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*English only*

**International Civil Aviation Organization  
South American Regional Office**

**FOURTH WORKSHOP /MEETING OF THE SAM IMPLEMENTATION GROUP (SAM/IG/4)  
REGIONAL PROJECT RLA/06/901**

**Lima, Peru, 3 to 7 November 2009**

**Agenda**

**Item 5: Implementation of the air traffic flow management (ATFM) in the SAM Region**

**ATC CAPACITY CALCULATION – SECTORS 9 AND 10 (COMBINED) OF FIR CURITIBA**

(Presented by CGNA- Brazilian Air Navigation Management Center)

**Summary**

This working paper aims to submit to ICAO, an example of ATC capacity calculation in the sector 09 combined with sector 10 of FIR Curitiba with the methodology adopted by Brazil.

**Reference:**

- ICA 100-30- ATC personnel planning and work timetable, Airspace Control Department (DECEA). Rio de Janeiro, 2007

**1 Introduction**

1.1 In order to maintain the air traffic flow near the optimal conditions, avoiding possible overflow in the system, the Brazilian Air Navigation Management Center (CGNA) applies standard analytical procedures for ATC Sector capacity calculations, defined by DECEA in ICA 100-30 (ATC personnel planning). These procedures help to cope with the variation in the demand/capacity at the sectors of a FIR or a TMA, giving parameters which support ATFM measures in advance and to keep the overall operation in harmony.

1.2 In the following sessions, it is presented the procedures used for the ATC capacity calculation in the sector 09 combined with sector 10 of FIR Curitiba with the methodology adopted by Brazil.

## 2 Discussion

### 2.1 Capacity investigation through mathematical model

In Brazil, the reference number of aircraft that can be simultaneously controlled by a controller (N), within the sector at issue, is calculated through the following formula (ICA 100-30 ATC personnel planning):

$$N = \phi \cdot \delta \cdot (\eta \cdot \tau_m \cdot v_m)^{-1} \quad (1)$$

In the formula (1), the ATC capacity is inverse or direct function of some factors, as follows:

- **Factores directly proportional to the ATC capacity:**

$\phi$  : factor of controller availability, defined as the percentage of time available for communications, after subtracting the time for manual activities and to plan the aircraft separation procedures. Efforts shall be focused on increasing this factor by applying measures which reduce the controller's engagement with manual activities and aircraft separation planning procedures. This can be achieved when it is possible to enhanced the Man / Machine Interface – MMI of the systems operated by the ATCO;

$\delta$  : average distance flown by aircraft in the sector, which is function of the pathways and route or terminal established for each sector;

- **Factors inversally proportional to the ATC capacity:**

$\eta$  : average number of communications between pilot and controller for each aircraft in the sector, which must be as small as possible. That number can be minimized by issuing a full clearance with the necessary anticipation to allow the flight planning;

$\tau_m$  : average length of time of each message between pilot and controller. This factor can be minimized by transmitting messages in an objective way, avoiding long explanations; and

$v_m$  : average speed of the aircraft in the sector.

Replacing  $\delta$  y  $v_m$  by the average flight time spent by the aircraft crossing the sector (T), the formula (1) can be replaced by a simpler version:

$$N = \phi \cdot T \cdot (\eta \cdot \tau_m)^{-1} \quad (2)$$

The values of the factors  $\phi$ , T,  $\eta$  and  $\tau_m$  are collected empirically, following the standardized procedures.

### 2.2 Calculation of ATC Capacity for the combined sectors 09 and 10 of FIR Curitiba

The sectors 09 and 10 combined are important in the Brazilian Air Traffic Flow Management's context. They enclose all flights coming from the North and the Northeast part of Brazil to Galeão International Airport (SBGL) and to Santos Dumont Airport (SBRJ), a busy Regional Airport.



Fig.1- Sectors 09 and 10 of Curitiba's FIR.

The following lines presents the results of the ATC capacity calculation of the 09/10 sectors when combined by ACC Curitiba.

Nowadays, Brazil collects part of the necessary data for the calculation with the help of recorded ATC communication. This provides some advantages since one can come back in some point of interest of the communication to check out some detail that was misunderstood. Another advantage of using recorded ATC communication is that it is possible to recalculate the capacity if it is necessary to adjust or check the values in future.

The samples used for the calculations were taken from the recorded ATC communication on 16<sup>th</sup>. of March 2009, from 22:58 until 23:58 UTC. This period was chosen considering the amount of available aircraft and ATCO to obtain the minimum sample size to guarantee the tolerable sampling error below 5% and the level of confidence of 95%. The sample size calculation is described in APPENDIX A, where it is obtained:

- number of ATCO to be listened per sector or combined sectors: 9;
- number of aircraft to be observed per ATCO for the average number of communication ( $\eta$ ): 39; and
- number of observations per ATCO for the average time of communication ( $\tau_m$ ): 30.

