



**Fifth Joint GREPECAS–RASG-PA Meeting (GREPECAS–RASG-PA/5) and
Twenty-Third Meeting of the Caribbean and South American Regional Planning and
Implementation Group (GREPECAS/23)**

Virtual Phase (Asynchronous, 19 January to 17 February 2026)

In-person Phase (Mexico City, Mexico, 2 to 6 March 2026)

Agenda Item 6: Progress on Regional and National air navigation planning

**DEVELOPMENT AND APPLICATION OF A MATHEMATICAL METHODOLOGY FOR THE
CALCULATION OF INSTANTANEOUS AIRCRAFT CAPACITY (PIAC) AS A KPI IN
TERMINAL CONTROL AREAS: CASE STUDY IN THE CANCÚN TMA**

(Presented by Mexico)

EXECUTIVE SUMMARY	
<p>This paper presents a mathematical methodology developed by the Mexican Air Navigation Services (SENEAM) to calculate the instantaneous aircraft capacity (PIAC) in sectors within Terminal Control Areas (TMAs). The model addresses the need to sequence traffic flows converging to the same aerodrome, incorporating analogies to the continuity principle in fluid mechanics, historical trajectory utilization percentages, and factors such as mean flight times and ground speed (GS). Unlike existing approaches, it prioritizes the formation of arrival sequences, enabling the determination of maximum PIAC and the minimum longitudinal separations required at entry points to prevent overload. The methodology was applied to the Cancún TMA (MMUN), obtaining instantaneous capacity values for each sector. The paper proposes that this methodology be considered to enrich regional practices in the CAR/SAM Region.</p>	
Action:	<p>The Meeting is invited to take note of the methodology presented, consider its potential integration into ICAO Doc 9971 (Manual on Collaborative Air Traffic Flow Management), and recommend its evaluation for adoption in TMA capacity studies in the CAR/SAM Region.</p>
<i>Strategic Objectives 2026-2050:</i>	<ul style="list-style-type: none"> • Every flight is safe and secure • Aviation is environmentally sustainable • Aviation delivers seamless, accessible, and reliable mobility for all • No country left behind • The International Civil Aviation Convention and Other Treaties, Laws and Regulations Address All Challenges • The Economic Development of Air Transport Assures the Delivery of Economic Prosperity and Societal Well-Being for All
References:	<ul style="list-style-type: none"> • Doc 9883, Manual on Global Performance of the Air Navigation System • Doc 9971, Manual on Collaborative Air Traffic Flow Management

1. Introduction

1.1 ICAO emphasizes the importance of effective Air Traffic Flow Management (ATFM) as a key enabler of efficiency and safety in Air Traffic Management (ATM). In this context, the accurate determination of capacity in controlled airspace—particularly within Terminal Control Areas (TMAs)—is essential to analyse flow forecasts and to avoid unnecessary delays, such as excessive tactical vectoring or holding patterns, which impact KPI 08 (“Additional time in terminal airspace”) in Doc 9971. ²

1.2 While existing methods proposed by ICAO and the Federal Aviation Administration (FAA) address en-route sector capacity through controller workload estimations (e.g., based on average flight times and availability factors), these approaches do not adequately incorporate the sequencing required in TMAs, where aircraft converge to a common destination and the limiting factor is the length of existing IFR trajectories ³.

1.3 In response to this gap, SENEAM developed a mathematical methodology to calculate instantaneous aircraft capacity (PIAC), defined in Doc 9883 as the maximum number of IFR flights simultaneously present in a sector at a given instant¹. This methodology integrates the aerodrome arrival acceptance rate (AAR), historical trajectory utilization percentages, mean flight times, and variations in aircraft GS; it also enables the determination of the longitudinal separations required at entry points to maintain constant flows without exceeding capacity. This study presents the theoretical development and practical application in the Cancún TMA (MMUN), a highly complex airspace with multiple sectors and runway configurations.

2. Background

2.1 Current sector-capacity methodologies, such as those described in Doc 9971, focus on controller workload, using formulas of the form:

$$C = \frac{T_f}{N_c \cdot T_m} \cdot (1 - D)$$

Where T_f is the average flight time in the sector, N_c the number of communications per aircraft, T_m the average duration of each message, and D the controller availability factor. This approach determines the maximum number of aircraft with which effective control can be maintained, but it omits the sequencing required in TMAs, where aircraft converge to a common destination.

2.2 Similarly, the FAA method incorporated in Doc 9971 simplifies the calculation by multiplying the average flight time by a factor of 1.6 to estimate simultaneous aircraft, resulting in values such as 25.6 for a 16-minute flight time in arrival sectors. However, documentary analyses show that these methods underestimate the impact of sequencing in terminal areas, where capacity is limited by the reduction of multiple inbound streams into a single runway sequence⁴.

2.3 Alternative studies (e.g., Civil Aviation Flight University of China) propose predictive models for hourly capacity based on a known PIAC, but they require prior data not always available in operational contexts such as Mexican TMAs⁵. Given these limitations, SENEAM developed a model based on physical flow-continuity principles.

3 Methodology description

3.1 The model assumes that, in order not to exceed the capacity of a TMA, the aircraft flow rate (throughput, Q , expressed in aircraft per minute) must remain constant between entry and exit points, analogous to the continuity principle in fluid mechanics. The maximum outbound flow rate is derived from the runway AAR:

$$Q_{max} = \frac{AAR}{60}$$

where AAR is expressed in aircraft per hour. For a sector with multiple converging trajectories, **PIAC** is computed by summing the PIAC capacities for each trajectory, allocating the AAR according to historical utilization percentages (p_i):

$$PIAC = \sum_{i=1}^n \left(\frac{AAR \cdot p_i}{60} \cdot T_i \right)$$

where T_i is the mean flight time (minutes) on trajectory i , and n is the number of trajectories within the sector.

3.2 Minimum longitudinal separations at entry points are determined in order to keep **Q** constant:

$$S_i = \frac{V_{GSi}}{AAR \cdot p_i}$$

where V_{GSi} is the average ground speed (knots) at the entry point, and the separation is the required nautical-mile spacing at the exit point (or prior to the runway). This approach incorporates the effects of deceleration, altitude changes, and different descent profiles, enabling the measurement of the impact of tactical vectoring on capacity (e.g., increases in **KPI 08** when PIAC capacity is exceeded).

3.3 The methodology is validated by comparing PIAC capacity with controller workload values, selecting the lower value as the declared capacity, thereby ensuring alignment with ICAO safety standards.

4 Application in the Cancún TMA (MMUN)

4.1 The MMUN TMA, serving aerodromes such as Cancún (MMUN), Cozumel (MMCZ), and Tulum (MMTL), is divided into sectors designated ARR, APP, FNL, DEP-N, DEP-S, and DEP-W, with different configurations for Runways 12 and 30. Using historical data for mean flight times and GS at terminal-area entry points, and an AAR of 33 aircraft per hour per runway, PIAC capacity was calculated for each sector (see Appendix A).

4.2 Results indicate that trajectory-based capacity is lower than workload-based capacity, confirming that sequencing is the limiting factor. The application also identified margins to optimize ATFM, reducing additional time in the Cancún terminal area and improving operational efficiency.

5 Conclusions

5.1 The methodology provides a robust analytical tool to calculate PIAC and separations in TMAs, overcoming limitations of existing approaches by explicitly integrating the sequencing factor and using real operational data. Its application in the MMUN terminal area demonstrates practical feasibility, with potential to reduce delays and enhance operational safety.

6 Suggested Actions

6.1 The meeting is invited to:

- a) Take note of the information submitted;
- b) evaluate both the regional adoption of the proposed methodology, as well as the possibility of integrating it into updates to Doc. 9971, and carry out comparative studies in other terminal control areas of the CAR/SAM region; and
- c) Other actions the meeting considers.

¹ International Civil Aviation Organization. (2009). Manual on Global Performance of the Air Navigation System (Doc 9883). First Edition.

² International Civil Aviation Organization. (2018). Manual on Collaborative Air Traffic Flow Management (ATFM) (Doc 9971). Third Edition.

³ Servicios a la Navegación en el Espacio Aéreo Mexicano (SENEAM). (2024). Airspace Capacity Study for Arrivals to the MMUN TMA. Included in Appendix A.

⁴ Federal Aviation Administration (FAA). (2020). Air Traffic Control Procedures Manual.

⁵ Civil Aviation Flight University of China. (2019). Predictive Models for Terminal Airspace Capacity. *Journal of Air Transport Management*, 78, 45–56.

⁶ International Civil Aviation Organization. GANP Portal: KPI Overview. Available at: <https://www4.icao.int/ganportal/ASBU/KPI> (accessed 18 December 2025).

APPENDIX A

AIRSPACE CAPACITY STUDY FOR ARRIVALS TO THE MMUN TMA

CHAPTER I – OBJECTIVES.

Determine, through the application of methodologies developed by SENEAM engineers and based on methods recommended by the International Civil Aviation Organization (ICAO), the airspace capacity of each arrival and approach sector within the MMUN TMA.

CHAPTER II – LEGAL AND REGULATORY FRAMEWORK.

This Study is a document supported by ICAO provisions, as well as by national regulations issued and approved by the Federal Civil Aviation Agency (AFAC).

In addition, documents from the Federal Aviation Administration (FAA) and EUROCONTROL were used as references, as listed below.:

Applicable legal and regulatory framework.

ICAO Annex 11	Air Traffic Services
ICAO Doc 4444	PANS-ATM (Air Traffic Management).
ICAO Doc 9971	Manual on Collaborative Air Traffic Flow Management (ATFM)
MGTAM - SENEAM	Manual de Gestión de Tránsito Aéreo (Air Traffic Management Manual).

Reference documents.

ICAO RLA/06/901	Guide for the application of a common methodology to estimate airport and atc sector capacity for the sam region.
Mou, Q.; Yang, Z.; Zhang, L. https://doi.org/10.3390/aerospace10100894	A Methodology for Assessing Capacity of the Terminal Maneuvering Area Based on Service Resource Equilibrium
SAM/IG/6-IP/03	Methodology adopted by Brazil to calculate the control capacity of ACC of brazilian FIR

CHAPTER III – ACRONYMS

AFAC (ES)	Agencia Federal de Aviación Civil / Federal Civil Aviation Agency
AICM (ES)	Aeropuerto Internacional de la Ciudad de México / Mexico City International Airport
ATS (EN)	Air Traffic Services / Servicios de Tránsito Aéreo
CFP (ES)	Cálculo de Capacidad Física de Pista / Physical Runway Capacity Calculation
FAA (EN)	Federal Aviation Administration (USA) / Administración Federal de Aviación (EE. UU.)
IFR (EN)	Instrument Flight Rules / Reglas de Vuelo por Instrumentos
ILS (EN)	Instrument Landing System / Sistema de Aterrizaje por Instrumentos
IMC (EN)	Instrument Meteorological Conditions / Condiciones Meteorológicas por Instrumentos
KT (EN)	Knots / Nudos (1 kt = 1 NM/h)
MATOP (ES)	Media Aritmética del Tiempo de Ocupación de Pista (Aterrizaje/Despegue) / Arithmetic Mean Runway Occupancy Time (Landing/Take-off)
MSL (EN)	Mean Sea Level / Nivel Medio del Mar
RNAV (EN)	Area Navigation / Navegación de Área
RNP (EN)	Required Navigation Performance / Rendimiento de Navegación Requerida
SAM (EN)	ICAO South American Region / Región Sudamérica de la OACI
SENEAM (ES)	Servicios a la Navegación en el Espacio Aéreo Mexicano / Air Navigation Services in the Mexican Airspace
SID (EN)	Standard Instrument Departure / Salida Normalizada por Instrumentos
TDG (EN)	Taxiway Design Group / Grupo de Diseño de Calles de Rodaje
TMOP (ES)	Tiempo Medio de Ocupación de Pista (cálculo) / Mean Runway Occupancy Time (MROT) calculation
TOPA (ES)	Tiempo de Ocupación de Pista en Aterrizaje / Runway Occupancy Time during Landing
TOPD (ES)	Tiempo de Ocupación de Pista en Despegue / Runway Occupancy Time during Take-off
VFR (EN)	Visual Flight Rules / Reglas de Vuelo Visual
VMC (EN)	Visual Meteorological Conditions / Condiciones Meteorológicas de Vuelo Visual

CHAPTER IV – METHODOLOGY.

A documentary review was conducted in order to identify the methodologies applicable to this study.

It was identified that, both in national and international regulatory material and in the available literature on the subject, there is very limited information on methodologies to calculate ATC sector capacity in a terminal control area, and no information applicable to capacity when aircraft are part of the same arrival sequence.

The methodologies proposed by ICAO for sector capacity calculation focus on estimating controller workload and the controller's ability to issue clearances as a function of the number of aircraft under control. Such methodologies do not account, within their calculations, for the need to establish an arrival sequence for a specific aerodrome, as shown in the following formula::

$$N = \phi * T * (\eta * \tau_m)$$

Where instantaneous sector capacity is determined by the average flight time in the sector, the number of communications per aircraft within the sector, the mean duration of each message, and a controller availability factor, defined as the percentage of time available to plan aircraft separation procedures. Therefore, the above formula is aimed at determining the maximum number of aircraft with which the controller can maintain communication and effective control, regardless of whether aircraft share the same destination and must be sequenced, which is the primary limiting factor within a terminal control area.

