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**INTERNATIONAL CIVIL AVIATION ORGANIZATION**

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**ATC SECTOR AND AIRPORT CAPACITY ASSESSMENT METHODOLOGY**

*SAM MODEL*

*Abuja, 8-12 July 2024*

*By ATM SECTION ICAO WACAF*

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**UNPREPAREDNESS LEADS TO CHAOS**



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# INTRODUCTION

**CONTEXT**
- Air traffic flow management (ATFM) shall be implemented for airspace where air traffic demand at times exceeds, or is expected to exceed, the declared capacity of the air traffic control services concerned. (AN11, STD 3.7.5.1)
- *ATFM should be implemented on the basis of regional air navigation agreements or, if appropriate, through multilateral agreements. Such agreements should make provision for common procedures and common methods of capacity determination. (AN11, REC 3.7.5.2)*

- Capacity determination requires the use of a selected suitable methodology.

- Several methodologies for determining ATC sector exist worldwide. However, there is no regionally agreed such methodologies for the AFI region.

- South America region has developed a methodology which is regionally accepted by its members as a guide on how to apply a common methodology to calculate airport and ATC sector capacity.
- There are similarities between SAM and AFI in some major traffic flow, in airspace operations, weather etc.

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# INTRODUCTION

**DEFINITIONS**

- ✓ **DECLARED CAPACITY:** A measure of the <span style="color:red">ability</span> of the ATC system or any of its subsystems or operating positions to provide service to aircraft during normal activities. It is expressed as the number of aircraft entering a specific portion of airspace in a given period of time, taking due account of weather, ATC unit configuration, available staff and equipment, and any other factor that may affect the workload of the controller responsible for the airspace.
- ✓ **ATC SECTOR CAPACITY** represents the <span style="color:red">maximum number</span> of flights entries that can be safely assigned to a sector air traffic controllers.

- ✓ **ATC OPERATIONAL CAPACITY:** the expected capacity associated with the tactical situation at the airport or airspace
- ✓ **ATC WORKLOAD:** The time spent by the ATC on observable and non-observable tasks in his/her sector to handle the flow of air traffic while on duty.
- ✓ **ATC AVAILABILITY:** The time needed by ATC to plan aircraft separation procedures (recuperation time)

- ✓ **ADJUSTMENT FACTORS:** Factors that can impact the flow of air traffic, thus influence the declared capacity.

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# BASE MODEL

## DORATASK MODEL

- ✓ **BACKGROUND:** Model developed by the United Kingdom Operational Research and Analysis Bureau to estimate ATC sector capacity (TMA and En-route).

- ✓ **SCOPE:** Centered on the assessment of ATC workload and recovery time

- ✓ **APPLICABILITY:** TMA and En Route sectors.

- ✓ **KEY ELEMENTS:**
  - **Observable tasks**: ATC actions that can be observed such as telephone coordination, RT clearance delivery, strip marking etc.
  - **Non-observable tasks**: ATC actions that cannot be traced with bare eyes such confliction detection, conflict resolution planning as well as flight progress monitoring on stripboard or radar screen.
  - **Recovery time**: Time needed by ATC out of busy time to recuperate as per safety consideration of operations.

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# BASE MODEL

**DORATASK MODEL**

✓ **PRINCIPLE:**

<mark>THE AVERAGE WORKLOAD AT CAPACITY MUST BE LESS THAN 80 PER CENT AND WORKLOADS OF 90 PER CENT MUST NOT BE EXCEEDED MORE THAN 2.5 PER CENT OF THE TIME."</mark>

*Example:* FOR A BASE WORKING TIME OF 60 MIN
The hourly average ATC workload will be 48min at most AND the hourly workload of 90% should not be exceeded for more than 1min30sec.

# MODEL COMPONENTS AND OUTPUT

❏ **SOUTH AMERICA METHODOLOGY FOR ATC SECTOR CAPACITY CALCULATION**

✓ **SUMMARY:** Based on the principles of the DORATASK Model. The methodology applies a mathematical formular that was established based on operational investigation by a special working group during five busiest days at APP and ACC sectors by observing and timing ATCOs' actions and availability to manage control sector.

