A SIMULATION MODEL FOR RUNWAY CAPACITY ANALYSIS APPLIED TO THE SAO PAULO AIRPORT

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ABSTRACT
Air transportation in the 21st century is increasingly subject to capacity constraints; growth in traffic is not being matched by appropriate increase in capacity, resulting in increasing congestion and delay suffered by airlines, passengers and airport authorities alike. Sao Paulo airport (SBSP) is one of the busiest and more important in Brazilian air transport system. This paper describes the conception and application of a simulation model addressed to perform an analysis of runway capacity on the Sao Paulo Airport.

1 INTRODUCTION

Airport is an operational system comprising of a framework of infrastructure, facilities, equipment, systems and personnel which collectively provide a service to a customer. It holds a key role in the aviation system.

Fast growth in air travel and, on the other hand, slow expansion of airport and air traffic control system capacity, resulting in increasing congestion and delay. The consequences for the air transport industry and the travelling public are greater inconvenience, higher costs, declining quality of service, and concerns about diminished safety (Ashford and Wright, 1992).

Although delays are attributable to various components of the aviation system, the airspace operational procedures in the vicinity of the airport and the runway subsystem seem to be the paramount limiting factors in increasingly overall airport capacity.

When a rough estimate is needed, the results of traditional queuing theory can be used to analyze airport runway systems, but when airports are too congested or a more realistic description of the system behavior is necessary, a simulation approach is a good alternative.

In Brazil, the terminal maneuvering area Sao Paulo (TMA-SP) has experienced significant congestion (Pereira et al., 2001; Hupalo,2003 and INFRAERO, 2007) that the aeronautical authorities have found difficult to mitigate (Muller and Santana, 2008).

Sao Paulo airport (SBSP) is located in the TMA – SP and is one of the busiest in Brazil with 186.964 aircrafts movements in 2008, where problems in his operation generate interference in the Brazilian air transportation system.

The present work aims are create, verify and validate a simulation model addressed to perform an analysis of runway capacity on the Sao Paulo International Airport. Based on Arena simulation software, the model represents the sequence performed by the aircrafts that characterize the landing and departure movement processes.

2 RUNWAY CAPACITY

The effectiveness of transport systems is usually measured in terms of its ability of processing, where the system capacity will be marked by the weak subsystem capacity.

Two types of runway capacity definitions were widely adopted.

- **Practical runway capacity** - "the number of aircraft operations during a specific time interval corresponding to a tolerable level of average delay" (FAA, 1968).
- **Ultimate runway capacity** - "the maximum number of aircraft operations that an airfield can accommodate during an hour when there is a continuous demand for service" (FAA, 1973).

Although runway capacity may be affected by a very large number of diverse factors it can, in an operational sense, be treated as being determined by just five main factors.

- Separations standards
- Aircraft characteristics
- Runway configuration
- Movement mix
- Air traffic control strategies

A different type of models may be employed to estimate runway capacities and delays, including the following (Ashford and Wright, 1992):

- **Empirical models** – The models bases capacity and delay estimates on the results of extensive traffic surveys performed at existing airports. Such surveys may serve as the sole basis for graphs and tables from which estimates may be directly made. Empirical surveys are also a vital component in the development and validation of both analytical and simulation models (Joline, 1974).
- **Analytical models** – These models relate the system capacity to delays, generating results that satisfy certain conditions of contour and intervals of time. Are very useful for the understanding of the capacity-delay relations.
- **Simulation models** – Simulation models are those using mathematical and logical representations of the real world, convert parameters and input data in output that characterized the system (Almeida, 1998). Are extremely useful for studying complex systems that cannot be represented by equations.

An important justification for using computer simulation to estimate runway capacity is to reduce the differences between the real world and the abstract world of the model (Horonjeff & McKelvey, 1994).

3 SIMULATION MODEL

The proposed procedure to carry on the creation of the model combines systems approach, capacity analysis and simulation techniques.

