AIR TRAFFIC CONTROLLER WORKLOAD – ANALYSIS OF BRASILIA TERMINAL CONTROL AREA

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Abstract

This paper presents an analysis of air traffic controller workload at APP-Brasilia, simulating six different scenarios. The academic version of RAMS Plus simulation software was used in this study. Airspace operations originating and terminating at the Juscelino Kubitschek Airport were considered. In each scenario a possible operation procedure was represented (different sectors and/or increased air traffic movement). The results have shown the importance of studies into the resectorization of this air space in terms of controller workload. In most of these case studies the workload is approaching unacceptable levels.

Keywords: Workload, Simulation, Air Traffic, Controllers.

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1. INTRODUCTION

The growth of the global air transport industry has been in evidence since the beginning of the first airline operations in 1930. Even given the economic crises that hit the sector in the 1970s (with the oil crisis), or even the 9/11 2001 terrorist attacks, the number of aircraft in worldwide has been growing at about 5% a year. If this continues, in fifteen years air traffic will have doubled (De Neufville, 2003). In this context it is of the utmost importance that all the links in the air transport industry be prepared to support the growth in the sector.

Air traffic control (ATC) plays a key role in the air transport industry. Besides being directly linked to passenger safety, contributing to its having the lowest accident rates in transport, ATC seeks to speed up the traffic movement of aircraft, preventing delays and reducing operational costs for users. It is estimated that in 1993 delays related to air traffic cost US$ 5 billion (Andreatta et al, 1997). This illustrates the importance of ATC to the sector, as well as the need to improve procedures to reduce costs related to aircraft delays.

The management of airspace under well defined international norms drawn up by the International Civil Aviation Organization (ICAO), the effective control of air traffic, and ground-level infrastructure are fundamental issues in the sustained and safe development of air transport. Operations involving aircraft flights are planned in extreme detail. There is total concern for the management of air traffic focused on aircraft safety throughout the route taken. Management of flights at peak hours and the traffic movement and implementation of routes that provide the greatest fluidity in the busiest airports are some of the strategies open.

In Brazil the situation that followed the air crash in September 2006 clearly illustrated that the workload for air traffic controllers (henceforth referred to simply as Controllers) is also an extremely important factor in the management of airspace.

Hence, a control body must be sufficiently equipped in terms of staff to fulfill its mission, or else run the risk of harming not only the flow of the aircraft but also threatening their safety. The simulation applied to the management of air traffic and used in analysis and the search for alternatives is of the utmost importance so that air traffic control rules and other factors related to the management of the space are tested. In this way the guarantee of user safety and the promotion of better use of airspace and of the infrastructure in airports can be achieved.

Unlike highway transport, airspace capacity cannot simply be defined by the international criteria of separation between aircraft based on performance. Experience in high-density areas shows that one safe measure of capacity is based on workload, which can be defined as the physical and mental work done by the Controller.

The development of analysis and planning tools to prepare air traffic control to support the inevitable growth of the transport sector in Brazil is highly relevant. The simulation models are excellent in representing systems with a large number of variables and with very complex dynamics, when the application of analytical models is restricted (Chwif, 1999).

In this study the applied simulation tool for airspace RAMS Plus was used, which has over the years been widely used in EUROCONTROL studies as well as in the USA (Labancová, 2004). The objective of this study is to analyze air traffic controller workload at the Terminal Area in Brasília. Different configurations will be assessed for sectorization and flight paths, and their consequences for the Controllers' workload.

2. REVIEW OF THE METHODOLOGY IN THE LITERATURE

2.1 About the simulation technique

In international literature real time simulation is known as RTS, and that done in accelerated time is known as FTS (*Fast Time Simulation)*. Majumdar *et al.*(2005) stressed that the best results can be achieved from a combination of the two simulation modes. In this study only FTS was used.

Woodward and Small (2000) >> não seria Taber et al.? stressed the relationship between the workload for Controller and Dynamic Resectorization, which comprises the search for new configurations of sectors for a certain airspace with the objective of balancing the workload between its sectors. In this study six main factors were chosen which lead to a resectorization with examples from American airspace: the lack of equipment, weather changes, changes to the configuration of the airports, special use of the airspace, the volume of traffic, and changes to flight paths over oceans.

Majumdar *et al.*(2005) showed that a reliable assessment of the workload for Controllers in the sectors of a control body is extremely important, above all in areas with a high traffic volume. In his study, Majumdar (data)assessed the methodologies used in different countries in Europe and in the USA

to estimate airspace capacity. He also discussed the impact that new technology from CNS/ATM had on the workload for Controllers, as some tasks will be eliminated.

Teixeira (2007) assessed air traffic controller workload at the Terminal Area in São Paulo, the busiest in Brazil. The study focused on dynamic resectorization to balance out the workload. This recent study was the first one done in Brazil to use the RAMS Plus simulator.

