PROJECT: DESIGN YOUR AIRPORT

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Abstract — *This document describes the design process of a Category 2C airport, adhering to the recommendations of the International Civil Aviation Organization (ICAO) and the designated airport reference code.*

It focuses on creating a functional and safe airport infrastructure, considering key factors such as location, governmental regulations, and the specific characteristics of Category 2C. Detailed discussions are provided on design decisions related to runway layout, terminal dimensions, and apron configuration, all aimed at ensuring operational efficiency and safety of air operations.

The project follows an approach, supported by official documents and well-founded assumptions, to ensure a practical design meeting Category 2C requirements.

1 Introduction

The aim of the project is to design an airport. Then, a minimum set of parameters should be chosen, that would define the airport characteristics.

To do so, current recommendations provided by ICAO [1] and a set of initial parameters will be considered.

A solid foundation that not only adheres to regulatory standards but also encompasses the operational requirements and safety considerations for efficient functioning will be established by the end of the study, based on the characteristics provided.

2 Airport Characteristics & Aircraft Type Reference

A set of input characteristics have been considered:

- Airport Characteristics: 2C
- Altitude: 800m
- Reference Temperature: 24ºC
- Wind Rose: Option 4 (Figure 1)
- 2 maximum runways

Bearing in mind the list of the requirements, the idea now is to decide the basis to follow with the airport design.

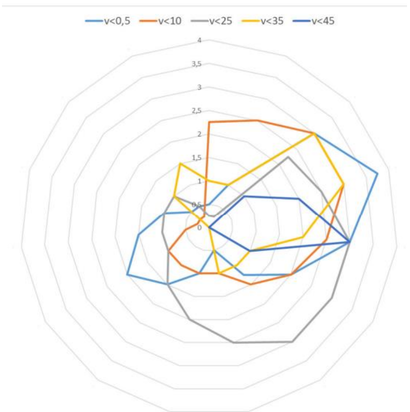

Figure 1. Wind Rose Option 4

The location situated 15 kilometers northeast of Salamanca has been selected as the designated site for the airport construction. It has an altitude of 800 meters, and the terrain is relatively flat, with a slope of 0%. This selection not only meets the requirements for the airport but also offers strategic advantages. Given the airport anticipated low-capacity demand, there is no need to locate it in a highly urbanized environment such as near Barcelona or Madrid.

Also, the decision to place the airport in a less urban area allows for more efficient land use, potentially reducing costs and environmental impact.

Having these requirements in mind; An Aircraft model should be chosen to take as a reference.

Thus, the airport category is 2C. Following the ICAO recommendations, reference field length must be in the range of 800 m to 1200 m, and aircraft that can land must have a wingspan from 24 m up to 36 m.

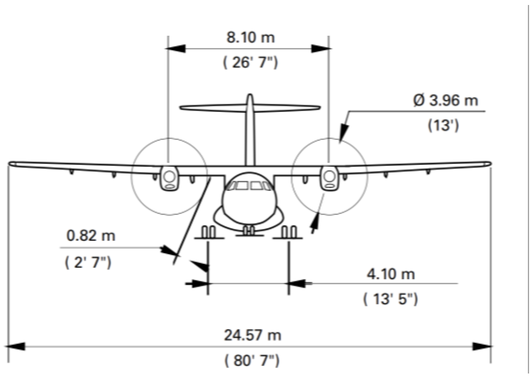

Figure 2. ATR-42 Specifications [2]

ATR-42 [2] have been chosen to accomplish the requirements, with a wingspan of 24,57 m, take-off distance of 1090 m and a landing distance of 886 m at sea level.

3 Runway

A runway at an airport is a designated strip where aircraft take off and land, typically made of asphalt or concrete, equipped with lighting and markings for safe operations. To perform a deep study, different aspects of the runway should be considered.

3.1 Orientation

To determine the runway directions and the number of runways required, an Excel spreadsheet from ATENEA [3] has been used. It indicates the different frequencies of various speeds in different directions.

Then, with the aim of determining the direction of the main runway, the one with the highest utilization ratio has been chosen. In this case, it is the ENE direction (67.5 º), with a utilization ratio of 81.25 %.

Since the utilization ratio is lower than 95 % required by ICAO [1], another runway needs to be added. In this case, the SSE direction (157.5 º) has been decided. This decision aims to optimize the distribution of future airport facilities, including taxiways, aprons, and the terminal building, to occupy minimal space while ensuring maximum accessibility to the different future installations.