(Gualda, 1995) combined the five identified elements of systematic analysis (De Neufville and Stafford, 1976) with the scientist thinking about the meaning of a system made by (Churchman, 1968). Resulting in the following steps for system approach application:

1. System identification and characterization (system objectives and performance measures of the whole system; system components with their activities, goals and

performance measures; system constraints; system resources; system management aspects);
2. Problem formulation considering the objectives, restrictions, resources and measures of effectiveness to be considered;
3. Generation of alternatives to solve the problem;
4. Evaluation of the alternatives taking into consideration the measures of effectiveness considered;
5. Selection of the best alternative.

Based in this work (Moser and Gualda, 2007) presents a procedure for airport airside evaluation. A simplified flow chart of the proposed framework was show in figure 1.

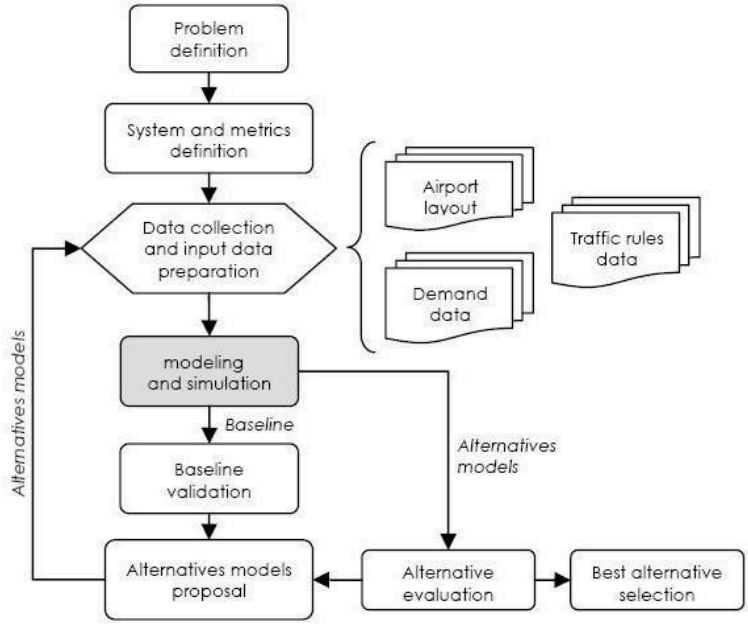


Figure 1 - Evaluation procedure flow chart

A variation of this evaluation procedure was used like an initial point to the model development.

The model was constructed in a simulation platform ARENA. Basically the model simulates the sequence performed by the aircraft on the landing and departure processes.

3.1 Landing Sequence

In the model, the landing process is broken down into six phases: Beginning of the process, waiting for runway clearance, final approach, landing, runway clearance, and exit. Figure 2 shows the landing sequence flow chart.

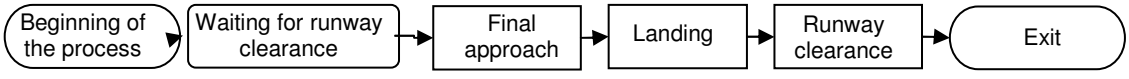


Figure 2 - Landing sequence flow chart

3.2 Take off Sequence

The take off process is broken down into five phases: Beginning of the process, waiting for runway clearance, take off, runway clearance, and exit. Figure 3 shows the take off sequence flow chart.

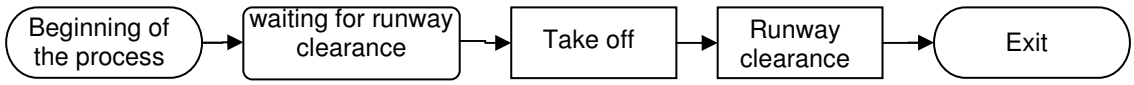


Figure 3 – Take off sequence flow chart

3.3 Inputs of the Model

The inputs of the model are:

- Demand characteristics (Mix of aircraft, Proportion for landings and departures)
- Operational procedures (Separation rules, ROT, Approach speeds)
- Physical layout (Length of runway, Number, type and location of runway exits)

3.4 Outputs of the Model

The model is capable of offering a large number of outputs, including:

- Number of landing operations per hour.
- Number of departure operations per hour.
- Number of mixed operations per hour.

