SUPPORT OF THE DETERMINATION OF THE DECLARED CAPACITY BY THE USE OF AIRSIDE SIMULATION FOR RUNWAY CAPACITY ANALYSIS

Stefan Theiss, graduate engineer
RWTH Aachen University – Department of Airport and Air Transportation Research
Mies-van-der-Rohe-Str.1 – 52056 Aachen – Germany
Phone: +49 (0)241 8025133 Fax: +49 (0)241 8022292
Email: theiss@airport.rwth-aachen.de

Abstract:

At present the definition of the declared capacity at German Airports is based on a consent decision of the coordinating committee of the respective airport. This decision is based on expert knowledge of the stakeholder. An inherent problem is the fact that the use of capacity analysis is not standardized. Therefore the support of this process is to be carried out through the use of Airside simulation for runway capacity analysis.

The elements of the procedure are the determination of runway capacity as well as the establishing of the declared capacity. In order to be able to find the declared capacity it is necessary to determine the runway capacity in dependence of a quality criterion. In this case the procedure is based on the application of the middle delay as a quality criterion. To investigate this special question the ASA-Tool-Software (Airside Simulation Analysis) was developed. The function and use of the ASA-Tool are explained. On the background of these results varied possibilities of the declared capacity can be derived and thus different scenarios can be developed.

Subsequently, daily flight plans have been developed for the scenarios, which correspond to the given parameters. The daily flight plans were simulated again with the help of the ASA-Tool. Finally the simulation results are compared to one another, in order to make a qualitative statement to the procedure presented here.

Keywords:

Airport, Runway Capacity, Airside Simulation, Simmod

1. INTRODUCTION

Air transportation in the 21st century is increasingly subject to capacity constraints. This is particularly true for airports, in terms that traffic demand exceeds the airport capacity.

To avoid an overload and any related delays, European airports define the maximum number of air movements within a schedule season that can be handled at any one airport. This figure is known as declared capacity which is the basis for the slot allocation process. The classification of the declared capacity generally describes a one-hour value regarding the possible departures and arrivals. Additionally 30-minute or 10-minute values can be classified, if capacity constraints require this. Usually the declared capacity is composed of three elements

- maximum number of total movements (departures and arrivals)
- maximum number of arrivals and
- maximum number of departures

which are possible within the respective period of time. The definition of the declared capacity is the responsibility of the coordination committee of the individual airport.

2. PROBLEM

The classification of the seasonal capacity supply as described by the declared capacity goes down to the decision of the members of the coordination committee. The decision is based on the experiences and estimations regarding the airport capacity of the individual stakeholders (airport authorities, air traffic control, airlines).

The airport capacity depends on several individual components of the airport such as the runway system, the apron and the terminal buildings. Furthermore political and legislative issues may influence an airport’s capacity. However most of the times the runway system capacity constitutes the critical factor.

The problem regarding the classification of the declared capacity is the danger of suboptimal capacity usage. This may lead to the unwanted situation of under-usage of valuable existing infrastructure at airports with excess demand. Any overload is to be avoided on the other hand since this leads to delays and irregularities.

The employment of capacity analysis and airside simulation might be a means to support the work of the coordination committee in this regard. Until today however there are no regimentations about the standardised employment of capacity analysis and simulation in order to calculate the runway capacity regarding the classification of the declared capacity.

3. CAPACITY ANALYSIS BY MEANS OF AIRSIDE SIMULATION

This paper aims to show exemplarily how the classification of the declared capacity can be supported by capacity analysis. Central to the capacity analysis will be the application of airside simulation.

The basis for the capacity analysis is the methodology of empirical capacity appraisal. Gilbo presents an approach in this regard incorporating a diagram which displays all actual movements on a runway system within a certain period of time. In this diagram a scatter plot represents all monitored traffic movements with reference to the ratio of departures and arrivals. By embracing the scatter plot an envelope can be generated as shown in figure 1. This envelope describes the maximum throughput capacity of the runway system in reference to the number of departures and arrivals.

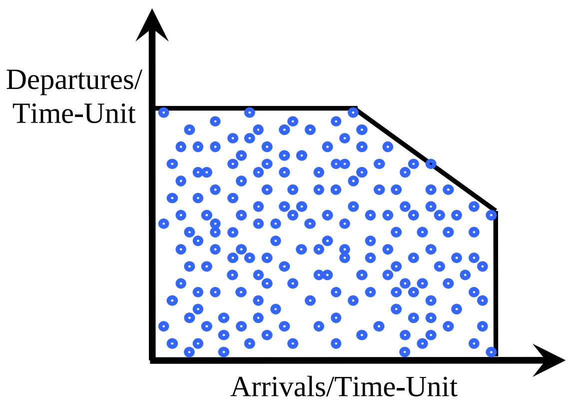

Figure 1 Gilbo-Diagram (empiric)

However the empirically obtained number of traffic movements is insufficient to utilize this methodology in order to calculate the declared capacity thus the available capacity for the next air traffic schedule. Instead airside simulation is applied in the context of this paper.

The idea is to implement a range of scenarios with various ratios of departures and arrivals as well as different traffic demands in the simulation. A simulation implying an adequately long period of time as well as a constant traffic demand can generate a constant traffic flow. The results of the individual simulation runs can then be transfused into a Gilbo diagram.