Among the simulation tools used in air traffic planning, RAMS Plus software has been used as the main one in decision making in EUROCONTROL and in studies in the USA, Asia and India. It has been on the market for over ten years, and has been updates many times. It was chosen for two main reasons. Despite its widespread use, it had scarcely been used in Brazil. This opened up a chance to learn about the software in Brazil. Also, there is unrestricted support by the developer, ISA Software (2006), both in getting the academic license and in user support during the research.

2.2 About workload

The tasks done by Controllers are varied and defined by factors such as the control body (ACC – Area Control, APP – Approach Control, or TWR- Control Tower). In a control body, the sectors and operational positions also have different characteristics, such as in the APP the feeding sectors are coordinated among themselves so that the traffic is delivered to the final sector after it has been sequenced. In turn the final sector is alert to the latest aircraft maneuvers before landing and monitors its height and final approach.

The level of automation at a control body also directly influences a Controller's tasks. Many tasks are done automatically by software, such as the transfer between sectors, the correlation between labels and flight plans, and others. These features reduce the workload for the Controller and increase capacity at a sector. The tasks in a control sector are shared between two Controllers: Tactician and Planner. The Tactician is responsible for direct contact with the pilots through a specific frequency which transmits authorizations and instructions. Generally, the Tactician concentrates on communications, surveillance of the aircraft, and conflict resolution.

The definition of arrival procedures (STAR) or climb procedures (SID) is of the utmost importance in increasing safety and reducing the workload for Controllers. Using specific charts and procedures, pilots are advised in advance of the following stages of their flight and Controllers are saved form making

decisions on the separation of aircraft, which often may require fast thinking and lead to human error. The main tasks carried out by the Tactician in controlling radar approach are:

- Initial contact with the pilot on takeoff and on entry into their sector
- Radar surveillance on exit and arrival
- Transfer of the flight progression form
- Transfer of communications to another sector or control body
- Instructions for the nose, level, speed reduction, waiting, and others
- Instructions for sequencing aircraft
- Information on airport and route conditions
- Information on traffic for aircraft approach and warnings to avoid it
- Final vectoring for approach, and
- Closure of the flight plan.

The Planner is responsible for the coordination between their sector and other sectors /bodies involved. They also play an important role in the organization of flight progression charts and information, mainly related to their sector/area of work. Their tasks are concentrated on coordination, data input and support for the Tactician. The less time given over to manual tasks and coordination, the more time the Planner can give to helping the Tactician in surveillance and resolving conflicts.

The main tasks carried out by the Planner are:

- Coordination of traffic between the sectors involved
- Organization of the flight progression charts
- Organization of information and important data for the pilots and Tactician
- Data input
- Support for the Tactician in solving technical problems (console, frequencies, and so on)
- Closure of the flight plan, and
- Information on problems for the Operational Team Supervisor.

The Controllers' tasks in this study were defined after careful analysis. Besides over ten years' experience held by the researcher in towers, APP and ACC, visits were made t the APP-SP (Congonhas), APP-CT (Curitiba), ACC-CT (Curitiba), ACC-BR (Brasília) and finally to the place being studied, APP-BR. Hence the tasks were surveyed and their weighting set through observation and measurement.

It must be stressed that with the effective implementation of the CNS/ATM concept (Communications, Navigation, Surveillance/ Air Traffic Management), the dynamic of ATM will be altered, with an expected reduction in the workload and a consequent increase in the control capacity as a result of the automation of the system. The instructions shall be issued via data link, which will offer greater speed and reliability in the management of air traffic (Massumi, 2007).

Taber *et al.*(2000) carried out a study on dynamic resectorization in which it was observed that the air traffic control service is

subject to certain variables that directly affect the Controllers' workload, chief among them:

- Unavailability of equipment
- Weather changes
- Traffic volume

MMA 100-30 comprises the basic documentation within the scope of Brazil's Airspace Control Department (DECEA) which handles norms on issues related to planning for staff and working hours at the ATC, widely used by the air traffic managers in running activities and creating operational routines at the control bodies. The issues dealt with in this document are:

- Definition of existing operational positions at the various control bodies
- Criteria to calculate the workload at the ATC bodies
- Controller availability factor (f)
- Average distance travelled by aircraft in the sector (d)
- Number of communications for each aircraft in the sector (n)
- Average length of each message (t_m)
- Average speed of aircraft in the sector (V_m)

The mathematical model presented in this document evaluates the factors above:

$$N = f.d / n . t_m . V_m$$

Where N represents the maximum number of aircraft controlled simultaneously by a Controller.

