkas Pura II, 2017 the existing apron area in 2016 = 690.5m x 76.8m + 240m x 150m = 89.039,40 m ² . This area was not sufficient for accommodating aircrafts parking in 2016 (89.039,40 m ² < 119.319,05 m ²)	

According to the aircraft's peak hours projection

in 2026, the apron is designed to accommodate 31 aircraft (table 2). Then, it was calculated that the future apron in 2026 would require the extension areas as follow (Table 6):

Table 7. Calculation of apron requirements in 2026

a. Clearances	4.5 m
b. The distances between parallel aircraft in the apron with other buildings	10 m
c. The clearances between parked aircraft with aircraft in the taxi lane and other obstructions	10 m
d. Distances between aircraft to the terminal building	9 m
Category I (B737-300) wingspan = 59,6 m and length = 70,7 m	
Length of the apron (wingspan + a)	74,60m
Width (aircraft length + d + wingspan + c)	149,30m
Category II (B737-900) wingspan = 34,3m and length = 42,1 m	
Length of the apron (wingspan + a)	38,80m
Width (aircraft length + d + wingspan + c)	92,90m
Category III (F27) wingspan = 29,00 m and length = 25,1 m	
Length of the apron (wingspan + a)	33,50m
Width (aircraft length + d + wingspan + c)	70,60m
Existing Apron Requirements (31 aircraft)	
Length of Apron = (11 x category I) + (16 x category II) + (4 x category III) + (2 x c) = (11 x 74,60) + (16 x 38,80) + (4 x 33,50) + (2 x 10) = 1595.40 m Width of Apron = 134,90 m Dimensions of planned apron = 1600 m x 150 m = 240.000,00 m ²	

Hence it was calculated that there would be constructed additional up to 240 thousand m² of the apron area in 2026 from 89 thousand m² in 2016. The magnitude scale of this development = 270%.

4. Conclusion

The existing Hang Nadim Airport runway 2016 was 4025 m. This runway is able to accommodate (wide-body aircraft of B747-300) in the new future demand 2026. The existing taxiways (2 Exit Taxiways of 150 m x 23 m and 2 Rapid Exit Taxiways of 300 m x 23 m) were also considered sufficient to accommodate the future demand in 2026. The existing apron (690,5 m x 76,8 m and 240 m x 150 m) has a capacity of 13 aircraft would in a

need to be expanded up to 1600 m x 150 m (in order to facilitate 31 aircraft (11 units B747- 300 + 16 units B737-900 + 4 units F27).

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