4 APPLIED THE SIMULATION MODEL

4.1 4.1 Sao Paulo International Airport

Sao Paulo / Congonhas Airport (SBSP), has a great importance on the Brazilian air transportation industry with an important participation in passenger and aircrafts traffic.

The figure 4 and table 1 shows the main features of the Sao Paulo Airport layout.

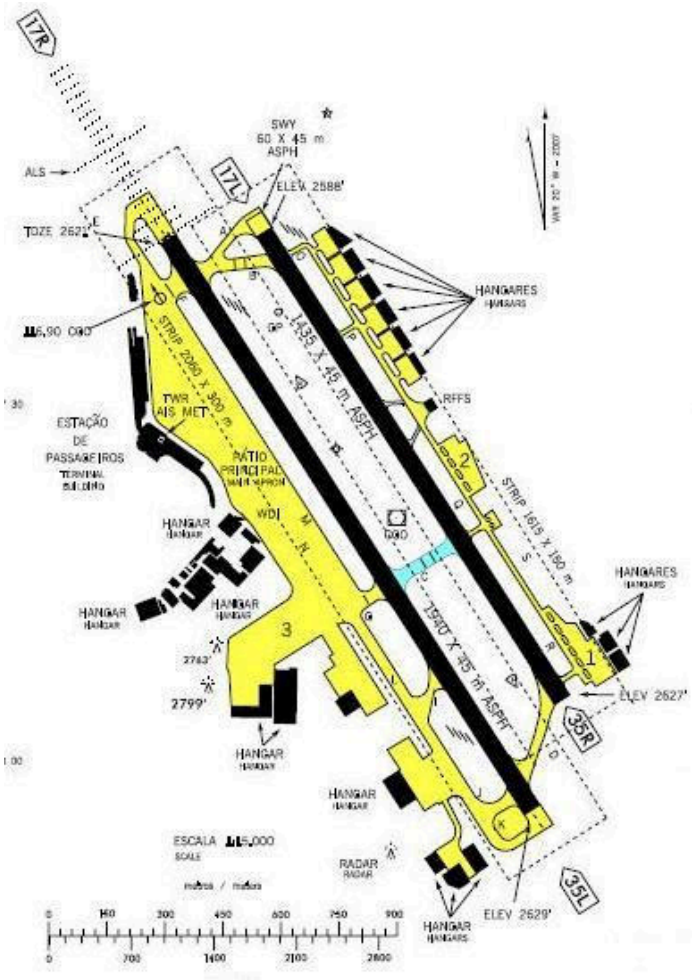


Figure 4 – General layout Sao Paulo Airport

Table 1 - Main features of the Sao Paulo Airport runways

	17R/35L	**17L/35R**
Length	1.940	1435
Wide	45	45
SWY		60*45
Surface Kind	ASPH	ASPH

4.2 Baseline scenario

The creation of a baseline scenario, representing the current situation of the airport, was the first step of modeling the Sao Paulo Airport. This scenario is the most important in the

process of modeling and simulation because it is supposed to represent the reality of the airport in its current configuration, related to the physical, traffic and rules aspects.
Aircrafts must be grouped in classes defined by weight criteria:

- Heavy – maximum take off weight 136.000 kg (300.000 lb) our more Ex: Boeing 747, Airbus A -300/310, Boeing 777, Douglas DC-10.
- Medium – Turbojet - maximum take off weight less than 136.000 kg (300.000 lb) and over 27.200 kg (60.000 lb). Ex: Boeing 737, Douglas DC-9, Beeck King Air 350, Cesna Cintation X, Gulfstream V.
- Medium – Propeller – maximum take off weight less than 27.200 kg (60.000 lb), and over 5.700 kg (12.500 lb). Ex: Beech Baron, Cessna 414/421, Piper Navajo;
- Light – maximum take off weight less than 5.700 kg (12.500 lb) Ex: Cessna 172 /182, Beech Bonanza, Piper Cherokee.