- Criteria for the creation and activation of operational positions in the control bodies
- Definition of shifts and creation of operational schedules
- Calculation of staff numbers at air traffic control bodies

2.3 About the Brasília Terminal Area

The Brasília Terminal Area (TMA-BR) has a lot of procedures and charts that facilitate pilot maneuvers and help Controllers. In the Brazilian context the TMA-BR figures as one of the terminals with most SIDs, AICs (Aeronautical Information Charts) and STARs in operation, totaling over 40 charts. Many of these procedures are supported by satellite, called the Global Navigation Satellite System (GNSS), which allow the configuration of more flexible and economical routes.

The service team as a whole is responsible for the safe and efficient operation of the various sectors. The responsibilities for compliance with the tasks attributed to an operational position are the same when one, two, or more people from the team are performing them. However, the team concept is not to make it responsible for the individual action of its members, when such action is inappropriate or not stipulated in the regulatory norms and results in damage to the interests of the users and/or final objectives of the system.

Controllers are distributed among the various existing functions, depending on experience, skill, and training. The Operational Model at APP-BR establishes the attributions for each function carried out by the team so as to guide them in the execution of various activities

necessary to the performance of air traffic control by the body.

The Operational Model sets out procedures between the APP-BR and adjacent bodies. So, key activities, such as the transfer of traffic, entrance and exit sectors, sequencing of aircraft, and restrictions on the routes are established in advance between the control bodies. In this way, irrespective of the service team, the procedures are observed by the control bodies and pilots. In sector management (grouping/ungrouping) the Operational Model at APP-BR considers the following parameters:

- Technical-operational conditions of the consoles
- Meteorological conditions a TMA-BR, and
- Quantitative analysis of aircraft per sector defined.

At the discretion of the Team Supervisor on judging the operation, the sectors will be ungrouped in the following conditions:

- When the limit of eight aircraft in the feeding sectors and five in the final sector has been exceeded
- Whenever aircraft are approaching surveillance
- When there is a presidential operation
- When an aircraft is in an emergency situation, and
- When there is a laboratory flight.

Besides the activities established in the manuals and operational agreements observed by the APP-BR and the control bodies in general, the Operational Model at APP-BR does the following:

- Coordinates traffic to comply with priorities in taxiing, takeoff and landing
- Applies normal procedures for the control of air traffic whenever the pilot in command of the presidential aircraft requests it
- Informs the pilots approaching that, in the event of there being no radar, they must wait until the presidential aircraft has landed
- Informs the pilot of the presidential aircraft that he has priority
- Whenever possible gives priority in bilateral communications to the presidential aircraft
- Maintains contact with local bodies responsible for the maintenance of flight protection equipment when there are indications of errors in said equipment, so that it is provided for by those responsible for it at the necessary time
- Maintains its discretion over presidential aircraft operations, providing information only to registered people, and
- Whenever possible, keeps the areas to be reached by the presidential aircraft free, and maintains the double longitudinal separation stipulated in current publications.

An aircraft may be authorized for a visual approach at the same time as another one on a visual approach or on instruments for the runways 11R (Right) and 11L (Left) or 29R and 29L, as long as the pilot states that they have the preceding aircraft in sight and reports that they can maintain visual separation. Simultaneous parallel approaches for the runways 11R/11L or 29R/29L may only be authorized with radar operation, except for

two aircraft approaching with a visual flight plan.

To facilitate one aircraft visualize another, a radar separation of up to 3NM at CTR Brasília is allowed, providing the conditions for the visual approach and simultaneous operations, as stipulated in AIC 02/00, from January 20th 2000. However, during simultaneous parallel approaches, the separation between the aircraft that are executing the IFR procedure for the same runway must never be less than 5NM. The APP/TWR coordination for simultaneous parallel approach must always occur at a distance of at least 15NM from the aerodrome, so that the TWR can arrange the imminent landings and takeoffs, preventing conflicts such as: aborted landings; vehicles, or people working on the runway.

The third busiest airport in passenger and aircraft numbers in Brazil, Brasilia serves as a distribution point for flights all over Brazil, with 30% of its flights being connections. Because of its strategic location, it is considered to be a civil aviation hub. In 2007 the airport handled 11,119,872 passengers in 126,853 aircraft traffic movement s. Figure 1 shows the airport map.