Therefore, there will be two runway systems, one designated as 07-25 and the other as 16-34, as shown in Figure 3.

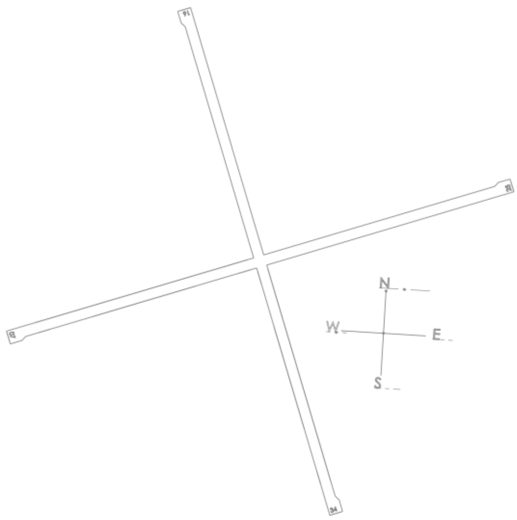

Figure 3. Runways Sketch

3.2 Length Correction

As the location of the aerodrome is not at sea level, a series of correction factors for temperature, slope and altitude will have to be applied.

The altitude where the airport is located is $h = 800\ m$, the reference temperature is, $T_{ref} = 24\ º\ C$ and we have no slope. Having this in mind the calculations can be done.

First, the Height Correction Factor is computed. As altitude increases, air density decreases, affecting aircraft performance during takeoff and landing. This correction factor adjusts the runway length requirement to compensate the reduced air density at higher elevations.

$$F_h = 1 + \frac{0.07 \cdot h}{300} = 1 + \frac{0.07 \cdot 800}{300} = \frac{89}{75}$$

$$L_h = L \cdot F_h = 1090 \cdot \frac{89}{75} = 1293.47\ m$$

The Temperature Correction Factor accounts for the effect of temperature on air density. Higher temperatures result in lower air density, impacting aircraft performance by increasing required takeoff and landing distances. This correction factor adjusts the runway length based on the prevailing temperature conditions to ensure safe operations.

$$\begin{aligned} F_T &= 1 + 0.01 \cdot (T_{ref} - T_{sh}) \\ &= 1 + 0.01 \cdot (24 - 9.8) \\ &= \frac{571}{500} = 1{,}142 \end{aligned}$$

$$\begin{aligned} L_T = L_h \cdot F_T &= 1293.47 \cdot 1.142 \\ &= 1477.14\ m \end{aligned}$$

As the slope is null, there is no need to correct it.

The minimum length is defined by the larger runway distance, in this case it will be 1477,14 m. To make it more secure it will be increased to 1500 m., and this will be applied to both runways.

3.3 Runway Declared Distances

Runway declared distances are crucial measurements for safe flight operations. They include Takeoff Run Available (TORA), Takeoff Distance Available (TODA), Accelerate-Stop Distance Available (ASDA), and Landing Distance Available (LDA). These distances make sure that safe takeoffs and landings are performed in the airport. It considers factors like runway length, slope, and any additional clearways or stopways available.

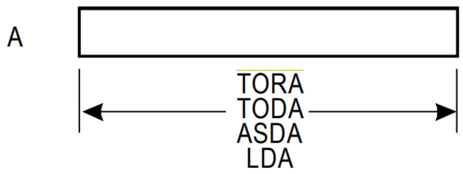

Figure 4. Runway distances [1]

3.3.1 Runway Width

Code number	Code letter A	B	C	D	E	F
1[a]	*18 m*	*18 m*	*23 m*	–	–	–
2[a]	*23 m*	*23 m*	*30 m*	–	–	–
3	*30 m*	*30 m*	*30 m*	*45 m*	–	–
4	–	–	*45 m*	*45 m*	*45 m*	*60 m*

Table 1. Runway width table [1]

As calculated previously the minimum length of the runway will correspond as take-off runway available. For economical and airport hourly low-capacity reasons, stopway and clearway will not be placed.

A threshold marking will be provided at the threshold cause of a paved instrument runway.

Referring to Table 1 for airport's runway width, we determined it to be 30 meters. Additionally, it is important to note that the runway approach will be non-precision.

3.3.2 Strip

The runway strip will be 60 meters along the sides and 75 meters wide from the centerline of the runway. Both values are obtained from the ICAO document [1].