In contrast, the methodology proposed by the FAA and reflected in ICAO Doc 9971 is even simpler, since capacity is derived solely from the average flight time in the sector multiplied by a factor of 1.6 to obtain the number of simultaneously airborne aircraft within the sector. It is straightforward to dismiss the FAA method for application in terminal control areas through a brief example:

Assuming an average flight time of 16 minutes in terminal arrival sectors, capacity would be given by:

$$N = 16 * 1.6 = 25 \text{ arriving aircraft}$$

Although the values are supported by ICAO, they are evidently not useful to determine capacity in a terminal area, and it can be verified that the limiting factor for ATC sector capacity in a TMA is the capacity of the arrival sequence established within that airspace.

In search of a more realistic approach to terminal-area capacity, studies conducted by the Civil Aviation Flight University of China were reviewed, identifying predictive models to calculate hourly capacity from a previously known instantaneous capacity. Therefore, although mathematically elegant, the method is not useful for application in Mexican terminal areas.

For all of the above reasons, a novel method was developed to calculate ATC sector capacity in terminal airspace. The general principles of the method are presented below.

The methodology is based on the fact that, in order not to exceed terminal airspace capacity, the aircraft flow must be kept constant at both entry and exit points. It provides values to measure maximum instantaneous capacity, expressed as the number of simultaneously airborne aircraft, as well as capacity expressed as the number of aircraft entering per unit time.

For the application of this methodology, the input data consist of the mean flight time of aircraft in each sector, combined with aircraft ground speed at the entry and exit points.

Using mean flight time for the calculation—rather than segmenting trajectories into constant-speed legs—allows the calculation to incorporate deceleration times resulting from in-flight thrust changes, as well as aircraft altitude changes along the trajectory.

Using ground speed for the calculations allows the model to incorporate aircraft performance characteristics and their impact on capacity, as well as the predefined vertical profiles established in the design of arrival and approach trajectories. This is because an aircraft changing altitude, even while maintaining constant indicated airspeed, will change its ground speed.

The methodology defines maximum capacity as a function of time through the following formula:

$$AAR = \sum_{y=1}^m \Delta T * \varphi_y * \delta_{max} \quad (1)$$

Where AAR is the declared arrival acceptance rate of the runway at the aerodrome concerned, φ_y is the fraction of total arrivals entering via trajectory “y”, m is the number of trajectories (or inbound flows) in the terminal area, δ_{max} is the maximum outbound aircraft flow, and ΔT defines the time interval over which capacity will be measured.

Likewise, the maximum instantaneous capacity of an ATC sector can be obtained using the following formula:

$$N = \sum_{y=1}^e \varepsilon_y * t_y \quad (2)$$

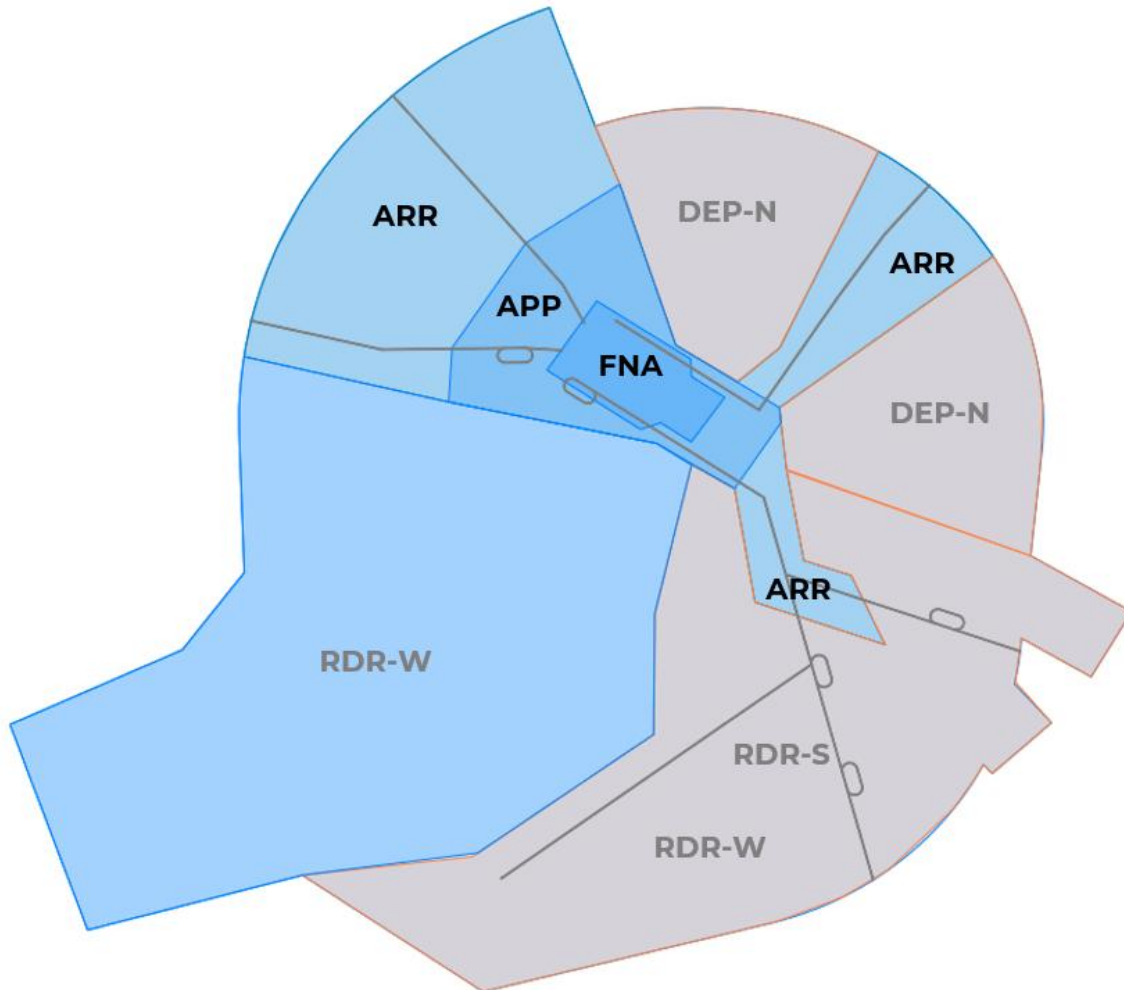
Where ε_y is the inbound flow on trajectory “y” and t_y is the mean flight time within the sector along trajectory “y”.

The methodology also enables the development of formulas to obtain a quantitative (mathematical) measure of capacity impacts resulting from extended tracks due to tactical vectoring, as well as trajectory modifications driven by meteorological conditions.

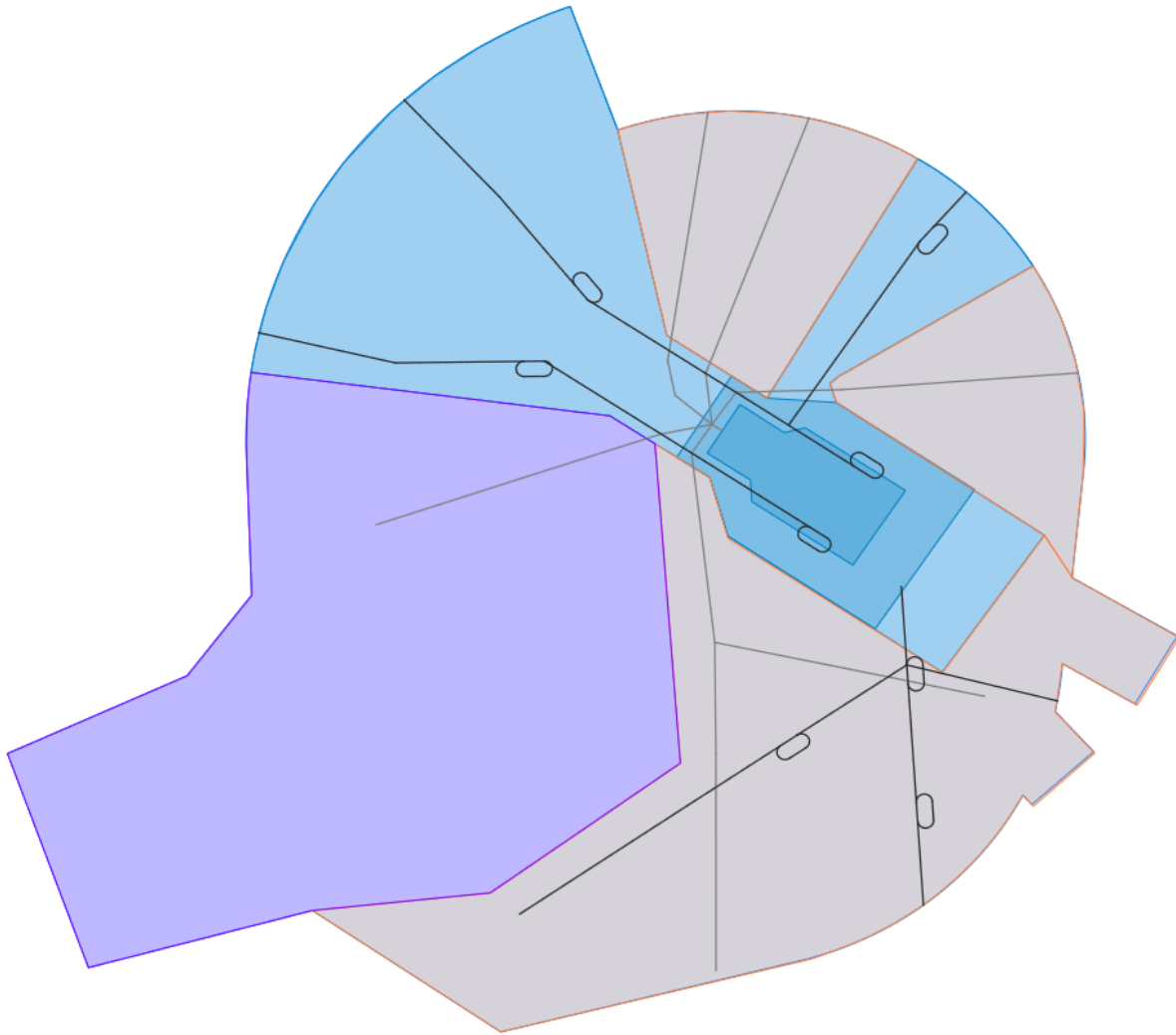
CHAPTER V – CURRENT CONDITIONS OF THE MMUN TERMINAL CONTROL AREA.

The MMUN TMA is divided into different sectors depending on the active runway configuration. The sectors involved are ARRIVALS (ARR), APPROACH (APP), FINAL APPROACH (FNA), as well as certain departure sectors such as RADAR SOUTH (RDR-S) and RADAR WEST (RDR-W).

The sectors comprising the MMUN TMA in the RWY 12 configuration, together with the corresponding arrival and approach procedures, are presented below.



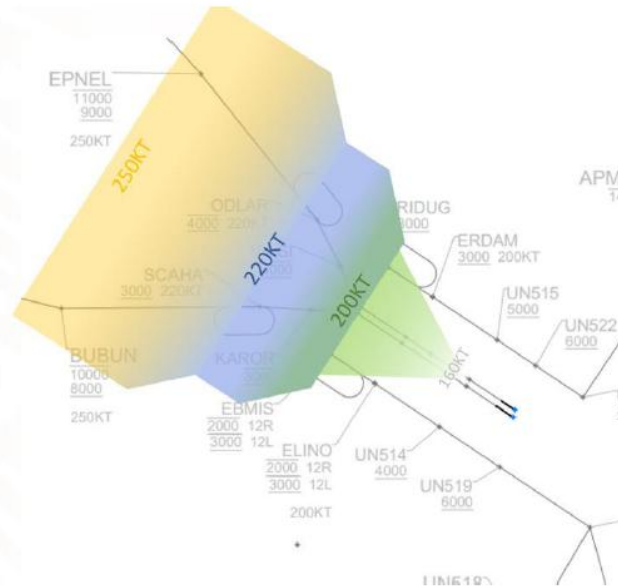
The sectors comprising the MMUN TMA in the RWY 30 configuration, together with the corresponding arrival and approach procedures, are presented below.



Within the MMUN TMA, standardized speeds are established and may be adjusted based on traffic or meteorological conditions.

For RWY 30 operations, the standardized speeds correspond to those published in the applicable arrival and approach procedures.

For RWY 12 operations, the standardized speeds correspond to those shown in the following figure:



The transfers of control are established as follows:

From ARR to APPa

- Traffic shall be transferred to APP in an orderly flow and at standardized speeds. To comply with the agreement with TWR to deliver traffic prior to the FAP/FAF with 4 NM spacing, ARR shall provide longitudinal separation between successive aircraft of 6 NM, and 12 NM for interleaving.
- These separations apply to aircraft of similar speed and wake turbulence category; greater separation shall be applied when low-speed aircraft or differing wake turbulence categories are involved.
- Properly routed.
- Established on the PBN STAR, or on a track to intercept it.
- Non-PBN-approved aircraft shall be vectored to emulate the PBN STAR, using standardized speeds and altitudes harmonized with PBN procedures, in order to sequence and integrate them into the approach stream. A different procedure may be assigned subject to coordination between the involved sectors.
- PBN aircraft under tactical vectoring shall be maintained at standardized speeds and altitudes harmonized with the PBN procedure, in order to sequence and integrate them into the approach stream.
- Identification and control shall be transferred to APP in the order in which the approach sequence was established.
- The transfer shall be effected prior to the common boundary, taking into account workload balance.

From ARR to RADAR WEST (RDR-W)

- Traffic from VIGTU: prior to the common boundary, unless otherwise coordinated.
- Traffic from EMOSA over the CUN VOR: unless otherwise coordinated.

From APP to FINAL (FNA)

- Prior to the sector boundary.
- For downwind traffic to be interleaved prior to the IAF: upon crossing waypoints UN515 and UN514 (RWY 12), and UN500 and UN608 (RWY 30).