5 APPLICATION RESULTS

The maximum capacity of landings calculated was 21 operations per hour. The maximum takeoffs capacity was calculated at 29 per hour.

A minimal standard radar separation of 5 NM was applied to all consecutive arrivals and 120 seconds between consecutive takeoffs.

The figure 5 shows the capacity curve calculated from the baseline scenario to the Sao Paulo Airport.

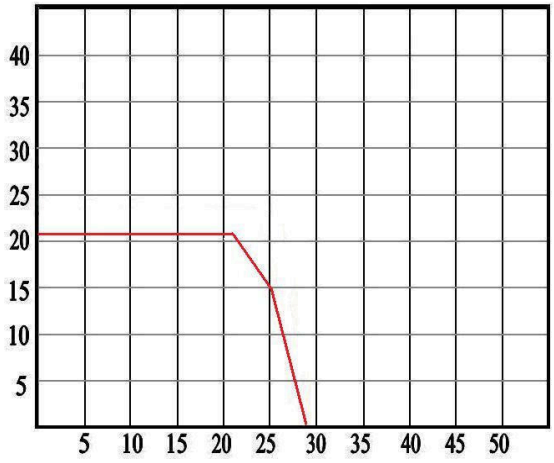


Figure 5 – Capacity curve Sao Paulo Airport.

6 CONCLUSIONS AND RECOMENDATIONS

The aim of this work was to contribute to the analysis of airport operations by developing a simulation model for runway capacity calculation and the applied of the model no Sao Paulo Airport.

The model appears like an option to runway capacity analysis offer a good overall performance in terms of simplicity, accuracy, and computational efficiency. Results produced through this model correlate well with the actual airport runway capacity.

The model can not be considered a definitive resource for runway capacity analysis based on the fact that their development was done considering the realities of the Sao Paulo airport, so their use in any other airport requires an analysis of local conditions.

The simulation tool used satisfactorily met the objectives of this work, showing its potential for use in operational analysis on the airport airside.

This simulation model could be improved through future research to handle the consideration of more airports subsystems.

REFERENCES

Ashford, N.; Wright, P. H., 1992. Airport Engineering. John Wiley & Sons, 3rd Edition.

Churchman, C.W., 1968. The Systems Approach. Delacorte, Press, New York.

FAA – Federal Aviation Administration, 1968. Airport Capacity Criteria Used in Preparing the National Airport Plan, Federal Aviation Administration Advisory Circular AC 150/5060-lA.

FAA – Federal Aviation Administration, 1973. Procedures for Determination of Airport Capacity, Federal Aviation Administration Report No FAA-RD-73-11.

Gualda, N. D. F., 1995. Terminais de Transportes: contribuição ao planejamento e ao dimensionamento operacional, Tese (Livre Docência) - Escola Politécnica, Universidade de São Paulo, São Paulo.

Hupalo, M. F., 2003. Analise da Area de Controle Terminal Sao Paulo (TMA-SP) por Meio de Simulaçao (Fast-Time Simulation). Master Degree Dissertation, ITA, Sao Jose dos Campos.

INFRAERO, 2007. Movimento operacional acumulado da rede INFRAERO, at <http://www.infraero.gov.br/upload/arquivos/movi/mov.operac._1207_revisado.pdf>.

Moser, R. F.; Gualda, N. D. F., 2007. Simulation and Analysis of Airport Configurations Using Visual SIMMOD: Application to the Sao Paulo/Guarulhos International Airport. ATRS proceedings.

Muller, C., Santana, E.S.M., 2008.Analysis of flight-operating costs and delays: The Sao Paulo terminal maneuvering area, Journal of Air Transport Management, doi:10.1016/j.jairtraman.2008.04.013

Pereira, B.D., Silva, C.M., Guedes, E.P., Feitosa, M.V.M., 2001. Estudo dos atrasos na
area terminal Sao Paulo: Situaçao atual e futura via modelo de simulaçao. Proceedings do XV Congresso de Pesquisa e Ensino em Transportes, ANPET vol.3, Campinas.