3.3.3 Shoulders

It is necessary to have shoulders if your airport's reference code letter is D or E (with runway width lower than 60 meters), or F (with runway width lower than 75 meters). Since the airport reference code letter is C, shoulders are not required.

3.3.4 Transverse slope

To promote rapid water drainage, 1.5 % transversal slope will be chosen, which is ideal for reference code letter C, as mentioned in the ICAO document [1].

At the runway's intersection, it will be 0.8 %.

3.3.4 Runway Turning Pad

An extension at the end of the runway have been designed, to approve a space for the planes so they can make a 180º turn, to take off or to go to RETIL, after landing.

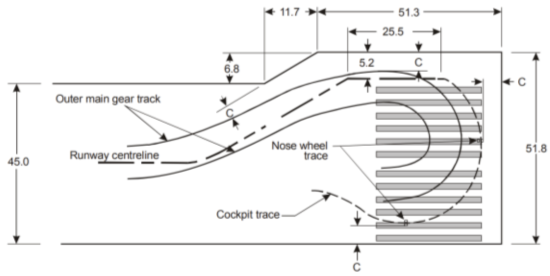

Figure 5. Turn Pad design for Code letter "C" aircraft [4]

3.3.6 Runway End Safety Area

The objective of a Runway End Safety Area (RESA) is to mitigate accidents in case of early landing or late departure. It is mandatory for reference codes 3 and 4, and for reference codes 1 and 2 only if instrumental approaches are in place. Since the designed airport utilizes non-precision approach procedures, having RESA is necessary.

According to ICAO documentation [1], the minimum length for the RESA should be 120 meters, whose width will be double up the runway's width.

3. 4 Taxiway

The main purpose of the taxiway is to guide aircrafts arriving at both runways for departure, to go from one runway to another or to arrive at the apron.

Now, the characteristics of the taxiways at the airport will be established following ICAO regulations.

3.4.1 Width

Letter of the reference key	Taxiway width
A	7,5m
B	10,5m
C	15m (Wheel track <6m)
	18m (Wheel track >6m)
D	18m (Wheel track <9m)
	23m (Wheel track >9m)
E	23m
F	25m

Table 2: Taxiway width table [3]

The reference aircraft has a wheel track of 4,1 meters and looking at table 2 the width that corresponds to the taxiways is 15 meters.

3.4.2 Slopes

3.4.2.1 Longitudinal slopes

As the terrain on which the airport will collide is flat, there will be a longitudinal slope of 0%.

3.4.2.2 Transverse slopes

To avoid the accumulation of water in periods of rain, it has been decided that the transverse slope will be 1.5%.

3.4.3 Separations

Code letter	Clearance
A	*1.5 m*
B	*2.25 m*
C	*3 m if the taxiway is intended to be used by aeroplanes with a wheel base less than 18 m;*
	4.5 m if the taxiway is intended to be used by aeroplanes with a wheel base equal to or greater than 18 m.
D	*4.5 m*
E	*4.5 m*
F	*4.5 m*

Table 3: Taxiway Clearance Distances [1]

Following ICAO recommendations, the distance between one of the external wheels of the main landing gear and the edge of the taxiway should not be less than 3 m. This is always true in the case of this airport since the thickness of the taxiway is 15 m, and the distance of the main landing gear of the ATR-42 is 4.10 m, 7.5 - 2.10 = 5.40 > 3 m.

The distance between a taxiway and the axis of the runway is not less than 87 m following the regulations established by ICAO. And the distance between the axis of a taxiway of access taxiway to a parking stand is more than 24.5 m.

3.4.3 Rapid Exit Taxiways

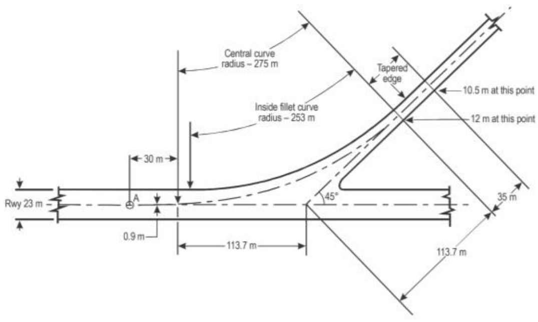

Figure 6. Design for Rapid exit Taxiways (code number 1 or 2) [4]

One pair of Rapid Exit Taxiways have been designed, for each runway, in order to improve the efficiency at the entrance of an aircraft that wants to use it to take off, following the instructions for reference code letter C runways given in the Aerodrome Design Manual Part 2 [5].