From RADAR WEST (RDR-W) to ARRIVALS (ARR)

- Transfer MMUN-bound traffic after CZM VOR, traffic-free, unless otherwise coordinated.

From RADAR WEST (RDR-W) to RADAR SOUTH (RDR-S)

- Transfer departing traffic from MMCZ whose route penetrates RADAR SOUTH airspace prior to the vertical limit of jurisdiction.
- From RADAR SOUTH (RDR-S) to ARRIVALS (ARR)
- Transfer MMUN-bound traffic prior to the jurisdiction boundary and traffic-free, unless otherwise coordinated.
- Coordinate separation and sequencing with the flow supervisor.

From RADAR SOUTH (RDR-S) to RADAR WEST (RDR-W)

- Transfer MMCZ-bound traffic from PAULE, SIGMA and ILUBA prior to the lateral or vertical jurisdiction boundary.
- Transferir el tránsito con destino a MMUN después del VOR CZM libre de tránsito, a menos que se coordine de otra forma.

De RADAR OESTE a RADAR SUR (RDR-S)

- Transferir antes del límite vertical de su jurisdicción al tránsito de salida de MMCZ cuya ruta penetre el espacio de RADAR SUR.

De RADAR SUR (RDR-S) a LLEGADAS (ARR)

- Transferir el tránsito con destino a MMUN antes del límite de su jurisdicción y libre de tránsito, a menos que se coordine una manera diferente.
- Coordinar con el supervisor de flujo la separación y secuenciación de tránsitos.

De RADAR SUR (RDR-S) a RADAR OESTE (RDR-W)

- Transferir el tránsito hacia MMCZ proveniente de PAULE, SIGMA e ILUBA antes del límite jurisdiccional lateral o vertical.

CHAPTER VI – DATA COLLECTION

In accordance with the methodology described, the capacity calculation is based on the airport’s potential Arrival Acceptance Rate (AAR).

On that basis, a specific study was conducted to determine this value for MMUN, as documented in “AIRSPACE AND AIRSIDE CAPACITY STUDY FOR CANCÚN INTERNATIONAL AIRPORT (MMUN)”.

The study applies a methodology based on the Runway and ATC Sector Capacity Calculation Manual – Version 1, presented by ICAO at the Twenty-Fourth Workshop/Meeting of the SAM Implementation Group (SAM/IG/24) under Regional Project RLA/06/901, held from 4 to 8 November 2019 in Lima, Peru. This methodology was adapted to express the AAR as a function of an associated percentage of expected missed approaches attributable to air traffic control, allowing the selection of an acceptable percentage to determine the potential AAR, as follows:

Valor propuesto de buffer	separación requerida en el FAF	TMOP (seg)	arr/h	% app. frustradas
1	5.616 NM	143.087056	25.2	0.9 %
0.9	5.3352 NM	135.932703	26.5	1 %
0.8	5.0544 NM	128.77835	28	1.1 %
0.7	4.7736 NM	121.623997	29.6	1.5 %
0.6	4.4928 NM	114.469645	31.4	2.2 %
0.5	4.212 NM	107.315292	33.5	2.6 %
0.425	4 NM	101.913857	35.3	3.9 %
0.4	3.9312 NM	100.160939	35.9	4.3 %
0.3	3.6504 NM	93.0065862	38.7	5.7 %
0.2	3.3696 NM	85.8522334	41.9	8.8 %
0.1	3.0888 NM	78.6978806	45.7	14.5 %
0	2.808 NM	71.5435278	50.3	26.3 %

Example of potential AAR values as a function of the proposed buffer value, for RWY 12.

Similarly, the aerodrome departure rate (ADR) can be derived by selecting a runway occupancy time that covers 95% of the times recorded in real operations, yielding the following result:

$$TMOPDP = 106.31 \text{ s}$$

This value has a reliability level associated with the reliability of the sample size.

$$\text{Number of departures} = \frac{3600}{TMOPDP}$$

$$\text{Number of departures} = 33.86 \text{ aircraft} \approx \mathbf{33 \text{ departures per hour}}$$

For capacity calculation purposes, it was necessary to measure flight times within each ATC sector of the MMUN terminal control area, in accordance with the following criteria::

- For arrival traffic, times were recorded from the first entry fix into the MMUN TMA, flying the complete published procedure, as follows:
 - VOMAR1A fix: AGNIX
 - NOSAT1B fix: HACHO
 - ILUBA1F fix: URVEN
 - SIGMA2H fix: OVGED
 - PAULE2E fix: UN530
 - XUDUN1A fix: BEPOR
- After crossing the horizontal boundary of each sector (ARR, APP and FNA), for southern arrivals (ILUBA, SIGMA and PAULE) the DEP-S position time was added, as this is where those aircraft establish initial communications. The final time was taken at the FAP (or FAF) crossing.
- For departure traffic, time was measured from the point of transfer between TWR and the applicable departure sector (DEP-N, DEP-W or DEP-S) until transfer to ACC MMID.

The collected data were processed to obtain the arithmetic mean flight time within each ATC sector. The results are presented in the tables below:

FLIGHT TIMES RWY 12 ARR-VOMAR			
	AVERAGE	MAX	MIN
ARR	5.66872839	6.68316666	4.757
APP	3.77298148	5.683	2.717
FNL	5.71590432	7.63066667	3.89816666

FLIGHT TIMES RWY 12 ARR -NOSAT			
	AVERAGE	MAX	MIN
ARR	8.46976389	9.184	7.6335
APP	3.16525	4.48333333	2.26666667
FNL	7.08652778	10.15	4.38333334

FLIGHT TIMES RWY 12 ARR -PAULE			
	AVERAGE	MAX	MIN
DEP-S	4.67534615	10.0495	3.16683334
ARR	4.70892308	5.333	2.75
APP	4.1538718	6.95049999	3.34983333
FNL	6.99695454	9.71683334	4.55033333

— All —

FLIGHT TIMES RWY 12 ARR -SIGMA			
	AVERAGE	MAX	MIN
DEP-S	7.7225	8.4665	7.13333333
ARR	5.02861111	6.33333334	4.50033334
APP	3.64156944	4.14966666	3.26683333
FNL	7.11572727	9.8835	3.733

FLIGHT TIMES RWY 12 DEP – TODAS LAS TRAYECTORIAS			
	AVERAGE	MAX	MIN
DEP-S	9.50499702	11.7163333	6.51666666
DEP-W	9.59264103	12.2976667	7.38316667
DEP N	8.61663889	10.8661667	7.30083334

FLIGHT TIMES RWY 30 ARR -SIGMA			
	AVERAGE	MAX	MIN
DEP-S	6.11666667	6.11666667	6.11666667
ARR	3.88333333	3.88333333	3.88333333
APP	5.06666667	5.06666667	5.06666667
FNL	6.38333334	6.38333334	6.38333334

FLIGHT TIMES RWY 30 ARR -PAULE			
	AVERAGE	MAX	MIN
DEP-S	8.64285714	13.4166667	5.7
ARR	3.67380952	6.05	1.48333333
APP	2.65595238	3.41666667	2.03333334
FNL	5.08333333	7.18333333	2.5

FLIGHT TIMES RWY 30 ARR - NOSAT			
	AVERAGE	MAX	MIN
ARR	6.75648148	7.99999999	2.5
APP	2.80925926	4.23333334	1.41666667
FNL	4.77314815	8.11666667	2.16666667

FLIGHT TIMES RWY 30 ARR - VOMAR			
	AVERAGE	MAX	MIN
ARR	11.1267677	12.5	3.4
APP	3.69292929	11.4166667	2.26666667
FNL	5.51464647	8.96666667	2.68333333

CALCULATION OF INSTANTANEOUS ATC SECTOR CAPACITY

Using the statistically derived data, the proposed methodology was applied to obtain instantaneous capacity, expressed as the number of simultaneously airborne aircraft (“N”) within each ATC sector. The results are presented below.

It should be noted that results are expressed in decimal form, since rounding may significantly impact total capacity.

Values are provided for: (i) scenarios where the flow is concentrated on a single trajectory (100%); (ii) scenarios where trajectories carry equal flows (50%); and (iii) scenarios where all trajectories are active, using percentages corresponding to the monthly average projected traffic distribution.

Accordingly, “N” values under the 100% column shall not be summed, as each represents total sector capacity for a “single-flow” scenario. “N” values in the 50% column may be summed in pairs, as they represent capacity values for “two-flow” scenarios. Finally, values in the last column may be summed, as they represent capacity per trajectory under an “all flows active” scenario, and total sector capacity is the sum of the capacities of all trajectories, as indicated in the following formula:

$$N = \sum_{y=1}^e N_y$$

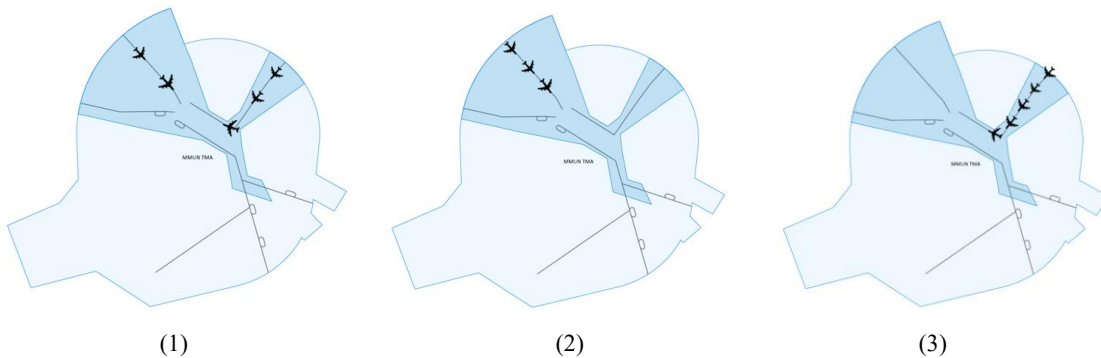
CALCULATION OF INSTANTANEOUS CAPACITY — ARRIVALS (ARR) SECTOR, RWY 12

The instantaneous capacity results for the ARRIVALS (ARR) sector for MMUN RWY 12 are presented below. Instantaneous capacity values range from 3.3 aircraft, corresponding to the scenario in which the total flow is concentrated on VOMAR, to 4.9 aircraft, corresponding to the scenario in which the total flow is concentrated on NOSAT.

For a scenario with two inbound flows from NOSAT and VOMAR, a total capacity of 4.12 aircraft is obtained by summing the “N” values in the 50% column corresponding to NOSAT and VOMAR.

For the all flows active scenario, the resulting capacity is 3.67 aircraft.

“ARR” SECTOR CAPACITY — RWY 12						
	%	N	%	N	%	N
VOMAR-XUDUN	100.00	3.30675823	50.00	1.65337912	44.06	1.45695768
NOSAT	100.00	4.9406956	50.00	2.4703478	30.53	1.50839437
PAULE	100.00	2.74687179	50.00	1.3734359	18.53	0.50899534
SIGMA	100.00	2.93335648	50.00	1.46667824	6.88	0.20181493
					TOTAL	3.67616231



The preceding figure depicts the ARR sector at maximum capacity under several different scenarios: (1) when the arrival flow is split between NOSAT (50%) and VOMAR (50%); (2) when all flow is concentrated on VOMAR (100%); and (3) when all flow is concentrated on NOSAT (100%). It can be observed that sector capacity is a function of the trajectory used, as well as the volume of traffic arriving via each trajectory.

Note: Decimal values of “N” represent aircraft that are exiting the sector or have just exited it, in order to remain consistent with the continuous aircraft-flow concept.

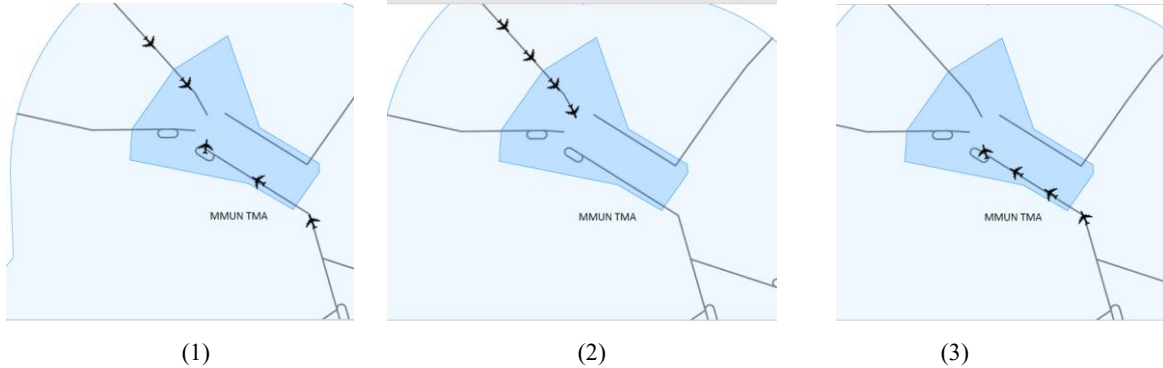
CALCULATION OF INSTANTANEOUS CAPACITY — APPROACH (APP) SECTOR, RWY 12

The instantaneous capacity results for the APPROACH (APP) sector for MMUN RWY 12 are presented below. Instantaneous capacity values range from 1.84 aircraft, corresponding to the scenario in which the total flow is concentrated on NOSAT, to 2.42 aircraft, corresponding to the scenario in which the total flow is concentrated on PAULE.

For a scenario with two inbound flows from PAULE and VOMAR, a total capacity of 2.3 aircraft is obtained by summing the “N” values in the 50% column corresponding to PAULE and VOMAR.