✓ **SCOPE:** The methodology applies to TMA and En route sectors.

✓ **ASSUMPTIONS:**
- Each observation last 60 minutes
- The number of observation of each parameter depends on the number of ATCOs in the sector but must be at least 30.
- Observation are done during the busiest periods of the year in the target sector
- Operational factors such as weather, airspace complexity, contingency events are not considered in the initial stage of the calculation.

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# MODEL COMPONENTS AND OUTPUT

❏ **SOUTH AMERICA METHODOLOGY FOR ATC SECTOR CAPACITY CALCULATION**

✓ **MODEL OUTPUT:** the number of aircraft (N) that can be controlled simultaneously by a single controller in a given sector is

$$(1) \quad N = \frac{\phi.\delta}{\eta.\tau_m.\nu_m}$$

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# MODEL COMPONENTS AND OUTPUT

❑ **SOUTH AMERICA METHODOLOGY FOR ATC SECTOR CAPACITY CALCULATION**

$$N = \frac{\Phi \cdot \delta}{\eta \cdot \tau_m \cdot \nu_m}$$

✓ **COMPONENTS**

- **N=Maximum number of aircraft simultaneously controlled by a single controller in a sector**
- $\Phi$=**The ATC availability factor. It is supplementary to the workload factor (W). Therefore, ϕ + W = 100%** **of 60min**
- $\delta$= **Average distance flown by aircraft in the sector**
- $\eta$= **Average number of communication for aircraft in the sector** (must be limited to the least possible number required for an understanding between the pilot and the controller)
- $\tau_m$ = **Average duration of each communication (**can be minimised by issuing messages objectively)

- $\nu_m$ = **Average speed of aircraft in the sector**

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# MODEL COMPONENTS AND OUTPUT

❑ **SOUTH AMERICA METHODOLOGY FOR ATC SECTOR CAPACITY CALCULATION**

$$(2) \quad N = \frac{\Phi \cdot T}{\eta \cdot \tau_m} \quad \left(\text{Where } T = \frac{\delta}{\nu_m}\right)$$

✓ **COMPONENTS**

- **N=Maximum number of aircraft simultaneously controlled by a single controller in a sector**
- **$\Phi$=The ATC availability factor. It is supplementary to the workload factor (W). Therefore, ϕ + W = 100% of 60min**
- *T*= *Average flight time of aircraft in the sector*
- **$\eta$= Average number of communication for aircraft in the sector** (must be limited to the least possible number required for an understanding between the pilot and the controller)
- **$\tau_m$ = Average duration of each communication.**

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# DATA SAMPLING TECHNIQUE

❑ **DATA TO COLLECT**

• *Data to calculate ATC workload*

✓ *Routine tasks* such as entry/exit coordination, normal A/G communication without conflict, strip marking.

✓ *Conflict detection and resolution tasks* including screen and flight strip screening, tactical resolution planning, actual communications for resolution, conflict monitoring

✓ *Level change tasks* including level change scrutiny, level change communications, level change monitoring.

| TABLE 4- ATC OBSERVABLE TASKS AVERAGE TIMING | | | | | | | |
|---|---|---|---|---|---|---|---|
| UNIT:          SECTOR:          DATE:    /    / | | | | | | | |
| ATC # | Average duration of entry coordination (in sec) | Avetage duration of ATC clearance delivery on RT (in sec) | Average duration of tactical conflict resolution on RT (in sec) | Average duration of level change without conflict | Average time spent on strip markings (in sec) | Average duration of exit coordination (in sec) | Average duration of tranfer of control (in sec) | Number of aircraft handled in 60 min during peak hours |
| | | | | | | | |
| ATC 1 | 10 | 10 | 120 | | 10 | 10 | 10 | 10 |
| ATC 2 | 10 | 10 | 60 | | 10 | 10 | 10 | 10 |
| ATC 3 | 10 | 10 | 60 | | 10 | 10 | 10 | 12 |
| ATC 4 | 10 | 10 | 80 | | 10 | 10 | 10 | 10 |