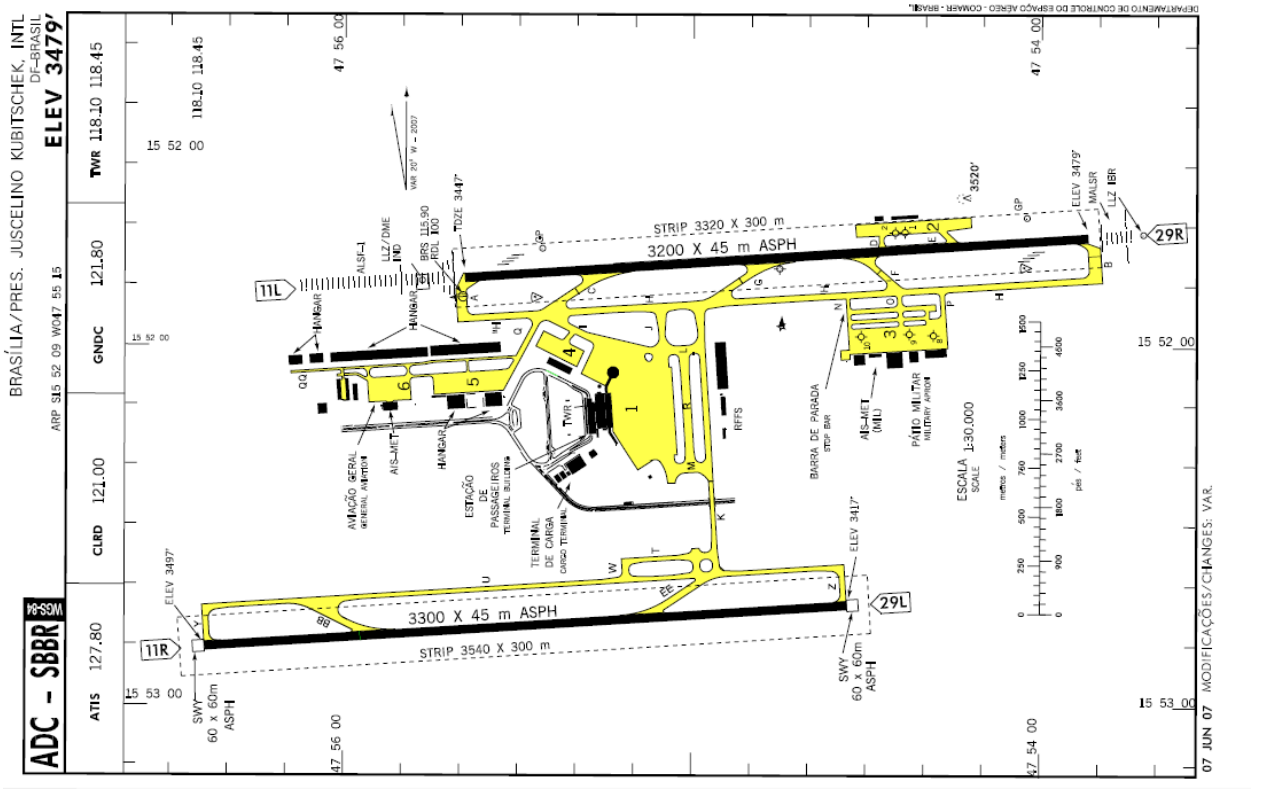


Figure 1- Brasília Airport (Source: ADC SBBR)

3. SCENARIOS STUDIED

The scenarios studied were based on two situations that have occurred at the place of study. Until 2005 TMA-BR was split into two sectors: North and South. Then, based on empirical claims, this split was changed to East and West. First, four scenarios were proposed (NS1, NS2, EO1 and EO2), called *initial scenarios* which will be detailed further on. Then scenario EO3 was developed, which has the same characteristics (East/West division of the sectors and the same flights paths) as scenario EO2, but with 30% more traffic.

Scenario EO2 presented the lesser total workload, and it was interesting to extrapolate the current traffic from this scenario. Furthermore, scenario TS2 was proposed. This scenario splits TMA-BR into three sectors, as in Figure 4, and sought to explore the possible reductions in the workload in regard to the initial scenarios with just two sectors.