4. Apron

The Apron of an aerodrome is defined as the area of the terrain where aircraft are parked, unloaded or loaded, refueled, boarded, or maintained. So, to calculate the size or layout of the airport's apron, all necessary functions and requirements must be considered.

4.1 Apron Capacity

Since it is a small airport and not much aircraft traffic is expected, 7 parking stands have been designed. So, Pi, which is the numbers of positions of type i, equals 7.

As it is expected that an aircraft will arrive in the morning and will depart in the afternoon, it has been considered that the time an aircraft occupies a parking stand is 8 hours. Therefore, the stay time for an aircraft of type i, Ti, equals 8 hours. This is due to low capacity.

Since all the aircraft operating at this airport are not bigger than type C, Mi, that represents percentage of aircraft of type i over the total of aircraft operating at the airport equals 1.

Now, all this data is used to determine how many stands are being used per hour.

$$F = \frac{\sum P_i}{\sum (M_i T_i)} = \frac{7}{1 \cdot 8} = 0.875 \text{ P. Stands/h}$$

$$t_i = \frac{M_i T_i}{\sum (M_i T_i)} = \frac{1 \cdot 8}{1 \cdot 8} = 1$$

$$C = \frac{P_i}{t_i} \cdot F = \frac{8}{1} \cdot 0.875 = 7 \text{ Parking Stands}$$

All these calculations have been done when “i” equals 8. It can be affirmed the assumptions taken previously: the total number of stands needed is equal to the number of stands designed.

The calculation continues to arrive to the operational air capacity.

It is considered that typically 3 out of the total 7 stands will be occupied. So, the Occupancy Factor equals: $U = \frac{3}{7} = 42.857\ \%$

Finally considering that half of the operations performed at the airport are arrivals and the other half are departures, the operational air capacity can be computed as:

$$Ca = F \cdot X_{min} \cdot \left(\frac{U}{\%Arrivals}\right) = 0.875 \cdot 1.01 \cdot \frac{42.857}{50} = 0.7575 \text{ Aircraft/hour}$$

The result obtained matches the expected low operational capacity of the airport.

4.2 Parking Stands

In consideration of the limited capacity of the airport and the characteristics of the reference aircraft, which is a small aircraft, it has been determined that implementing remote parking stands instead of traditional finger stands is the optimal choice.

This decision is based on several advantages associated with remote parking. In small airports, where ramp space or parking areas are often restricted, remote parking frees up valuable space on the main ramp, facilitating the movement of other planes. Additionally, remote parking offers ease of access for passengers boarding and disembarking small aircraft, as they can utilize portable stairs or ramps without the need for gates or jet bridges.

Given that the airport is not situated near any vacation or tourist destinations, there is no need to have many parking stands. With an anticipated average of 0.7575 operations per hour, the airport will feature 7 stands designated for remote parking in front of the terminal.

It is noted that the aircraft reference is ATR-42 indicating that the size of the stands corresponds to Type VIII. The dimensions of Type VIII stands are 34.5 meters in length by 37 meters in width. Furthermore, the minimum separation between aircraft-aircraft and aircraft-terminal must be maintained at 4.5 meters.

Since the ATR 72 has been taken as the reference aircraft and will be the largest aircraft to operate at the airport, the smallest parking stands have been chosen for designing the apron.

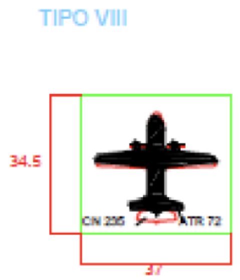

Figure 7. Parking Stand Type VIII [3]

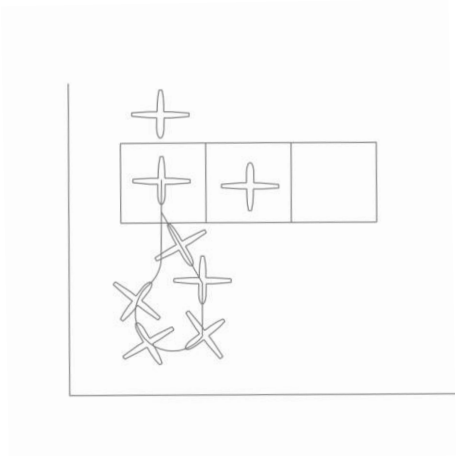

Figure 8. Parking Stands

The apron and parking stands have been designed so that aircraft can park autonomously, respecting thus eliminating the need for additional apron assistance services.