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# DATA SAMPLING TECHNIQUE

❑ **DATA TO COLLECT**

• *Data to calculate the average flight time of aircraft in the sector*

  ✓ *aircraft registration,*

  ✓ *type of aircraft,*

  ✓ *Entry and exit time*

  ✓ *Entry and exit flight levels*

| TABLE 2-SURVEY OF FLIGHYT TIME IN THE SECTOR | | | | | | |
|---|---|---|---|---|---|---|
| UNIT: | SECTOR: | | DATE: / / | | TIMING: 60 MIN | |
| A/C Registration | A/C Type | Entry time into sector | Exit time from sector | Duration | Entry Flight level | Exit Flight level |
| | | | | | | |
| | | 11:00 | 12:12 | 900 | 340 | 360 |
| | | 11:01 | | 900 | | |

# DATA SAMPLING TECHNIQUE

❑ **DATA TO COLLECT**
- ***Data to calculate the average number of communication and related duration for each aircraft***
  - ✓ *Aircraft registration*
  - ✓ *Type of aircraft*
  - ✓ *Duration of each communication with ATC*
  - ✓ *Number of communications*

| TABLE 3-ATC AIR-GROUND COMMUNICATION TIMING | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| UNIT:       SECTOR:       DATE:   /   / | | | | | | | | | | |
| **A/C Registration** | **Timing of A/G radiotelephony communication messages (in seconds)** | | | | | | | | | |
| | A/G Msg 1 | A/G Msg 2 | A/G Msg 3 | A/G Msg 4 | A/G Msg 5 | A/G Msg 6 | A/G Msg 7 | A/G Msg 8 | A/G Msg 9 | A/G Msg 10 |
| | 22 | 10.00 | 10.00 | 10.00 | 8.00 | 9.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | 10.00 | 10.00 | 10.00 | 10.00 | 7.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | 11.00 | 9.00 | 10.00 | 11.00 | 9.00 | 20.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | 11.00 | 9.00 | 10.00 | 11.00 | 9.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | 11.00 | 9.00 | 10.00 | 11.00 | 9.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |

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# DATA SAMPLING TECHNIQUE

❑ **DETERMINING THE MINIMUM NUMBER OF INVESTIGATION SESSIONS IN THE SECTOR**

✓ **One ATCO at a time is observed at each session**
✓ **The number of sessions considers:**
  -*the number of sectors to be included in the study*

  -*the total number of air traffic controllers in the sectors combined*

  -*the number of shifts in 24 Hours.*

  -*A sample reliability level of 1.96*

  -*A tolerance factor of 0.05*

  -*the proportion of the population to be observed (the likelihood of a targeted ATC being observed in each session)*

  -*the proportion of the population not in interest (the likelihood of observing different ATCOs in each session)*

**Minimum number of sessions=30**

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# DATA SAMPLING TECHNIQUE

❑ **DETERNIMING THE MINIMUM NUMBER OF OBSERVATION OF EACH PARAMETER**

Study conducted indicates that it is advisable to make at **least 30 observations of each parameter** for each controller, during peak traffic, respecting the minimum number of controllers specified by the sampling technique used.

| Sessions | Parameter 1=communication | Parameter 2=strip marking | Parameter 3=conflict resolution | Parameter 4=level change management | Parameter 5=coordination | Parameter n... |
|---|---|---|---|---|---|---|
| Session 1 | 30 | 30 | 30 | 30 | 30 | 30 |
| Session 2 | 30 | 30 | 30 | 30 | 30 | 30 |
| Session 3 | 30 | 30 | 30 | 30 | 30 | 30 |
| Session 4 | 30 | 30 | 30 | 30 | 30 | 30 |
| Etc. | 30 | 30 | 30 | 30 | 30 | 30 |