For the all flows active scenario, the resulting capacity is 2.128 aircraft.

“APP” SECTOR CAPACITY — RWY 12						
	%	N	%	N	%	N
VOMAR-XUDUN	100.00	2.20090586	50.00	1.10045293	44.06	0.969719124
NOSAT	100.00	1.84639583	50.00	0.92319792	30.53	0.563704648
PAULE	100.00	2.42309188	50.00	1.21154594	18.53	0.448998925
SIGMA	100.00	2.12424884	50.00	1.06212442	6.88	0.14614832
					TOTAL	2.128571018



The preceding figure depicts the APP sector at maximum capacity under several different scenarios: (1) when the arrival flow is split between PAULE (50%) and VOMAR (50%); (2) when all flow is concentrated on VOMAR (100%); and (3) when all flow is concentrated on PAULE (100%). It can be observed that sector capacity is a function of the trajectory used, as well as the volume of traffic arriving via each trajectory.

It should be noted that aircraft are depicted that are exiting the sector, or that have not yet entered it, in order to illustrate continuous flow along the entire trajectory.

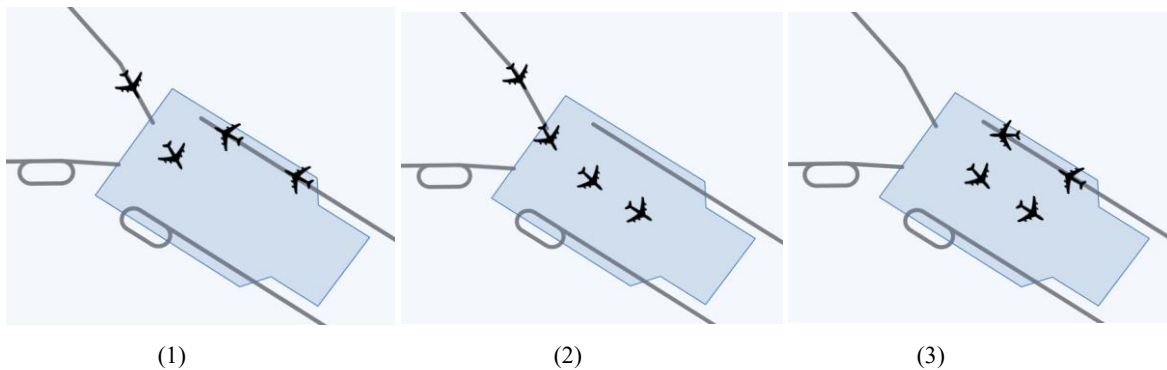
CALCULATION OF INSTANTANEOUS CAPACITY — FINAL (FNA) SECTOR, RWY 12

The instantaneous capacity results for the FINAL (FNA) sector for MMUN RWY 12 are presented below. Instantaneous capacity values range from 3.33 aircraft, corresponding to the scenario in which the total flow is concentrated on VOMAR, to 4.15 aircraft, corresponding to the scenario in which the total flow is concentrated on SIGMA. It should be noted that, in theory, the capacities for the NOSAT, PAULE and SIGMA trajectories should be equal (no traffic was recorded entering via ILUBA); therefore, they may be assumed equal and averaged.

For a scenario with two inbound flows from NOSAT and VOMAR, a total capacity of 3.72 aircraft is obtained by summing the “N” values in the 50% column corresponding to NOSAT and VOMAR.

For the all flows active scenario, the resulting capacity is 3.77 aircraft.

“FNA” SECTOR CAPACITY — RWY 12						
	%	N	%	N	%	N
VOMAR-XUDUN	100.00	3.33427752	50.00	1.66713876	44.06	1.469082675
NOSAT	100.00	4.13380787	50.00	2.06690394	30.53	1.262051543
PAULE	100.00	4.08155682	50.00	2.04077841	18.53	0.756312478
SIGMA	100.00	4.15084091	50.00	2.07542045	6.88	0.285577855
					TOTAL	3.773024551



The preceding figure depicts the FNL/FNA sector at maximum capacity under several different scenarios: (1) when the arrival flow is split between NOSAT (50%) and VOMAR (50%); (2) when all flow is concentrated on VOMAR (100%); and (3) when all flow is concentrated on NOSAT (100%). It can be observed that sector capacity is a function of the trajectory used, as well as the volume of traffic arriving via each trajectory.

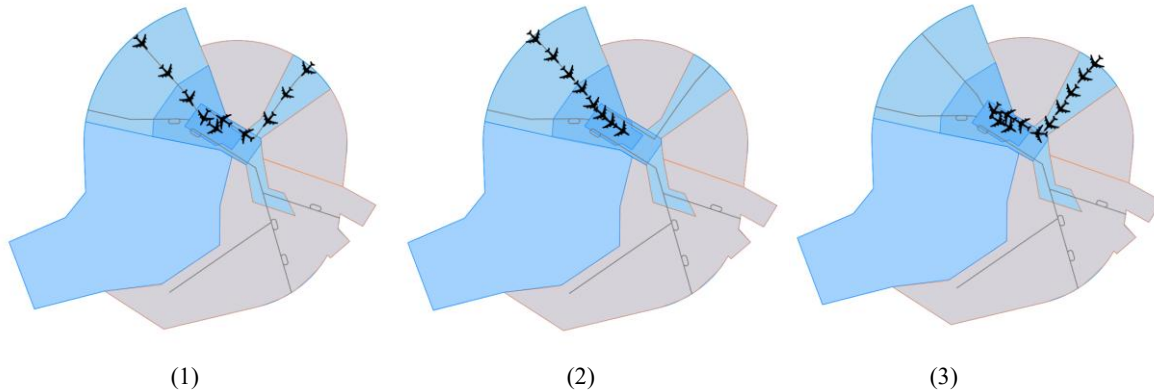
TOTAL INSTANTANEOUS TERMINAL AREA (TMA) CAPACITY — ARRIVALS, RWY 12

Finally, the instantaneous capacity results for the terminal control area (TMA) for MMUN RWY 12 arrivals are presented below. Instantaneous capacity values range from 8.84 aircraft, corresponding to the scenario in which the total flow is concentrated on VOMAR, to 13.71 aircraft, corresponding to the scenario in which the total flow is concentrated on SIGMA.

For a scenario with two inbound flows from NOSAT and VOMAR, a total capacity of 9.88 aircraft is obtained by summing the “N” values in the 50% column corresponding to NOSAT and VOMAR.

For the all flows active scenario, the resulting capacity is 10.34 aircraft.

CAPACIDAD TOTAL TMA (ARR) RWY 12						
	%	N	%	N	%	N
VOMAR-XUDUN	100.00	8.84194161	50.00	4.42097081	44.06	3.89575948
NOSAT	100.00	10.9208993	50.00	5.46044965	30.53	3.33415056
PAULE	100.00	11.6768404	50.00	7.12623269	18.53	2.16371852
SIGMA	100.00	13.7132379	50.00	6.3882509	6.88	0.94347077
	0	0	0	0	0	10.3370993



The preceding figure depicts the TMA at maximum instantaneous capacity under several different scenarios: (1) when the arrival flow is split between NOSAT (50%) and VOMAR (50%); (2) when all flow is concentrated on VOMAR (100%); and (3) when all flow is concentrated on NOSAT (100%). It can be observed that capacity is a function of the trajectory used, as well as the volume of traffic arriving via each trajectory.

CALCULATION OF TERMINAL AREA (TMA) CAPACITY — DEPARTURES, RWY 12 (ALL SECTORS)

Due to the aerodrome separation necessarily applied between two consecutive departures, departures are naturally sequenced before being delivered to the MMUN TMA departure sectors.

In accordance with the Letter of Agreement between MMUN APP and ACC MMID, APP shall transfer departing traffic established on the same ATS route with a minimum longitudinal separation of 10 NM.

In accordance with the methodology formulas, by applying the (de)compression factor, the separation that two aircraft will have at the transfer point to ACC MMID can be derived from the runway-applied separation used by MMUN TWR:

$$Q_x = \frac{v_x}{S_x}$$

$$S_x = \frac{v_x}{Q_x} = \frac{6.6185 \text{ NM/min}}{.55} = 12.033 \text{ NM}$$

The resulting separation is greater than the minimum established in the Letter of Agreement; therefore, this theoretical separation will be used for the TMA capacity calculation.

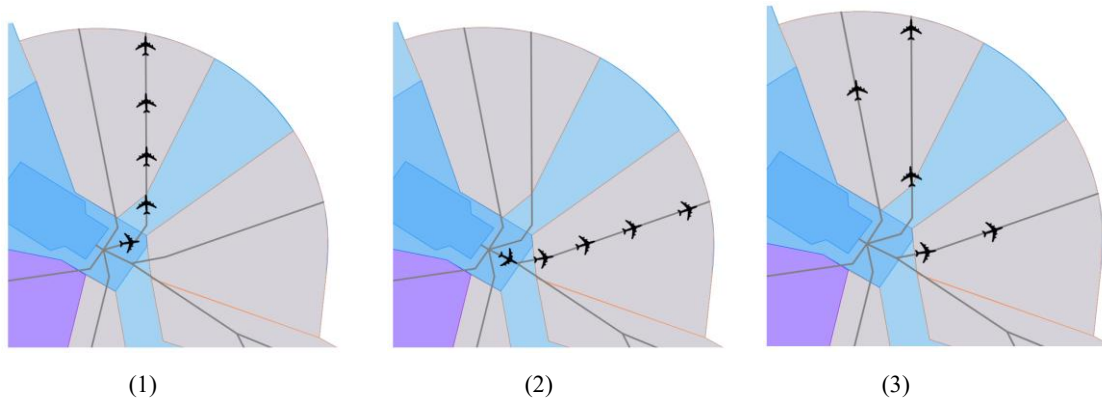
Since all departures for this analysis originate from the same runway, it is not possible for the departure sectors to be simultaneously at maximum capacity. Accordingly, the maximum capacity of each departure sector is broadly similar to the overall TMA capacity.

CALCULATION OF INSTANTANEOUS CAPACITY — NORTH DEPARTURES (DEP-N) SECTOR, RWY 12

The instantaneous capacity results for the DEP-N sector for MMUN RWY 12 departures are presented below. Instantaneous capacity values range from 4.77 aircraft, corresponding to the scenario in which the total flow is routed via NUDAL, to 5.36 aircraft, corresponding to the scenario in which the total flow is concentrated on OMSUK.

For the all flows active scenario, the resulting capacity is **5.23 aircraft**.

"DEP-N" SECTOR CAPACITY — RWY 12								
	%	N	%	N	%	N	%	N
ENEBA	100.00	5.27665417	50.00	2.63832708	33.333	1.75886713	32.14	1.69591665
NUDAL	100.00	4.76978333	50.00	2.38489167	33.333	1.58991188	17.86	0.8518833
OMSUK	100.00	5.35986786	50.00	2.67993393	33.333	1.78660475	50	2.67993393
							TOTAL	5.22773388



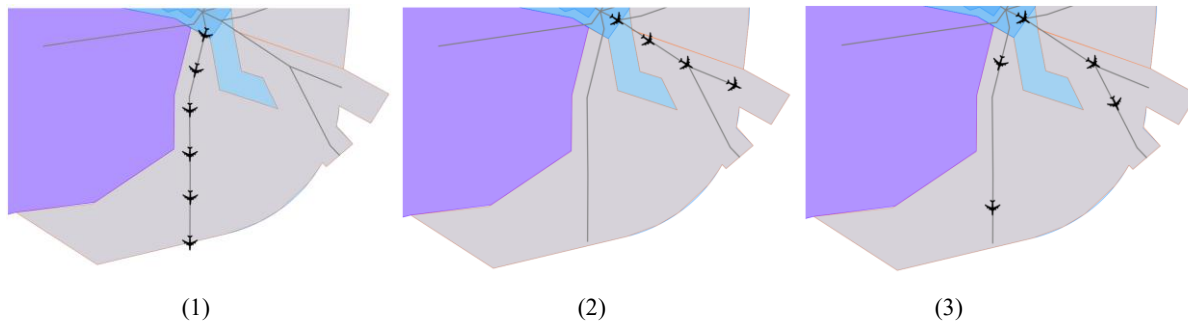
The preceding figure depicts the DEP-N sector at maximum capacity under several different scenarios: (1) when all flow is concentrated on OMSUK (100%); (2) when all flow is concentrated on NUDAL (100%); and (3) when the flow is distributed among the three trajectories. Sector capacity is broadly consistent, regardless of the trajectories used.

CALCULATION OF INSTANTANEOUS CAPACITY — SOUTH DEPARTURES (DEP-S) SECTOR, RWY 12

The instantaneous capacity results for the DEP-S sector for MMUN RWY 12 departures are presented below. Instantaneous capacity values range from 4.015 aircraft, corresponding to the scenario in which the total flow is routed via HECAT, to 5.75 aircraft, corresponding to the scenario in which the total flow is concentrated on ALSUP.

For the all flows active scenario, the resulting capacity is **5.08 aircraft**

“DEP-S” SECTOR CAPACITY — RWY 12								
	%	N	%	N	%	N	%	N
ALSUP	100.00	5.75119722	50.00	2.87559861	33.333	1.91704657	33.33	1.91687403
HECAT	100.00	4.01545834	50.00	2.00772917	33.333	1.33847273	11.11	0.44611742
TAKUX	100.00	4.88389	50.00	2.441945	33.333	1.62794705	55.56	2.71348928
							TOTAL	5.07648074

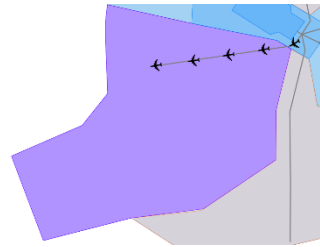


The preceding figure depicts the DEP-S sector at maximum capacity under several different scenarios: (1) when all flow is concentrated on ALSUP (100%); (2) when all flow is concentrated on HECAT (100%); and (3) when the flow is distributed among the three trajectories.