Code letter	Clearance
A	*3 m*
B	*3 m*
C	*4.5 m*
D	*7.5 m*
E	*7.5 m*
F	*7.5 m*

Table 4. Clearance Distances between Aircraft [1]

4.3 Apron Length

The parking stands have been designed to maintain safe distances between all possible obstacles, including between aircraft and between aircraft and the terminal building.

With 7 stands, each having a base of 37 m and considering the safety distances between an aircraft stand and an object, this gives us a total apron length of 304 m.

$$Apron\ length = 7 \cdot 37 + 2 \cdot 22.5 = 304\ m$$

4.4 Apron Width

To calculate the width, it has been considered the distance from the apron center line to an object, in this case, an aircraft, plus the distance needed for the ATR 72 to make a 180º turn (which is 70 m), plus the distance that should be left between the aircraft and the terminal building.

Apron width = Apron taxiway centerline to object + width parking stand+ distance that takes the ATR 72 to make the 180º turning + separation clearance:

26 + 34.5+ 70 + 4.5 = 135 m

4.5 Service Roads

Two service roads will be designed, one at the front of the apron, and one behind the parking stands, to provide minimal services to aircraft.

5. Terminal Building

The terminal building at the airport serves as a pivotal facility facilitating the embarkation and disembarkation of passengers from aircraft. It functions as a centralized hub overseeing essential operations associated with air travel, encompassing ticketing, check-in procedures, security screenings, baggage handling, boarding gate management, and requisite amenities. To optimize operational efficiency, the decision has been made to develop a single-floor terminal, streamlining design to incorporate only the essential zones mandated by regulatory standards. This means that it will not save space for restaurants, retail shops, duty free, etc.
The proposed layout delineates the air side commencing from the boarding gates, juxtaposed with the city side, which initiates at the check-in area.

Furthermore, a strategic consideration involves the incorporation of an industrial zone within the terminal infrastructure. This decision is due to subdued passenger volumes, thereby offering an opportunity to implement functions of commercial activities and freight transportation purposes in the airport.

5.1 Check-in Area

The check-in area of the terminal building is a designated space where passengers can check in for their flights. As our airport is a low-capacity airport, this area will consist of a small number of check-in counters where passengers can drop off their luggage and receive their boarding passes from airline staff or automated systems.

The check-in process in airports like ours is typically very efficient due to the smaller number of passengers.

5.2 Check-in queue area (time)

The maximum number of passengers per hour in a part of the airport is the Peak hour passengers (PHP) and would be the number of passengers for an ATR 72.

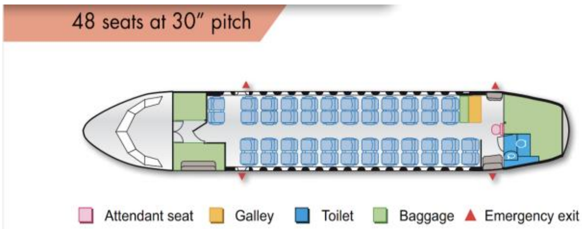

Figure 9. ATR-42 Standard Configuration [2]

Considering that the operational capacity is almost one hour, and the largest aircraft operating is the ATR 72; The maximum number of passengers that can stay in same instant is 48, thus, the PHP equals to 48 passengers.

For subsequent calculations, it has been decided that the Design Peak Hour Passengers (DPHP) will be 80% of the PHP. Thus, DPHP = 0.80 * 48 = 39 passengers.

$$CD_y = \frac{DPHP_{sal} \cdot PK \cdot PT}{60} \cdot \frac{1}{(30 + MQT)}$$

The CDy is the approximate number of counters [Check-in Desks], and the following calculations have been made to determine the value of the number of counters.

The peak factor in a 30 min period is equal to the percentage of DPHP, thus, PK = 80 %.

The average time to process a passenger has been assumed to be equal to 5 minutes per passenger, PT = 5 min/passenger = 300 s/passenger.

Also, the maximum amount of time that a passenger should be in the queue is 10 minutes, so the maximum waiting time equals 10 minutes. MQT = 10 min.

Consequently, the approximate number of check-in encounters equals:

$$\text{CDy} = \frac{48 \cdot 0.80 \cdot 300}{60} \cdot \left(\frac{1}{(30 + 10)}\right) = 4.8$$

Correction Factor (Cf) for Demand Variability (when less than 30 min. peak)	
For MQT	CF
3	1.21
4	1.22
5	1.15
10	1.06
15	1.01
20	1.00
25	1.00
30	1.00

Table 5. CDy Correction Factor [3]

Now, applying the correction factor obtained from Table 5, the number of check-in desks can be computed:

$$CD = Cf \cdot CDy = 1.06 \cdot 4.8 = 5.088 = 5$$
Check-In desks.