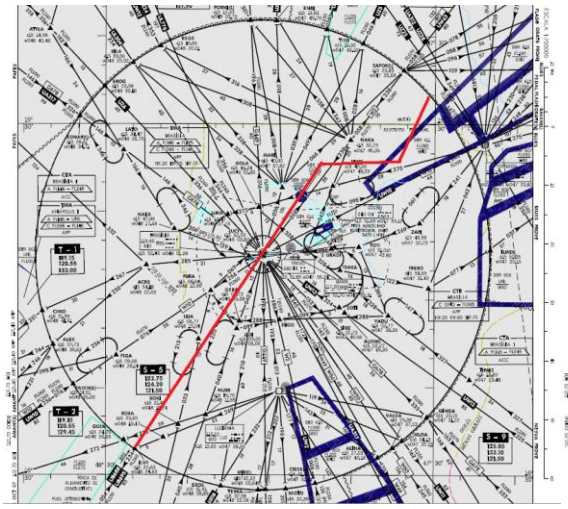


Figure 2: East/West Sectorization

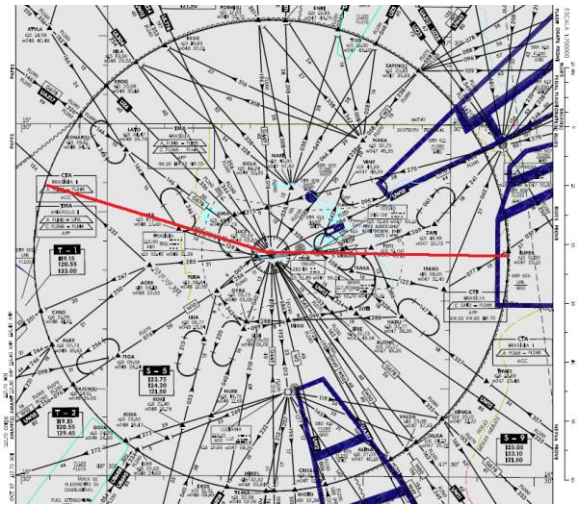


Figure 3: North/South Sectorization

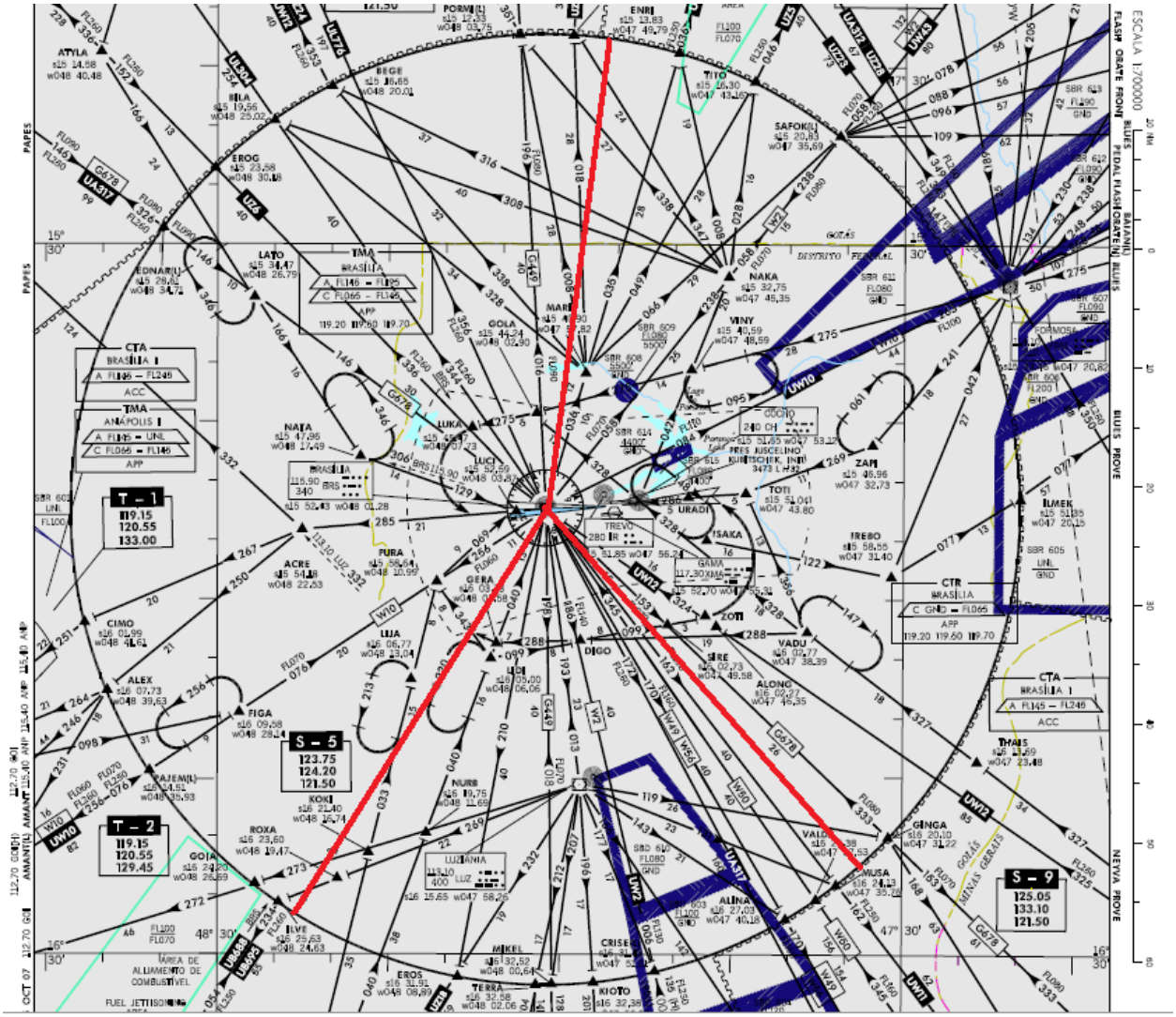


Figure 4: Sectorization TS2

All the scenarios were established with landing in runway 11L and takeoffs on runway 11R, which studies by Brazil's Aerial Navigation Management Center – the CGNA - (http://www.cgna.gov.br/aeroportos/sbbr) - say accounts for 90.36% of the aerodrome's operations.