CALCULATION OF INSTANTANEOUS CAPACITY — WEST DEPARTURES (DEP-W) SECTOR, RWY 12

The instantaneous capacity results for the DEP-W sector for MMUN RWY 12 departures are presented below. Since this sector has only one departure trajectory associated with MMUN RWY 12 operations, the resulting capacity is **5.28 aircraft**

“DEP-W” SECTOR CAPACITY — RWY 12		
	%	N
UDGUV	100.00	5.27595256
	TOTAL	5.27595256

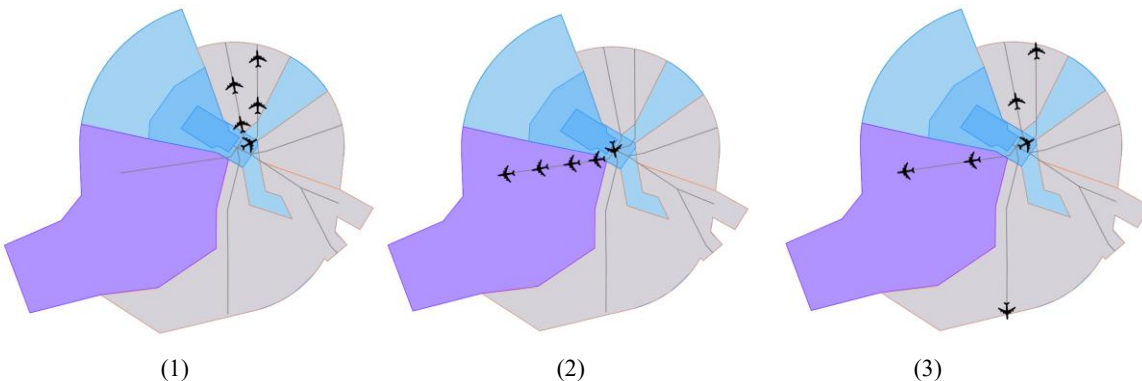


TOTAL INSTANTANEOUS TERMINAL AREA (TMA) CAPACITY — DEPARTURES, RWY 12

The instantaneous capacity results for the terminal control area (TMA) for MMUN RWY 12 departures are presented below. Instantaneous capacity values range from 4.74 aircraft, corresponding to the scenario in which the total flow is routed via SOUTH DEPARTURES (DEP-S), to 5.276 aircraft, corresponding to the scenario in which the total flow is routed via WEST DEPARTURES (DEP-W).

For the all flows active scenario, the resulting capacity is **5.23 aircraft**.

TOTAL TMA CAPACITY (DEPARTURES) — RWY 12								
	%	N	%	N	%	N	%	N
DEP-N	100.00	5.22774836	50.00	2.61387418	33.333	1.74256536	53.85	2.81514249
DEP-W	100.00	5.27595256	50.00	2.63797628	33.333	1.75863327	37.5	1.97848221
DEP-S	100.00	5.0765	50.00	2.53825	33.333	1.69214974	8.65	0.43911725
							TOTAL	5.23274196

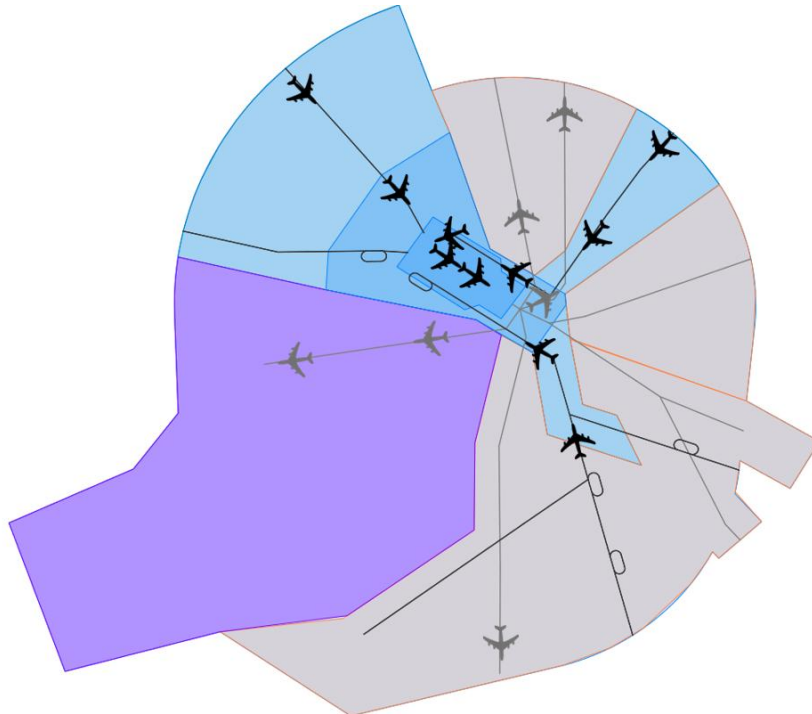


The preceding figure depicts the TMA at maximum capacity under several different scenarios: (1) when all flow is concentrated on DEP-N (100%); (2) when all flow is concentrated on DEP-W (100%); and (3) when the flow is distributed among the three sectors. TMA capacity is broadly consistent, regardless of the trajectories used.

TOTAL INSTANTANEOUS TERMINAL AREA (TMA) CAPACITY — RWY 12

The instantaneous capacity results for the terminal control area (TMA) for MMUN RWY 12 are presented below. Given the multiple possible scenarios, the value corresponding to a scenario in which aircraft are distributed among trajectories according to their historical utilization percentages is presented. The maximum values are also shown for scenarios in which departures and arrivals are each concentrated into a single flow (i.e., all departures via one sector and all arrivals via one trajectory), as well as scenarios in which departures and arrivals are split across two trajectories.

TOTAL TMA CAPACITY — RWY 12						
	%	N	%	N	%	N
VOMAR-XUDUN	100.00	8.84194161	50.00	4.42097081	44.06	3.89575948
NOSAT	100.00	10.9208993	50.00	5.46044965	30.53	3.33415056
PAULE	100.00	11.6768404	50.00	7.12623269	18.53	2.16371852
SIGMA	100.00	13.7132379	50.00	6.3882509	6.88	0.94347077
DEP-N	100.00	5.22774836	50.00	2.61387418	53.85	2.81514249
DEP-W	100.00	5.27595256	50.00	2.63797628	37.5	1.97848221
DEP-S	100.00	4.73915139	50.00	2.36957569	8.65	0.43911725
	Total Máx.	18.9409863	Total Máx.	18.7663341	TOTAL	15.5698413



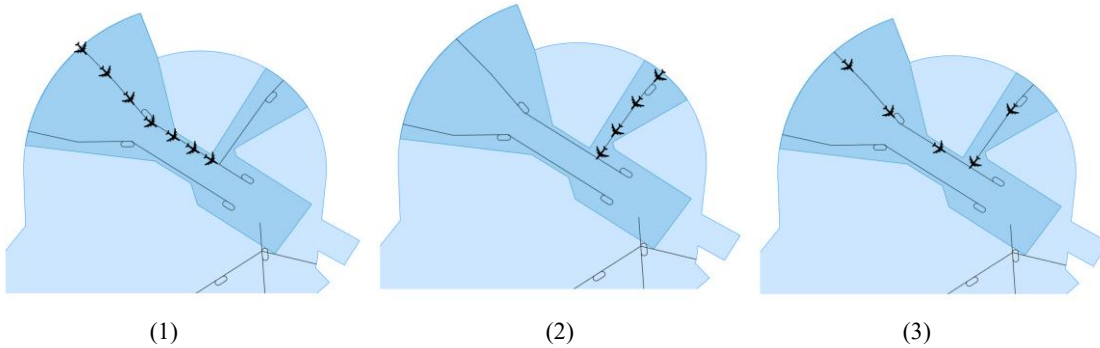
CALCULATION OF INSTANTANEOUS CAPACITY — ARRIVALS (ARR) SECTOR, RWY 30

The instantaneous capacity results for the ARRIVALS (ARR) sector for MMUN RWY 30 are presented below. Instantaneous capacity values range from 2.14 aircraft, corresponding to the scenario in which the total flow is concentrated on PAULE, to 6.5 aircraft, corresponding to the scenario in which the total flow is concentrated on VOMAR.

For a scenario with two inbound flows from NOSAT and VOMAR, a total capacity of 5.21 aircraft is obtained by summing the “N” values in the 50% column corresponding to NOSAT and VOMAR.

For the all flows active scenario, the resulting capacity is **4.62 aircraft**.

“ARR” SECTOR CAPACITY — RWY 30								
	%	N	%	N	%	N	%	N
VOMAR-XUDUN	100.00	6.49061448	50.00	3.24530724	33.333	2.16351652	44.06	2.85976474
NOSAT	100.00	3.94128086	50.00	1.97064043	33.333	1.31374715	30.53	1.20327305
PAULE	100.00	2.14305556	50.00	1.07152778	33.333	0.71434471	18.53	0.39710819
SIGMA	100.00	2.26527778	50.00	1.13263889	33.333	0.75508504	6.88	0.15585111
							TOTAL	4.61599709



The preceding figure depicts the ARR sector at maximum capacity under several different scenarios: (1) when all flow is concentrated on VOMAR (100%); (2) when all flow is concentrated on NOSAT (100%); and (3) when the flow is split between VOMAR and NOSAT.

It can be observed that sector capacity is a function of the trajectory used, as well as the volume of traffic arriving via each trajectory.

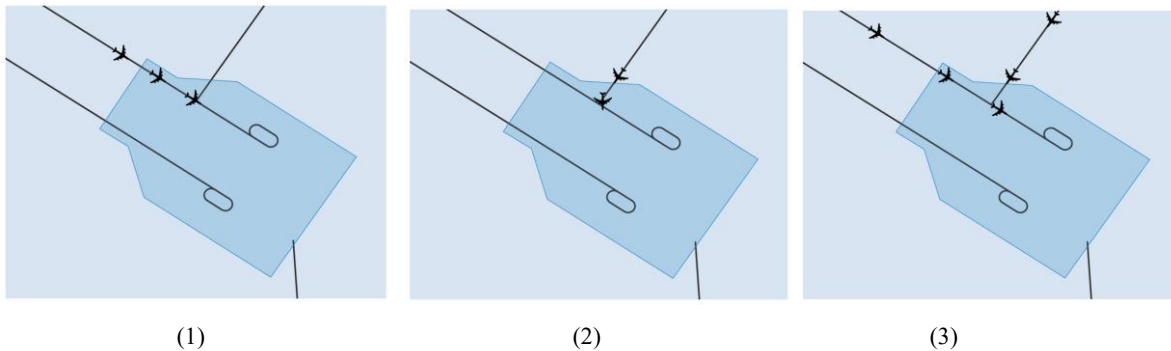
Note: Decimal values of “N” represent aircraft that are exiting the sector or have just exited it, in order to remain consistent with the continuous aircraft-flow concept.

CALCULATION OF INSTANTANEOUS CAPACITY — APPROACH (APP) SECTOR, RWY 30

The instantaneous capacity results for the APPROACH (APP) sector for MMUN RWY 30 are presented below. Instantaneous capacity values range from 1.55 aircraft, corresponding to the scenario in which the total flow is concentrated on PAULE, to 2.95 aircraft, corresponding to the scenario in which the total flow is concentrated on SIGMA.

For the all flows active scenario, the resulting capacity is **1.94 aircraft**.

“APP” SECTOR CAPACITY — RWY 30								
	%	N	%	N	%	N	%	N
VOMAR-XUDUN	100.00	2.15420875	50.00	1.07710438	33.333	0.7180624	44.06	0.94914438
NOSAT	100.00	1.63873457	50.00	0.81936728	33.333	0.54623939	30.53	0.50030566
PAULE	100.00	1.54930556	50.00	0.77465278	33.333	0.51643002	18.53	0.28708632
SIGMA	100.00	2.95555556	50.00	1.47777778	33.333	0.98517533	6.88	0.20334222
							TOTAL	1.93987858



The preceding figure depicts the APP sector at maximum capacity under several different scenarios: (1) when the arrival flow is split between PAULE (50%) and VOMAR (50%); (2) when all flow is concentrated on VOMAR (100%); and (3) when all flow is concentrated on PAULE (100%). It can be observed that sector capacity is a function of the trajectory used, as well as the volume of traffic arriving via each trajectory.