Taking into account the sample size above mentioned, the obtained average message length ( $\tau_m$ ) and the average number of communications per aircraft in the sector are:

- $\tau_m = 14,5s$ ; and
- $\eta = 02$  communications/aircraft.

The average flight time spent by the aircraft crossing the combined sectors 9 and 10 of FIR Curitiba is  $T = 15,1$  min. This time is the result of the harmonic average of the values extracted from SYNCROMAX (ATFM software user by CGNA).

With the formula (2),  $\tau_m = 14,5s$ ,  $\eta = 02$  communications/aircraft and considering the availability factor  $\phi=60\%$ , the obtained ATC capacity for the combined sectors 9 and 10 of FIR Curitiba is 18,7 simultaneous aircraft per operational position.

The declared ATC capacity is some value between 80% and 100% of the ATC capacity found in the calculations, in order to minimize the probability of delays in case of some short peak demand. Therefore, the declared ATC capacity for the combined sectors 9 and 10 of FIR Curitiba is 16 simultaneous aircraft per operational position. It is important to observe that in some situations it is possible to have 19 simultaneous aircraft for a short period of time without problems.

### 3 **Suggested Action**

3.1 The meeting is invited to:

- a) Analyze the information presented in the Working Paper.

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## APPENDIX A

### SAMPLE SIZE FOR THE COMBINED SECTORS 9 AND 10 OF FIR CURITIBA

The minimum sample size for the number of ATCO to be listened and the number of aircraft observations for each ATCO for obtaining  $\eta$  is determined using the simple random sampling technique for finite population considering 5% of sampling error tolerance and 95% of level of confidence, according to the following formula:

$$n = \frac{Z_{\alpha/2}^2 \cdot p \cdot q \cdot N}{\varepsilon^2 \cdot (N-1) + Z_{\alpha/2}^2 \cdot p \cdot q} \quad (a1)$$

Where:

$n$  = sample length;

$Z_{\alpha/2}$  = level of confidence (for 95%  $Z_{\alpha/2} = 1,96$ );

$p$  = percentage of elements that belongs to the interested category;

$q$  = percentage of elements that doesn't belong to the interested category ( $q=1-p$ );

$N$  = size of the population; and

$\varepsilon$  = sampling error tolerance (5%).

- **Number of ATC to be listened**

In order to obtain the minimum number of ATCO to have a sample that give us 95% of confidence and 5% of error tolerance in the measurements, we consider  $p$  as the probability of an ATCO to be on his position in one given day and in one given period of work. If a day has  $x$  periods of work ( $x=4$ ), therefore  $p$  is given by dividing  $x$  by the total number of ATCO of the ACC Curitiba (population size  $N=130$ ) and multiplied by the number of sectors of FIR Curitiba (10 sectors):

$$p = \frac{x}{N} \cdot \text{number of setors} = \frac{4}{130} \cdot 10 = 0,31 \quad (a2)$$

With formulas (a1) and (a2) the minimum necessary number of ATCO is defined in 94. As all ATCO works in all positions in ACC Curitiba, the minimum number 94 of ATCO can be divided by the 10 existing sectors, which means, **in each sector shall be collected data from at least 9 ATCO.**

- **Number of aircraft to be observed per ATCO**

In order to obtain the minimum number of aircraft per ATCO to have a sample that give us 95% of confidence and 5% of error tolerance in the measurements of  $\eta$ , we estimate the size of the aircraft population for the sectors of interest ( $N=43$  aircraft for the formula (a1)) as the maximum number of aircraft in a peak day and in a peak hour.

As it is not possible to estimate  $p$  for this case, we can consider  $p = 0,5$ .

With formula (a1),  $N=43$  and  $p=0,5$ , **the minimum necessary number of aircraft per ATCO is defined in 39.**

The minimum sample size for the number of observations per ATCO for the average time of communication ( $\tau_m$ ) is determined using the simple random sampling technique for infinite population considering 5% of sampling error tolerance and 95% of level of confidence, according to the following formula:

$$n = \left( \frac{Z_{\alpha/2} \cdot \sigma}{\varepsilon} \right)^2 \quad (a3)$$

where:

$n$  = sample length;

$Z_{\alpha/2}$  = level of confidence (for 95%  $Z_{\alpha/2} = 1,96$ );

$\sigma$  = standard deviation (obtained from a pilot sample,  $\sigma = 11,72$ s in 122 measurements); and

$\varepsilon$  = sampling error tolerance (5%).

The pilot sample was taken from recorded ATC communication of March 16th. 2009, a typical day. The overall audio time was 60 minutes in the peak hour from 22:58 to 23:58 UTC.

From formula a3 and the above mentioned parameters, it follows:

$$n = \left( \frac{Z_{\alpha/2} \cdot S}{\varepsilon} \right)^2 = \left( \frac{1,96 \cdot 11,72}{5} \right)^2 = 21,105 \quad (a4)$$

As the obtained number of observations per ATCO for the average time of communication ( $\tau_m$ ) is bellow 30, this number must be increased to be equal to **30 observations per ATCO.**