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# STEPS OF THE METHODOLOGY

❏ **STEP 1: DETERMINE THE SIZE OF THE SAMPLE NEEDED**

*-Size of the population to be observed*

*-Size of each parameter to be timed during observation*

❏ **STEP 2: COLLECTION, PROCESSING AND STORAGE OF DATA FOR THE CALCULATION OF ATC SECTOR CAPACITY**

*-Classify data based on their subsequent utilization : Data related to ATC workload, data related to flight time, data related to communication between ATC and aircraft.*

❏ **STEP 3: CALCULATE THE ATC WORKLOAD**

*-Sum up the time spent by each ATC on each parameter during 60 min*

*-Calculate the average time spent on tasks by all ATC observed in 60 min which will be the ATC workload.*

*-Calculate the workload factor {W=(average time spent on tasks by all ATC/60)X100}*

❏ **STEP 4: CALCULATE THE AVAILABILITY FACTOR (φ)**

**Φ = 100 - W**

❏ **STEP 5 : CALCULATE THE AVERAGE FLIGHT TIME IN THE SECTOR**

-Sum up the flight time of all aircraft recorded during the observations

-Divide the sum of flight times by the number of aircraft observed in the sector in 60min.

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# STEPS OF THE METHODOLOGY

❑ **STEP 6: CALCULATE THE AVERAGE TIME DEDICATED TO COMMUNICATION**

*-Count the number of communication per type (entry com, conflict resolution com, level change com, transfer com etc.)*

*-Sum up the times of each type of communication then multiply it by the corresponding number of communications (the weighted average times for each type communication)*

*-Calculate the time dedicated to communication by summing up all weighted total time of each communication type divided by the number of types.*

❑ **STEP 7: CALCULATE THE ATC SECTOR CAPACITY (N)**

*-Calculate the ATC Sector capacity by multiply the ATC availability factor by the average flight time of aircraft in the sector then divide by the average weighted communication time.*

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# STEPS OF THE METHODOLOGY

❑ **DEMO**

**Scenario:** In sector A, the average hourly workload is 36min. 5 Aircraft (V1=480Kts) spend 20min, 3 aircraft (V2=440Kts) spend 30min, 2 aircraft (V3=400Kts) spend 35min in average in the sector during which ATC communicates for 5s of entry communication with each, 5s for 3 level changes, 10s for one conflict resolution and 5s for each transfer of control. Calculate the capacity of sector A.

- Availability factor **φ**= 100%-(36/60)x100%=(100-60)%=**40%**
- Average flight time:

-For aircraft in V1: 20X5=100min

-For aircraft in V2: 30X3=90min          T=(100 + 90 + 70)/10= **26 minutes in sector A=26min x60s= 1560s**

-For aircraft in V3: 35X2=70min

- **Average weighted communication time:**

-For entry communication: 5sX10= 50s          $\tau_m$ = (50+15+10+50)/24=5.2s     $\eta$=24/10=3 messages per aircraft

-For level change: 5sX3= 15s          $\eta . \tau_m$ = 5.2x3= **15.6s**

-For conflict resolution: 10sX1=10s

-For Transfer of control: 5sX10= 50s

$$N= \frac{40\% \times 1560}{15.6} = 40 \text{ aircraft/hour}$$

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# ADJUSTMENT FACTORS

❑ **FACTORS TO CONSIDER**
- Bad weather
- Airspace characteristics (Size, type, number of SUA, routes configurations, FRA)
- Type of traffic (mix civil/military, cruise, climb/descent, IFR, VFR etc.)
- Number of ATCOs
- CNS infrastructure (COM (VHF, HF, CPDLC); NAV (Conventional, PBN); SUR (ADS-B, ADS-C))

❑ **ADJUSTMENT FACTORS TO APPLY**
**percentage?    Relative values?**

❑ **ATC SECTOR CAPACITY ADJUSTED**

ATC SECTOR CAPACITY ADJUSTED = DECLARED ATC CAPACITY +/- ADJUSTMENT VALUE

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Thank You!