It should be noted that aircraft are depicted that are exiting the sector, or that have not yet entered it, in order to illustrate continuous flow along the entire trajectory

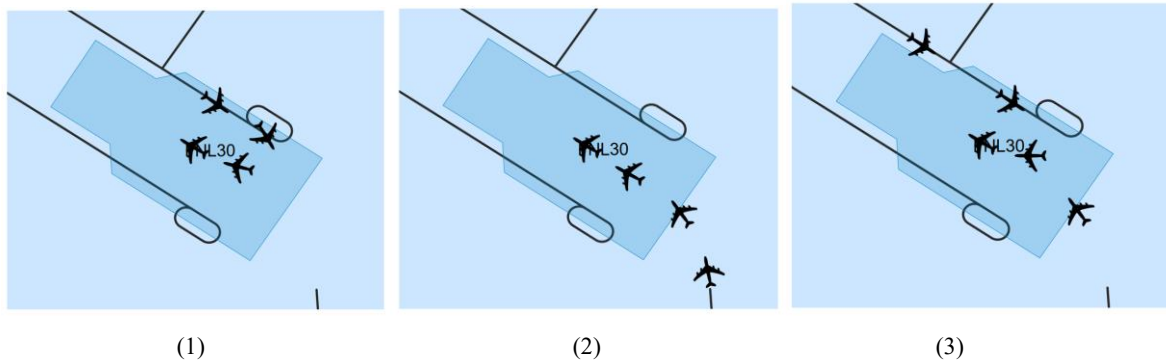
CALCULATION OF INSTANTANEOUS CAPACITY — FINAL (FNA) SECTOR, RWY 30

A continuación, se muestran los resultados de la capacidad instantánea de sector “FINAL” (FNA) para la pista 30 de MMUN. Los valores de capacidad instantánea oscilan entre las 2.78 aeronaves, correspondiente al escenario donde el total del flujo se concentra en NOSAT, y las 3.72 aeronaves, correspondiente al escenario donde el total del flujo se concentra en VOMAR. Cabe señalar que teóricamente la capacidad de las trayectorias VOMAR y NOSAT, así como SIGMA y PAULE deberían ser iguales (no se tiene registro de aeronaves ingresando por ILUBA), así que se pueden asumir como tal y promediarse.

Para un escenario donde existen dos flujos provenientes de NOSAT y VOMAR, se obtiene una capacidad total de 3.01 aeronaves, que resulta de sumar los valores de “N” de la columna de 50%, correspondientes a NOSAT y a VOMAR.

Para el escenario de todos los flujos activos, la capacidad resulta en **3.07 aeronaves**.

“FNA” SECTOR CAPACITY — RWY 30								
	%	N	%	N	%	N	%	N
VOMAR-XUDUN	100.00	3.2168771	50.00	1.60843855	33.333	1.07228165	44.06	1.41735605
NOSAT	100.00	2.78433642	50.00	1.39216821	33.333	0.92810286	30.53	0.85005791
PAULE	100.00	2.96527778	50.00	1.48263889	33.333	0.98841604	18.53	0.54946597
SIGMA	100.00	3.72361111	50.00	1.86180556	33.333	1.24119129	6.88	0.25618444
							TOTAL	3.07306438



The preceding figure depicts the FNA sector at maximum capacity under several different scenarios: (1) when all flow is concentrated on VOMAR (100%); (2) when all flow is concentrated on SIGMA (100%); and (3) when the arrival flow is split between SIGMA (50%) and VOMAR (50%). It can be observed that sector capacity is a function of the trajectory used, as well as the volume of traffic arriving via each trajectory.

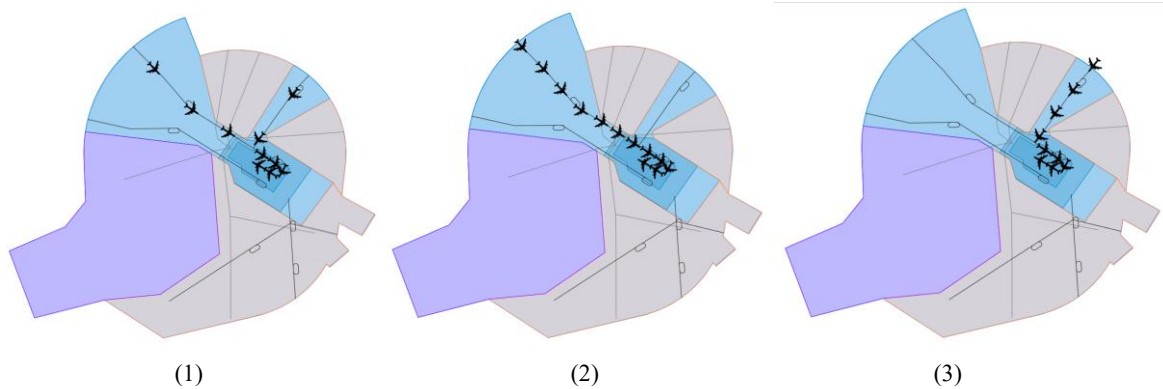
TOTAL INSTANTANEOUS TERMINAL AREA (TMA) CAPACITY — ARRIVALS, RWY 30

Finally, the instantaneous capacity results for the terminal control area (TMA) for MMUN RWY 30 arrivals are presented below. Instantaneous capacity values range from 8.364 aircraft, corresponding to the scenario in which the total flow is concentrated on NOSAT, to 12.51 aircraft, corresponding to the scenario in which the total flow is concentrated on SIGMA.

For a scenario with two inbound flows from NOSAT and VOMAR, a total capacity of 10.11 aircraft is obtained by summing the “N” values in the 50% column corresponding to NOSAT and VOMAR.

For the all flows active scenario, the resulting capacity is **10.8 aircraft**.

CAPACIDAD TOTAL TMA ARR RWY 30						
	%	N	%	N	%	N
VOMAR-XUDUN	100.00	11.8617003	50.00	5.93085017	44.06	5.22626517
NOSAT	100.00	8.36435185	50.00	4.18217593	30.53	2.55363662
PAULE	100.00	11.6993056	50.00	5.84965278	18.53	2.16788132
SIGMA	100.00	12.5125	50.00	6.25625	6.88	0.86086
					TOTAL	10.8086431



The preceding figure depicts the TMA at maximum instantaneous capacity under several different scenarios: (1) when the arrival flow is split between NOSAT (50%) and VOMAR (50%); (2) when all flow is concentrated on VOMAR (100%); and (3) when all flow is concentrated on NOSAT (100%). It can be observed that capacity is a function of the trajectory used, as well as the volume of traffic arriving via each trajectory.

CALCULATION OF TERMINAL AREA (TMA) CAPACITY — DEPARTURES, RWY 30 (ALL SECTORS)

Due to the aerodrome separation necessarily applied between two consecutive departures, departures are naturally sequenced before being delivered to the MMUN TMA departure sectors.

In accordance with the Letter of Agreement between MMUN APP and ACC MMID, APP shall transfer departing traffic established on the same ATS route with a minimum longitudinal separation of 10 NM.

In accordance with the methodology formulas, by applying the (de)compression factor, the separation that two aircraft will have at the transfer point to ACC MMID can be derived from the runway-applied separation used by MMUN TWR:

$$Q_x = \frac{v_x}{S_x}$$

$$S_x = \frac{v_x}{Q_x} = \frac{6.6185 \text{ NM/min}}{.55} = 12.033 \text{ NM}$$

The resulting separation is greater than the minimum established in the Letter of Agreement; therefore, this theoretical separation will be used for the TMA capacity calculation.

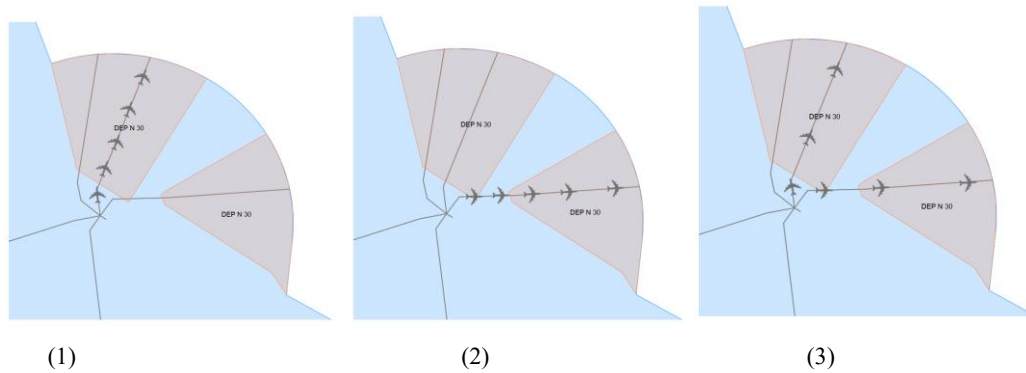
Since all departures for this analysis originate from the same runway, it is not possible for the departure sectors to be simultaneously at maximum capacity. Accordingly, the maximum capacity of each departure sector is broadly similar to the overall TMA capacity.

CALCULATION OF INSTANTANEOUS CAPACITY — NORTH DEPARTURES (DEP-N) SECTOR, RWY 30

The instantaneous capacity results for the DEP-N sector for MMUN RWY 30 departures are presented below. Instantaneous capacity values range from 5.39 aircraft, corresponding to the scenario in which the total flow is routed via NOSUG, to 6.23 aircraft, corresponding to the scenario in which the total flow is concentrated on DUGNI.

For the all flows active scenario, the resulting capacity is 5.56 aircraft

DEP- N CAPACITY								
	%	N	%	N	%	N	%	N
NOSUG	100.00	5.39883929	50.00	2.69941964	33.333	1.7995951	40.58	2.19084898
DUGNI	100.00	6.23416667	50.00	3.11708333	33.333	2.07803478	15.94	0.99372617
OMSUK	100.00	5.48594444	50.00	2.74297222	33.333	1.82862986	43.48	2.38528864
							TOTAL	5.56986379



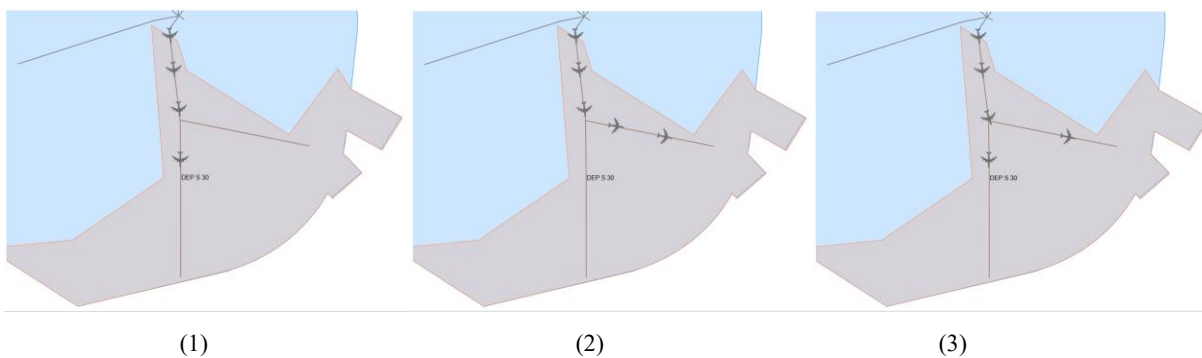
The preceding figure depicts the DEP-N sector at maximum capacity under several different scenarios: (1) when all flow is concentrated on OMSUK (100%); (2) when all flow is concentrated on DUGNI (100%); and (3) when the flow is distributed between the two trajectories above.

CALCULATION OF INSTANTANEOUS CAPACITY — SOUTH DEPARTURES (DEP-S) SECTOR, RWY 30

The instantaneous capacity results for the DEP-S sector for MMUN RWY 30 departures are presented below. Instantaneous capacity values range from 4.37 aircraft, corresponding to the scenario in which the total flow is routed via ALSUP, to 4.88 aircraft, corresponding to the scenario in which the total flow is concentrated on AVSEB.

For the all flows active scenario, the resulting capacity is **4.71 aircraft**.

DEP-S CAPACITY						
	%	N	%	N	%	N
ALSUP	100.00	4.37861111	50.00	2.18930556	33.33	1.45939108
AVSEB	100.00	4.88583333	50.00	2.44291667	66.67	3.25738508
					TOTAL	4.71677617

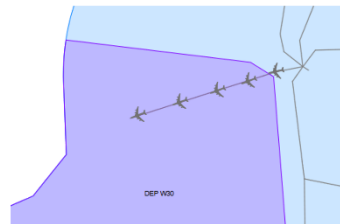


The preceding figure depicts the DEP-S sector at maximum capacity under several different scenarios: (1) when all flow is concentrated on ALSUP (100%); (2) when all flow is concentrated on AVSEB (100%); and (3) when the flow is distributed between the two trajectories above. It should be noted that, although from a horizontal perspective the trajectories could accommodate a greater number of simultaneously airborne aircraft, vertically the aircraft exit terminal airspace before the end of the departure procedure; therefore, capacity is determined by the vertical limit of the TMA in the sector concerned.

CALCULATION OF INSTANTANEOUS CAPACITY — WEST DEPARTURES (DEP-W) SECTOR, RWY 30

The instantaneous capacity results for the DEP-W sector for MMUN RWY 30 departures are presented below. Since this sector has only one departure trajectory associated with MMUN RWY 30 operations, the resulting capacity is **4.82 aircraft**.

DEP-W CAPACITY		
	%	N
UDGUV	100.00	4.82836538
TOTAL		4.82836538

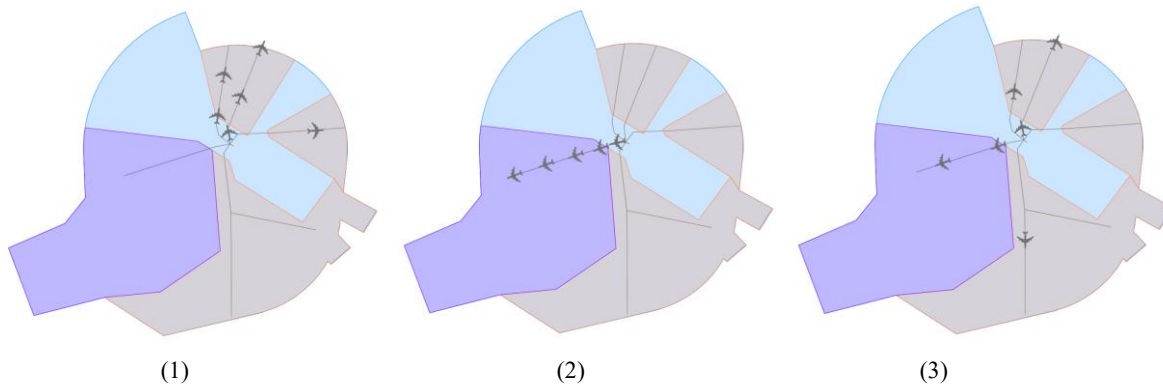


TOTAL INSTANTANEOUS TERMINAL AREA (TMA) CAPACITY — DEPARTURES, RWY 30

The instantaneous capacity results for the terminal control area (TMA) for MMUN RWY 30 departures are presented below. Instantaneous capacity values range from 4.71 aircraft, corresponding to the scenario in which the total flow is routed via SOUTH DEPARTURES (DEP-S), to 5.56 aircraft, corresponding to the scenario in which the total flow is routed via NORTH DEPARTURES (DEP-N).