The data base used was from March 23 2006, which represents a typical day of operation at the area studied. The data was taken from the flights plan report X-4000, which presented a total of 424 traffic movement s, 216 takeoffs and 208 landings at Brasília International Airport.

Not considering the early morning (00:00 – 06:00h), where demand for flights is very low, traffic movement in Brasília was an average of 23 aircraft on the day, which is close to the average for the busiest terminals in Brazil: São Paulo and Rio de Janeiro. It was also possible to identify peaks with an average of 30 traffic movement s, the first being the

longest duration (12:00 – 15:00h) and the second shorter (21:00 – 22:00h). Figure 5 illustrates the traffic movement profile for the day corresponding to the data base for the study:

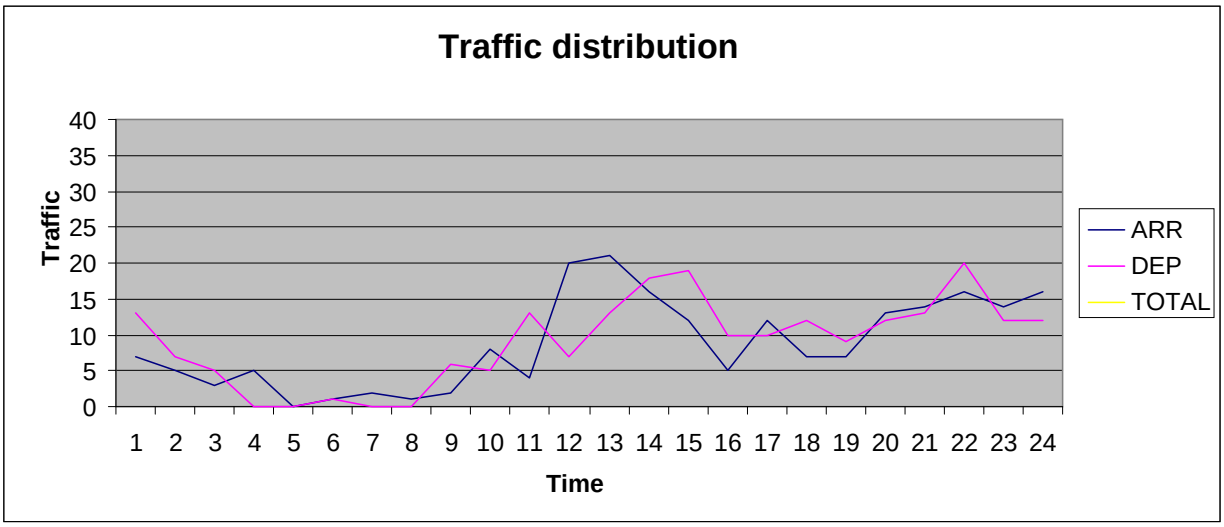


Figure 5: Distribution of traffic on MAR 23 2006

After analyzing traffic movement, the study focused on the peak times, which was the highest workload for Controllers. The period from 21:00 to 22:00 hours, which had traffic movement of 36 aircraft was evaluated in detail. The scenarios analyzed in this study are defined in the following manner:

NS1: North/South Sectorization of the terminal area, all the traffic landing in the entrance sector

NS2: sectorization North/South of the terminal area, traffic from SBVT (Vitória), SBCF (Confins), SBBH (Belo Horizonte), SBRJ (Santos Dumont) and SBGL (Galeão) landing in the Northwest sector of the aerodrome (sector transfer), the rest of the traffic landing in the entrance sector

EO1: East/West Sectorization of the terminal area, all the traffic landing in the entrance sector

EO2: East/West Sectorization of the terminal area, the traffic from SBVT, SBCF, SBBH, SBRJ and SBGL landing with the Northwest sector of the aerodrome (sector transfer), the rest of the traffic landing in the entrance sector; and

EO3: similar to sectorization EO2**,** plus 30% more traffic.

The difference in conception between the scenarios *type 1 and 2* is in the aircraft's path. The objective of the division of the scenarios into Paths 1 and 2 is to analyze the impact that the reduced path of the arrival flights could have on the workload for Controllers.

TS2: configuration of the sectors as presented in Figure 4 and arrival paths for aircraft defined by path 2.

4. THE SIMULATION

4.1 Verification and validation of the scenarios

Verification of the scenarios was carried out systematically through observations of the animations generated by the RAMS Plus simulator. In this stage, besides interviews with Air Traffic Controllers, the animations were presented at various opportunities to some experienced Controllers at APP-BR at the Airspace Control Institute (ICEA).