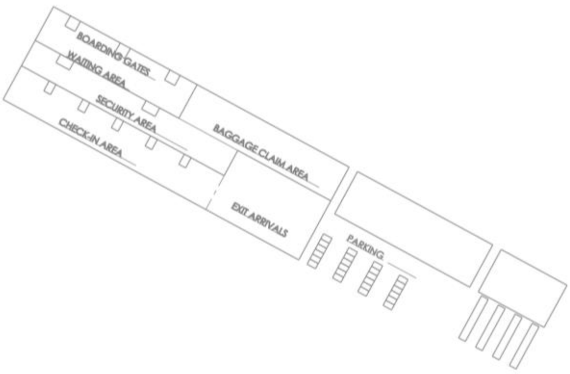

Figure 10. Terminal Building Distribution

7 References

[1] «Annex 14 - Aerodromes - Volume I - Aerodromes Design and Operations», ICAO. Accesed on May 1st , 2024. [Online]. Availabe at: https://store.icao.int/en/annex-14-aerodromes

[2] «ATR ATR-42-300/320 | SKYbrary Aviation Safety». Accesed on May 1st , 2024. [Online]. Available on: https://skybrary.aero/aircraft/at43

[3] «Curs: ENGINYERIA AEROPORTUÀRIA (Curs Total) | CAMPUS VIRTUAL UPC». Accesed on May 1st , 2024. [On line]. Available on: https://atenea.upc.edu/course/view.php?id=90675

[4] «Aerodrome Design Manual - Runways (Doc 9157 - Part 1)», ICAO. Accesed on May 1st , 2024. [Online]. Availabe at: https://store.icao.int/en/aerodrome-design-manual-runways-doc-9157-part-1

[5] «Aerodrome Design Manual - Part 2 - Taxiways, Aprons and Holding Bays (Doc 9157 - Part 2)», ICAO. Accesed on May 1st , 2024. [Online]. Availabe at: https://store.icao.int/en/aerodrome-design-manual-part-2-taxiways-aprons-and-holding-bays-doc-9157-part-2

6. Conclusions

The airport design presented adheres to the specified reference airport code, with certain discretionary adjustments made to accommodate factors such as location and budgetary considerations.

While rigorous adherence to ICAO regulations and procedures has been observed in this conceptualization, it is acknowledged that the practical implementation of such a project would necessitate a comprehensive analysis encompassing factors such as site-specific characteristics, connectivity with transportation hubs, and socioeconomic conditions of the relevant regions or countries.

To conclude, the main objective of designing an airport with all its parts has been achieved. This experience has provided us with a valuable opportunity to gain a deep understanding of the intricate processes and considerations involved in airport planning.

ANNEX

Table 1-1. Aerodrome reference code
(see 1.6.2 to 1.6.4)

Code element 1		Code element 2		
Code number (1)	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.

Note.— Guidance on planning for aeroplanes with wing spans greater than 80 m is given in the Aerodrome Design Manual, *Parts 1 and 2.*

Table 6. Aerodrome Reference code [1]

Heading	Degrees	v<0,5	v<10	v<25	v<35	v<45	T
N	0	0,5	2,25	0,25	1	0	4
NNE	22,5	1	2,5	0,25	1	0	4,75
NE	45	2	3	0,25	2	0,5	7,75
ENE	67,5	3	3	2,25	3	1	12,25
E	90	3,75	3	2,5	3	2	14,25
ESE	112,5	3	2,5	3	2	3	13,5
SE	135	2	2	3	1	1	9
SSE	157,5	1,25	1,5	3	1	0	6,75
S	180	0,5	1	2,5	1	0	5
SSW	202,5	1	1	2	0	0	4
SW	225	1,5	1	1,5	0	0	4
WSW	247,5	2	1	1	0	0	4
W	270	1,5	0,5	1	0	0	3
WNW	292,5	1	0,25	1	0	0	2,25
NW	315	0,5	0,25	1	1	0	2,75
NNW	337,5	0,5	0,25	0,5	1,5	0	2,75
		25	25	25	17,5	7,5	100

Table 7. Wind Frequencies Option 4 [3]