For the all flows active scenario, the resulting capacity is **5.307 aircraft**.

TOTAL TMA CAPACITY								
	%	N	%	N	%	N	%	N
DEP-N	100.00	5.56416667	50.00	2.78208333	33.333	1.85470368	66.35	3.69182458
DEP-W	100.00	4.82836538	50.00	2.41418269	33.333	1.60943903	25	1.20709135
DEP-S	100.00	4.71675926	50.00	2.35837963	33.333	1.57223736	8.65	0.40799968
							TOTAL	5.30691561

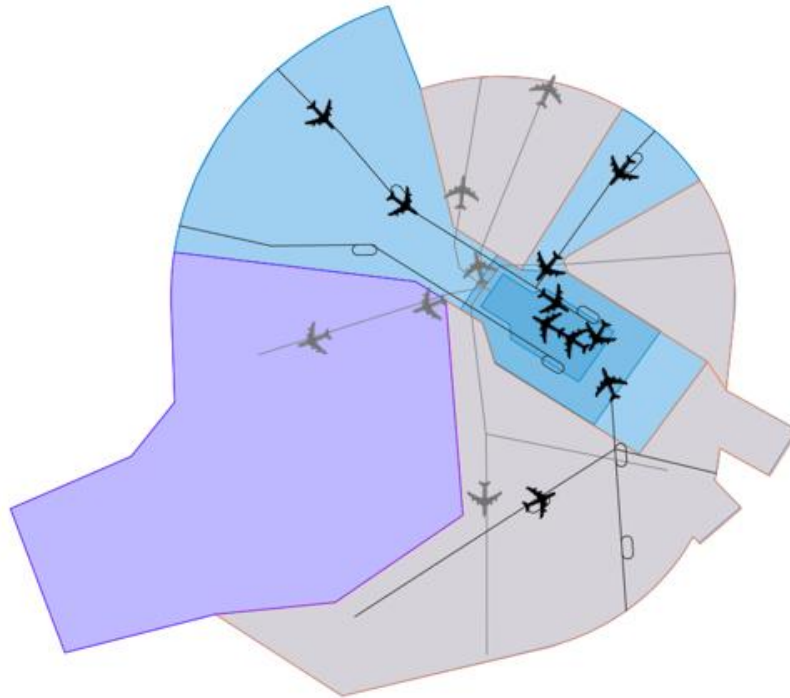


The preceding figure depicts the TMA at maximum capacity under several different scenarios: (1) when all flow is concentrated on DEP-N (100%); (2) when all flow is concentrated on DEP-W (100%); and (3) when the flow is distributed among the three sectors. TMA capacity is broadly consistent, regardless of the trajectories used.

TOTAL INSTANTANEOUS TERMINAL AREA (TMA) CAPACITY — RWY 30

The instantaneous capacity results for the terminal control area (TMA) for MMUN RWY 30 are presented below. Given the multiple possible scenarios, the value corresponding to a scenario in which aircraft are distributed among trajectories according to their historical utilization percentages is presented. The maximum values are also shown for scenarios in which departures and arrivals are each concentrated into a single flow (i.e., all departures via one sector and all arrivals via one trajectory), as well as scenarios in which departures and arrivals are split across two trajectories.

TOTAL TMA CAPACITY — RWY 30						
	%	N	%	N	%	N
VOMAR-XUDUN	100.00	11.8617003	50.00	5.93085017	44.06	5.22626517
NOSAT	100.00	8.36435185	50.00	4.18217593	30.53	2.55363662
PAULE	100.00	11.6993056	50.00	5.84965278	18.53	2.16788132
SIGMA	100.00	12.5125	50.00	6.25625	6.88	0.86086
DEP-N	100.00	5.56416667	50.00	2.61387418	66.35	3.69182458
DEP-W	100.00	4.82836538	50.00	2.63797628	25	1.20709135
DEP-S	100.00	4.71675926	50.00	2.36957569	8.65	0.40799968
	Total Máx.	18.0766667	Total Máx.	17.4389506	TOTAL	16.1155587



CALCULATION OF INSTANTANEOUS CAPACITIES — MMCZ RWY 12

In accordance with the methodology presented previously, the corresponding calculations were performed for MMCZ under the RWY 12 configuration, yielding the following results:

Arrivals - RWY 12:

- DEP-W sector capacity: 1.89 aircraft
- ARR sector capacity: 1.52 aircraft
- Total TMA capacity (ARR): 2.29 aircraft

“DEP-W” SECTOR CAPACITY — ARR, CZM RWY 12								
	%	N	%	N	%	N	%	N
EMOSA	100.00	0.95	50.00	0.475	33.333	0.3166635	26.3157895	0.25
ULIPA	100.00	2.2287037	50.00	1.11435185	33.333	0.74289381	42.1052632	0.93840156
VIGTU	100.00	2.23819445	50.00	1.11909722	33.333	0.74605735	31.5789474	0.70679825
							TOTAL	1.89519981

ARR” SECTOR CAPACITY — ARR, CZM RWY 12								
	%	N	%	N	%	N	%	N
EMOSA	100.00	1.52111111	50.00	0.76055556	33.333	0.50703197	26.3157895	0.4002924
							TOTAL	1.52111111

TOTAL TMA CAPACITY (ARRIVALS) — CZM						
	%	N	%	N	%	N
EMOSA	100.00	2.47111111	50.00	1.23555556	44.06	0.6502924
ULIPA	100.00	2.2287037	50.00	1.11435185	30.53	0.93840156
VIGTU	100.00	2.23819445	50.00	1.11909722	18.53	0.70679825
						2.2954922

Departures - RWY 12:

- DEP-S sector capacity: 1.89 aircraft
- Total TMA capacity (DEP): 2.29 aircraft

“DEP-S” SECTOR CAPACITY — CZM RWY 12 (DEP)								
	%	N	%	N	%	N	%	N
DEP-N	100.00	1.55555556	50.00	0.77777778	33.333	0.51851333	53.85	0.83766667
DEP-W	100.00	0	50.00	0	33.333	0	37.5	0
DEP-S	100.00	0	50.00	0	33.333	0	8.65	0
							TOTAL	1.55555556

CALCULATION OF INSTANTANEOUS CAPACITIES — MMTL RWY 12

In accordance with the methodology presented previously, the corresponding calculations were performed for MMTL under the RWY 12 configuration, yielding the following results:

Arrivals - RWY 12:

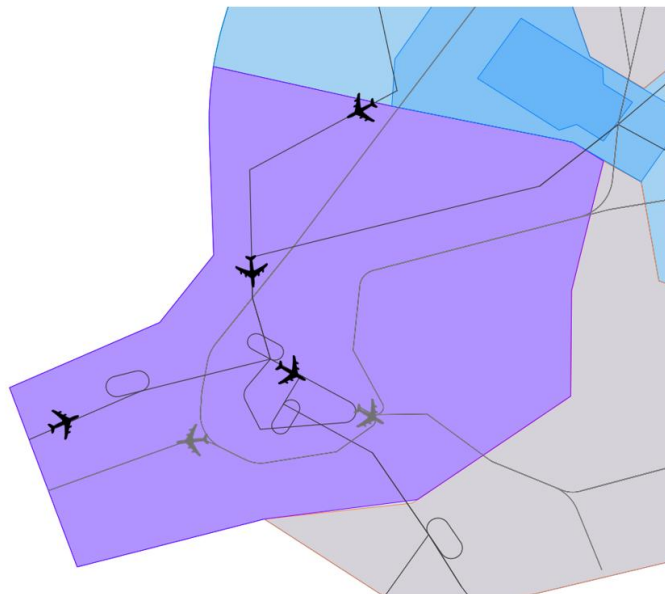
- DEP-W sector capacity: 3.6 aircraft
- Total TMA capacity (ARR): 3.6 aircraft

DEP-W" SECTOR CAPACITY — ARR, TQO RWY 12								
	%	N	%	N	%	N	%	N
EMOSA	100.00	4.15555555	50.00	2.07777778	33.333	1.38517133	8	0.33244444
VIGTU	100.00	3.27733333	50.00	1.78296296	33.333	1.18863009	72	2.56746667
VIVUS	100.00	3.58111111	50.00	1.79055556	33.333	1.19369177	20	0.71622222
							TOTAL	3.61613333

Departures - RWY 12:

- DEP-W sector capacity: 2.29 aircraft
- Total TMA capacity (DEP): 2.29 aircraft

"DEP-W" SECTOR CAPACITY — TQO RWY 12 (DEP)		
	%	N
DEP-W	100.00	2.29888889
	TOTAL	2.29888889



MAXIMUM INSTANTANEOUS CAPACITY CALCULATIONS FOR EACH SECTOR — MMUN TMA (RWY 12)

Based on the information presented above in this document, the maximum instantaneous capacities of each sector within the MMUN TMA, for each aerodrome, can be summarized in the following tables:

Independent maximum instantaneous capacity (based on trajectory capacity, without considering a single arrival sequence per aerodrome):

SECTOR	ARR	APP	FNA	DEP-S	DEP-W	DEP-N
CUN ARR 12	4.9406956	2.4230918	4.1508409	3.004215		
CUN DEP 12				5.076481	5.275953	5.227734
CZM ARR 12	1.521111				1.8952	
CZM DEP 12				1.55555556		
TQO ARR 12					3.616133	
TQO DEP 12					2.298889	
TOTAL	6.461807	2.423092	4.150841	9.636252	13.08617	5.227734

Dependent maximum instantaneous capacity (based on trajectory capacity, and considering a single arrival sequence for each aerodrome):

SECTOR	ARR	APP	FNA	DEP-S	DEP-W	DEP-N
CUN ARR 12	3.676162	2.128571	3.773025	0.766887		
CUN DEP 12				0.439117	1.978482	2.815142
CZM ARR 12	0.400292				1.8952	
CZM DEP 12				1.55555556		
TQO ARR 12					3.616133	
TQO DEP 12					2.298889	
TOTAL	4.076455	2.128571	3.773025	2.76156	9.788704	2.815142
TOTAL GENERAL	25.343457					

The dependent maximum instantaneous capacity values may be summed to obtain the TMA maximum instantaneous capacity. Aircraft are distributed among sectors in accordance with historical flow percentages.

Capacity as a Function of Controller Workload.

Analogously to the previous tables, sector capacity may be derived by taking controller workload into account, as a function of the mean flight time in each sector. The flight times are presented in the following table:

SECTOR	ARR	APP	FNA	DEP-S	DEP-W	DEP-N
CUN ARR 12	6.009818	3.625155	6.728778	5.975		
CUN DEP 12				9.23	9.592641	9.504997
CZM ARR 12	5.7				8.982014	
CZM DEP 12				9.333333		
TQO ARR 12					14.2413333	
TQO DEP 12					8.620833	
PROM. TOTAL	5.854909	3.625155	6.728778	8.179444	10.35921	9.504997

A partir de los tiempos anteriores, es posible calcular, utilizando la fórmula expuesta en el capítulo IV, la capacidad de cada sector tomando en cuenta únicamente la carga de trabajo del controlador:

SECTOR	ARR	APP	FNA	DEP-S	DEP-W	DEP-N
T PROM.	5.854909	3.625155	6.728778	8.179444	10.35921	9.504997
Capacidad	9.75818167	6.041925	11.21463	13.6324067	17.26535	15.8416617

Por lo cual, se puede establecer como la capacidad instantánea máxima, al menor de los valores de capacidad instantánea obtenida, ya sea por capacidad de trayectorias, o por carga de trabajo