Contributions made at this stage of the simulation were important in improving the scenarios. Among some of the characteristics which were enhanced, the most important were:

- Correction of direction of takeoffs and landings as a result of the incorrect definition of the direction of the runways
- Adjustment of final approach speeds, as the program sets the performance parameters as a result of altitude
- Correction of acceleration and deceleration for aircraft according to new altitudes, and
- Correction of fuel consumption figures for aircraft that have to turn.

The last correction was only made after support given by the technicians at ISA Software. The observation made in this study identified to the program developers an important deficiency to be corrected in the upcoming versions of the program.

Validation of the models was achieved through comparing real values of traffic movement (landings and takeoffs) obtained from the APP-BR flight reports and the values generated in the simulation. As explained in item 2.1, the purpose of this stage of the simulation is to guarantee that the scenario developed represents, with a certain degree of precision, what happens in reality in the system studied.

4.2 Results

Table 1 shows the results of the RAMS Plus application in terms of workload for the 4 initial scenarios.

Table 1--: Workload in minutes

Comparison between workloads for initial scenarios									
Scenario	Sector	Position	Activity category					Position Total	Sector Total	Scenario Total
			Conflict	Coord.	Data	Common	Radar			
NS1	North	Planner	3.62	27.25	5.48	0.00	0.00	36.35	77.22	159.28
		Tactician	0.00	2.78	7.47	19.15	11.47	40.87		
	South	Planner	3.50	34.15	5.12	0.00	0.00	42.77	82.07	
		Tactician	0.00	3.72	9.92	12.52	13.15	39.30		
NS2	North	Planner	3.62	27.25	5.48	0.00	0.00	36.35	77.57	160.69
		Tactician	0.00	2.78	7.47	19.15	11.82	41.22		
	South	Planner	3.50	34.80	5.28	0.00	0.00	43.58	83.12	
		Tactician	0.00	3.85	10.27	12.97	12.45	39.54		
EO1	East	Planner	3.62	28.65	5.65	0.00	0.00	37.92	82.43	154.32
		Tactician	0.00	3.05	8.28	20.47	12.72	44.52		
	West	Planner	3.73	29.30	4.12	0.00	0.00	37.15	71.88	
		Tactician	0.00	3.45	8.75	11.28	11.25	34.73		
EO2	East	Planner	3.50	28.47	5.65	0.00	0.00	37.62	81.48	150.29
		Tactician	0.00	3.05	8.28	20.13	12.40	43.86		
	West	Planner	3.62	27.90	3.95	0.00	0.00	35.47	68.81	
		Tactician	0.00	3.32	8.52	10.92	10.58	33.34		

Overall in the four scenarios the workload among Controllers in the positions Tactician and Planner is well balanced, with the workload in the sector practically shared. In the eight sectors under analysis, the difference between the two operational positions was between 2.13 and 6.60 minutes.

All four scenarios had operational positions with a workload of over 42 minutes/hour. According to Majumdar and Polak (2001), this is the limit for planning sectorization in the control bodies in Europe. Scenario EO2 had the lowest total workload, however the Controller/Tactician had a workload of 43.86 minutes. This shows that APP-BR needs a configuration comprising a larger number of sectors.

Scenario EO3 has the same configuration as scenario EO2, which had a total workload among the *initial scenarios*, but there was a 30% addition of traffic. This was used as a base for a forecast in international growth in demand for the medium term. According to De Neufville (2003), annual traffic growth worldwide is at 5%. Taking this as a parameter, this new demand will be reached in approximately five years.

The fifth scenario (EO3) served to explore the distribution of the workload in detail as a result of the kind of task done. Hence it was possible to verify which of the activities provided the greatest contribution to workload and to help in the effectiveness of measures designed to reduce it. Table 2 has the

workload figures obtained in this new scenario:

Table 2- Workload in minutes

Distribution of workload – scenario EO3						
Controller	Conflict	Coord.	Data	Common	Radar	**Total**
Planner	7.00	70.53	12.38	0.00	0.00	89.68
Tactician	0.00	8.14	22.05	40.83	23.73	94.72
Total	7.00	78.67	34.32	40.83	23.73	184.08

The figures show that the growth rate for the workload is directly related to the increase of traffic. A 30% increase in traffic in scenario **EO2** resulted in a 22.48% increase in workload. Majumdar and Ochieng (2002) listed the physical aspects of the control sector, the factors related to traffic movement in airspace, and the combination of the first two elements as determinant in the workload for Controllers.

Finally, Scenario TS2 was designed to analyze a potential reduction in the workload after the division of the airspace being studied into more sectors. The figures for total time spent by the aircraft in this scenario, as well as the cost of these operations is the same obtained for scenarios NS2 and EO2, as these factors depend on the flight path taken by the aircraft.