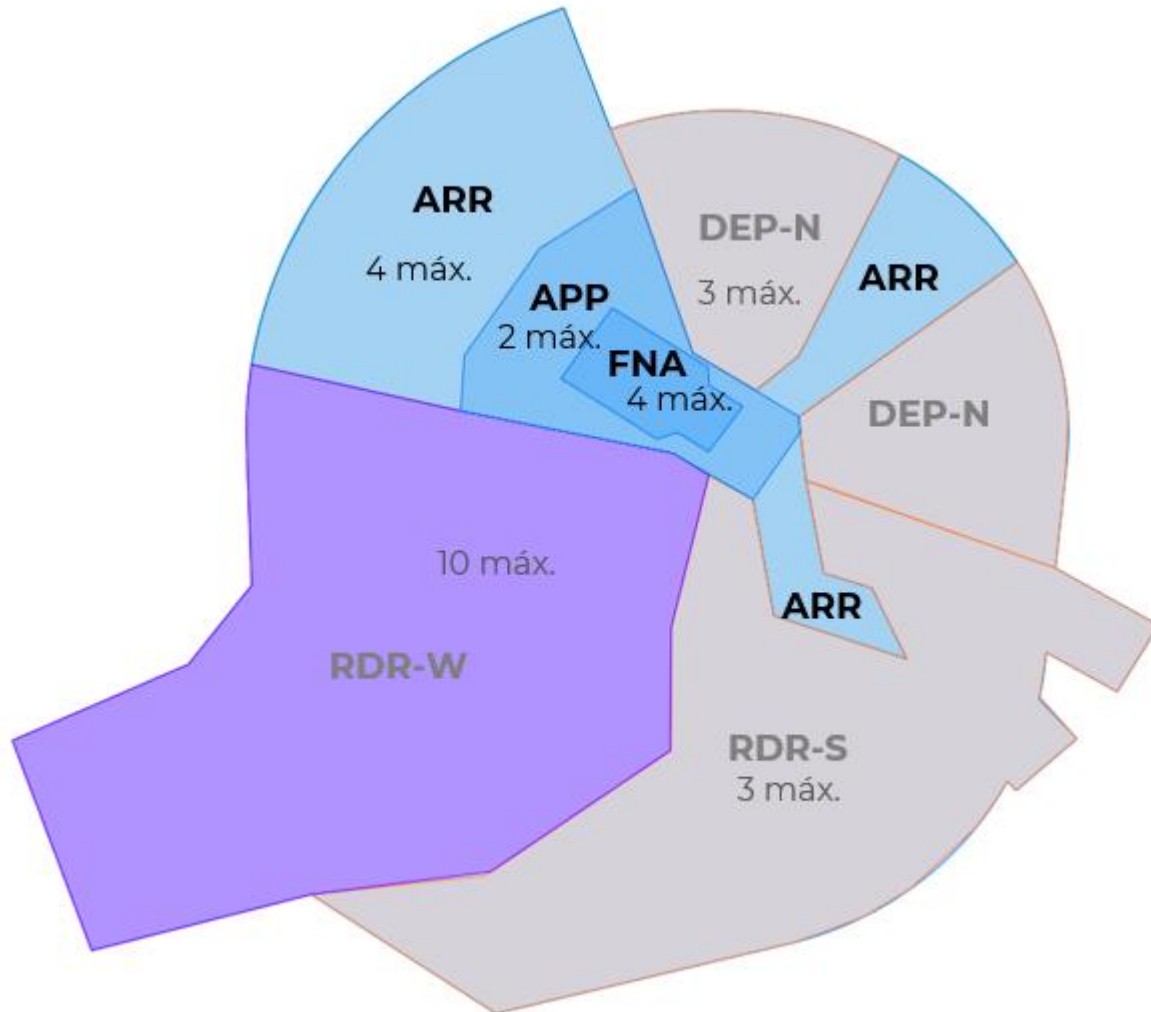
Capacidad	ARR	APP	FNA	DEP-S	DEP-W	DEP-N
Carga trabajo ATC	9.75818167	6.041925	11.21463	13.6324067	17.26535	15.8416617
independiente	6.461807	2.423092	4.150841	9.636252	13.08617	5.227734
dependiente	4.076455	2.128571	3.773025	2.76156	9.788704	2.815142
declarada	4.076455	2.128571	3.773025	2.76156	9.788704	2.815142

Se puede observar que, en todos los casos, la capacidad por trayectorias es menor a la determinada por la carga de trabajo del ATC, por lo cual la primera se toma como definitiva para establecer la capacidad declarada.

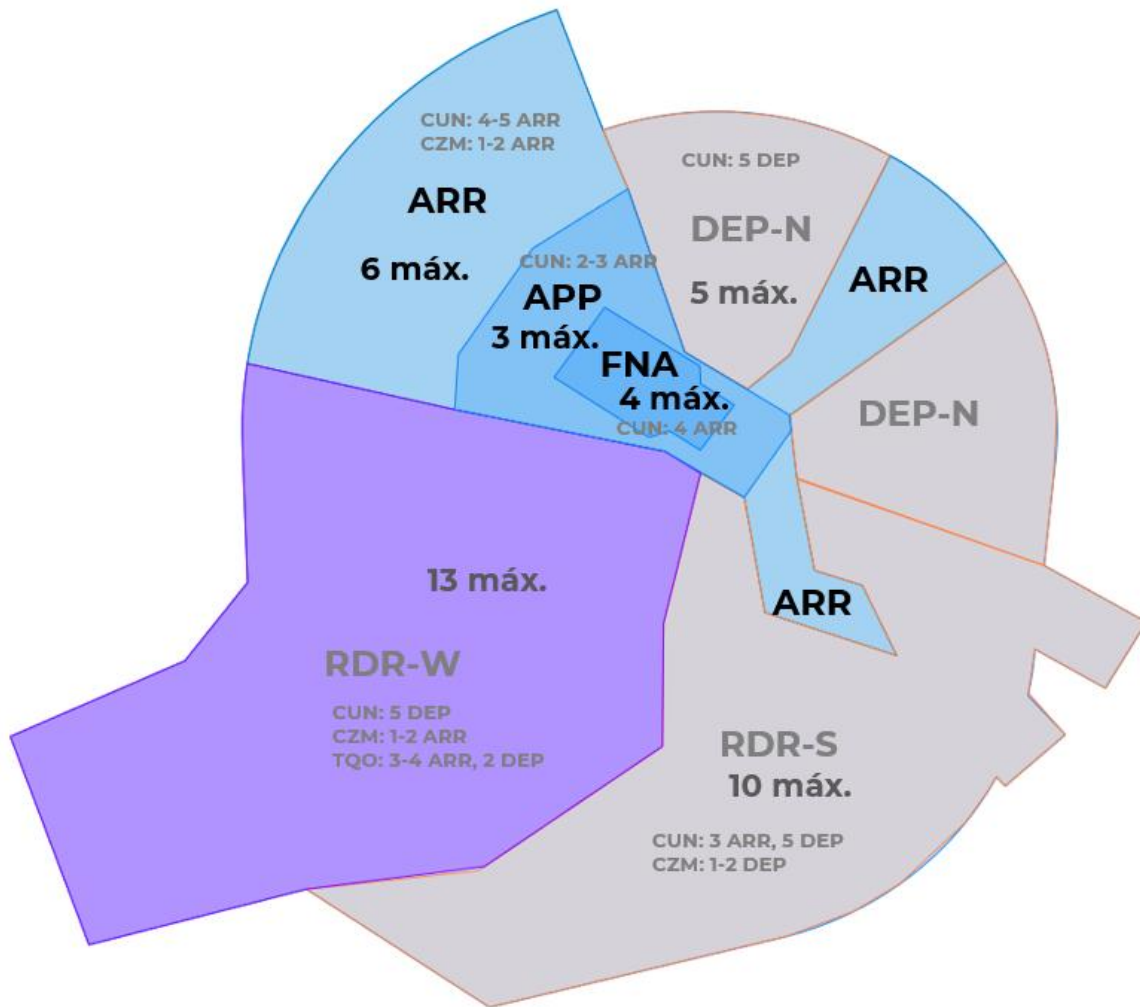
CHAPTER VI – DECLARED INSTANTANEOUS ATC SECTOR CAPACITY

The declared maximum instantaneous capacity values for each terminal sector of the MMUN TMA, under the RWY 12 configuration, are presented below.

All flows active:



The values presented herein correspond to the maximum sector capacity under an all-flows-active scenario. In this case, not all sectors are at their true maximum capacity (i.e., their trajectories are not fully saturated); however, this capacity “margin” is required in order to enable sequencing of traffic from all trajectories and to consolidate them into only three arrival flows (one for each aerodrome).

Absolute maximum capacity:

The values shown in the preceding diagram correspond to the maximum simultaneous capacity of the trajectories contained within each terminal sector of the MMUN TMA. It should be noted that these capacities can only be achieved when the entirety of a given aerodrome's arrival or departure flow is concentrated within a single sector; therefore, it is physically impossible for these values to be achieved simultaneously.

In other words, if at any given time the maximum capacity of, for example, the RDR-W sector is reached, this implies that the DEP-N sector would have virtually no aircraft airborne (since the entire CUN departure flow would be routed to RDR-W via UDGUV). Conversely, when the DEP-N sector is at its absolute maximum capacity, this would imply that RDR-W would not exceed approximately 7 simultaneously airborne aircraft (corresponding to traffic from CZM and TQO, with none from CUN).

CHAPTER VI – SEPARATION CALCULATIONS

Based on the results obtained previously, the required longitudinal separations between aircraft operating on the same trajectory can be determined in accordance with the formulas established in the methodology and the sampled ground speed (GS) values.

Longitudinal separations — MMUN RWY 12

Trajectory	Single flow	2 Flows	3 Flows
VOMAR	11.3727608	22.7455215	34.1182823
NOSAT	11.3727608	22.7455215	34.1182823
PAULE	12.1994222	24.398844	36.598266
SIGMA	11.3727608	22.7455215	34.1182823
ILUBA	11.3727608	22.7455215	34.1182823

Separaciones longitudinales para MMUN- RWY 30

Trajectory	Single flow	2 Flows	3 Flows
VOMAR-AGNIX	12.5323	25.0645999	37.596899
NOSAT	11.3727608	22.7455215	34.1182823
PAULE	11.5715251	23.1430502	34.7145753
SIGMA	11.3727608	22.7455215	34.1182823
ILUBA	11.3727608	22.7455215	34.1182823

PROPOSED STANDARDIZED SEPARATIONS FOR MMUN — BOTH RUNWAYS

Considering the preceding results, the following standardized separations are proposed for practical use by the involved ATC units. These separations account for the increase in terminal airspace capacity attributable to the tactical vectoring required to sequence traffic arriving via different trajectories and to integrate it into a single flow to the runway.

The PAULE, SIGMA and ILUBA trajectories are treated as dependent and are integrated into a single flow.

Trajectory	Single flow	2 Flows	3 Flows
VOMAR	12 NM	20 NM	22 NM
NOSAT	12 NM	20 NM	22 NM
PAULE/SIGMA/ILUBA	N/A	N/A	30 NM

It should be noted that no minimum separation values are established for the southern flow (PAULE/SIGMA/ILUBA), since statistically this flow is only observed in practice in conjunction with the NOSAT and VOMAR flows.

The above separations reduce, within an operationally acceptable safety margin, the values obtained by calculation; however, they require air traffic controller intervention and, therefore, do not guarantee that traffic will remain on the published lateral path and vertical profile of the procedure. Greater separations are required to ensure maximum operational efficiency within the MMUN terminal area.

APPENDIX B
EXAMPLE APPLICATION OF THE MATHEMATICAL MODEL IN AN ATC SECTOR OF A FICTITIOUS
TERMINAL CONTROL AREA.

The objective is to determine the ATC sector capacity for “ARRIVALS W” within a terminal control area serving a single-runway aerodrome.

The aerodrome runway has an AAR of 40 aircraft per hour for the RWY 09 configuration. There are four arrival trajectories, designated a, b, c, and d. The diagram indicates the traffic percentages for each trajectory over one hour.

Trajectories “a” and “b” are the only ones that traverse the “ARRIVALS W” ATC sector. The published terminal entry speeds are 280 kt IAS, which correspond to 390 kt ground speed (GS).

The average flight times within the sector for trajectories “a” and “b” are $t_a = 14 \text{ min}$ and $t_b = 12 \text{ min}$, respectively.

The average aircraft speed in the final approach segment is 120 kt.

The following data are available:

$$AAR = 40 \text{ acft/h}$$

$$v_f = 130 \text{ kts (120 IAS)}$$

For the inbound trajectories:

$$p_a = .50$$

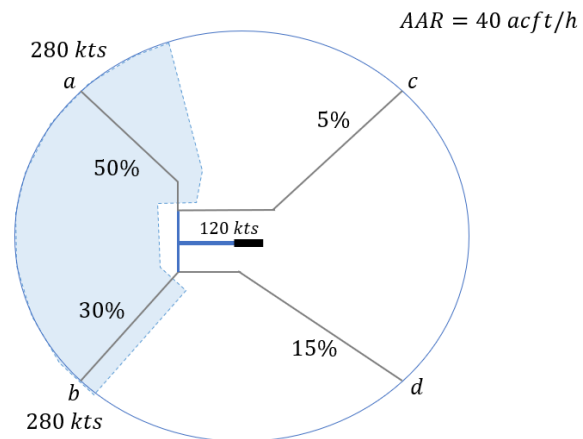
$$p_b = .30$$

$$p_c = .15$$

$$p_d = .05$$

$$v_a = v_b = 390 \text{ kts (280 IAS)}$$

$$T_a = 14 \text{ min}, T_b = 12 \text{ min}$$



Procedure.

Based on the AAR, the arrival percentages for trajectories “a” and “b” (which are the trajectories that traverse the sector in question), and the average flight time for each trajectory, the capacity of each trajectory within the sector can be calculated as follows:

$$n_a = \frac{AAR \cdot p_a}{60} \cdot T_a$$

$$n_a = \left(\frac{40 \frac{acft}{h} \cdot (.5)}{60} \right) \cdot (14 \text{ min}) = 4.666 \text{ acft}$$

$$n_b = \left(\frac{40 \frac{acft}{h} \cdot (.3)}{60} \right) \cdot (12 \text{ min}) = 2.4 \text{ acft}$$

This yields the total sector capacity:

$$PIAC = \sum_{y=1}^e n_y = n_a + n_b$$

$$PIAC = 7.066 \text{ acfts} \approx 7 \text{ Aircraft}$$

Additionally, based on the ground speed values at the entry points, the required longitudinal separations at those points can be calculated in order to sequence the aircraft:

$$S_a = \frac{V_{Gsa}}{AAR * p_a}$$

$$S_a = \frac{280 \text{ kts}}{40 \frac{acft}{h} \cdot (.5)}$$

$$S_a = 14 \text{ NM}$$

$$S_b = \frac{280 \text{ kts}}{40 \frac{acft}{h} \cdot (.3)}$$

$$S_b = 23 \text{ NM}$$