Figure 5 compares the quantity of simultaneous aircraft by sector for the different scenarios studied. This analysis showed the potential for reducing the workload by dividing the airspace into sectors, which could be an effective tool in eliminating restrictions on capacity by saturated control bodies. There is a problem in making this scenario viable, which is the availability of teams (more people) and equipment compatible with this procedure. The workload per Controller is reduced, showing that using one more sector in the area studied helped reduce the workload in each operational position. It can also be observed that the workload per position fell away from the limit per hour, adding safety to control at APP-BR.

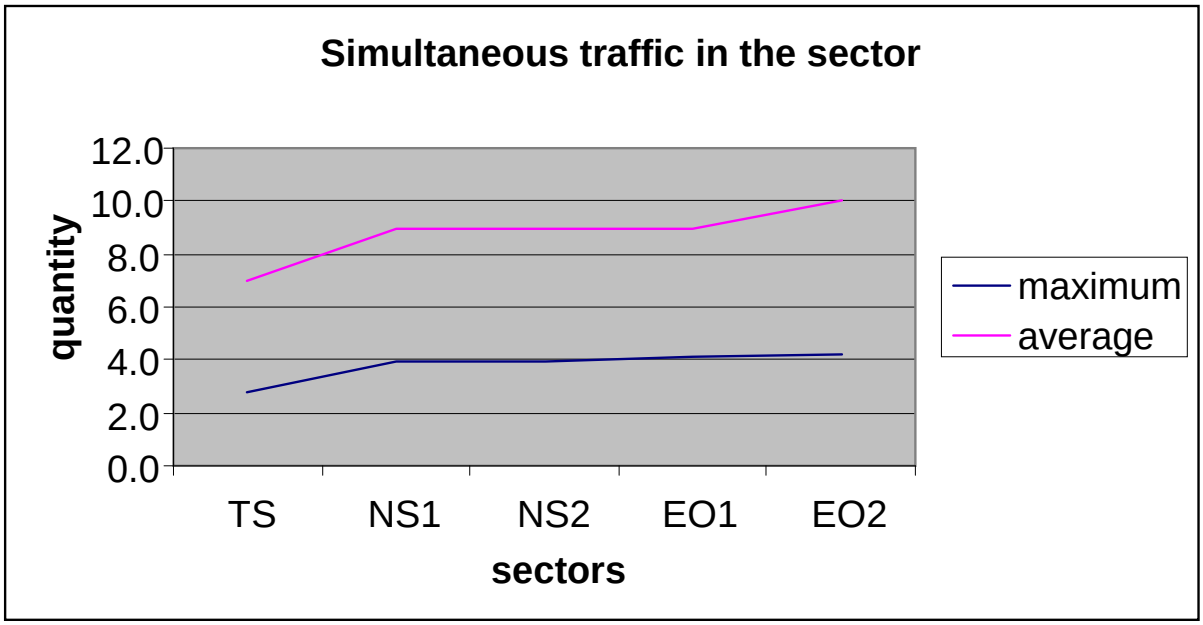


Figure 5: Quantity of simultaneous aircraft per sector

5. CONCLUSIONS

Given the results observed, the viability of using the methodology in support of decision making in the planning of airspace and evaluation of Controllers' workloads can be attested to. Likewise its contribution to analysis is valid, supporting problem solving as it describes the behavior of variables in a detailed manner.

At the Brasília Terminal Area it was noted that for the four *initial scenarios* the situation is near to saturation point in terms of workload. Scenario **EO3** forecasts traffic growth of 30% and confirms the need for new configurations for the APP-BR sectors which reduce the workload and distribute it well among operational positions.

Analysis of circulation (circulation 1 and 2) showed that a small increase in arrival paths helped reduce conflicts, contributing to reducing the workload for Controllers. This is a highly important factor as the sectors are very close to saturation point, if not saturated.

Modification of North/South sectorization to East/West better shared the work, and reduced the total load. The figures attest that the modification of the circulation achieved on an empirical basis benefitted APP-BR.

Scenario TS2, with three sectors, indicated that the division of airspace into more sectors could result in benefits for capacity as there is a reduced workload and the traffic under simultaneous control falls.

Although the scenarios analyzed do not consider a final sector, in practice APP-BR makes use of this sector. Therefore, so that some immediate decisions are taken at the control body based on this study it is essential

that the differences in conception of the sectorization are taken into consideration.

The reference used here for the workload limit is that practiced by the European control bodies, where most studies using RAMS Plus software have been done. However, workload parameters for control bodies in Brazil must be examined, taking into account particularities involving operational infrastructure, socio-organizational and psychological factors.

The results showed that increased workload is directly related to an increase in traffic (as was to be expected). However, factors such as the number of sectors, flight path crossings and airports in the area have a strong impact on workload. These are known to be complex factors and must be evaluated in detail, above all in analyzing areas with the highest traffic movement.

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