Another fault of the standard application of the Gilbo method lies in the missing recognition of any quality criteria in order to assess the traffic flow. However the quality of the operation of flights has a significant impact on classification of the declared capacity. A common criterion to assess the quality regarding the runway system capacity is the average delay per aircraft. Based on a survey by the FAA (Federal Aviation Administration) the practical hourly capacity (PHCAP) is, as described by Odoni and de Neufville, the value at which the average delay per aircraft is four minutes. The relation between traffic flow and delay is illustrated exemplarily in Figure 2.

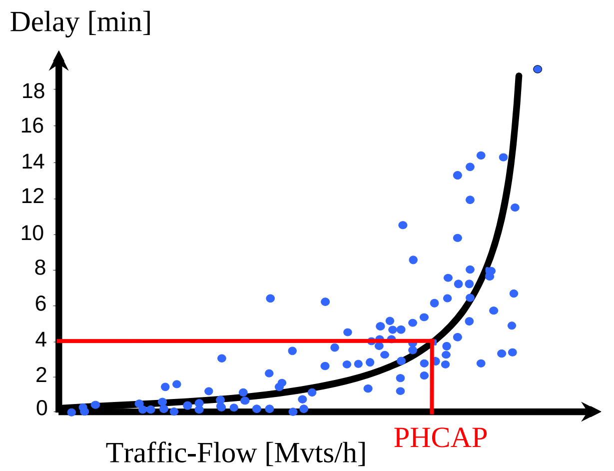

Figure 2 Flow-Delay Diagram

The application of airside simulation on the ground of the capacity analysis allows a flexible increase of traffic demand und thus the design of a flow-delay-diagram. This diagram shows both the maximum throughput capacity as well as the point in which departing and arriving aircraft have an average delay of four minutes. The maximum throughput capacity corresponds with the pole which the graph approaches.

To simplify the implementation of different scenarios and the related complexity of the simulation, the display of different ratios of departures and arrivals is carried out gradually, for example in 10% steps as shown in figure 3.

The simulation of the different individual proportions of departures and arrivals is conducted through several simulation runs. The traffic demand is increased with each simulation run. The simulating continues until the stop-criterion is reached which could be an average delay per aircraft of more than four minutes. In that case the PHCAP is classified for the individual ratios of departures and arrivals.

In transferring the results to the Gilbo diagram and connecting the individual data points the envelope can be redesigned which now incorporates the given quality criterion. Additionally during the simulation runs the traffic demand can be increased to the point where no further traffic flow can be achieved. At this point the maximum throughput capacity is reached which can be displayed in the Gilbo diagram as well.

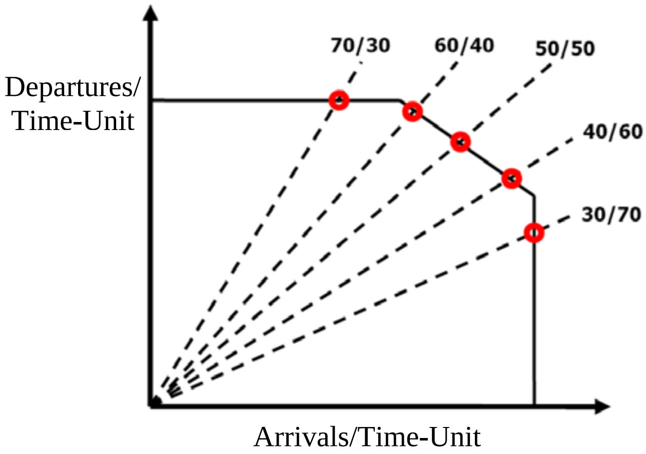

Figure 3 Gilbo-Diagram (Simulation)

4. ASA-TOOL

To look at the problem mentioned above the Department of Airport and Air Transportation at the RWTH Aachen University uses the simulation software SimmodPlus. Simmod is a discrete event simulation which algorithms are based on research by the FAA. The programme’s user-interface however is inadequate for controlling the simulation runs and the assessment of the results. An applicable instrument in this context is the Airside Simulation Analysis (ASA) Tool which especially supports the capacity analysis of runway systems.

The ASA-Tool is a development of the Department of Airport and Air Transportation at the RWTH Aachen University. The Objective in creating this tool was the ability to control Simmod especially on the subject of capacity analysis of runway systems. The following ideas were paramount in the development:

- the generation of traffic demand (schedules) with freely definable attributes
- (multiple-) simulation and incrementing traffic demand
- processing of the simulation results to be used for the capacity analysis (relevant parameter: flow, demand, delay…etc)
- results displayable in a diagram

The ASA-Tool is JAVA based and accesses the simmod simulation engine directly. The simulation- and analysis parameter are controlled directly by ASA.

Referring to the problem above the traffic demand is distributed equally over a simulation period. The programme recognises any adjustments set by the user as to the distribution of the traffic demand meaning different routes or aircraft categories are considered for example.

A flexible setting of the traffic demand allows calculating different scenarios in the simulation.

An adequate number of iterations ensure that ASA meets the stochastic effects as defined in simmod like wake vortex separation.

The multiple-simulation is a function of the ASA-Tool which is especially of importance for the capacity analysis. This is a simulation of certain traffic scenarios with a fixed ratio of departures and arrivals as well as aircraft categories (heavy, medium, light) but with variable traffic demand. The ASA-Tool shows the result as a flow-delay-diagram. The diagram illustrates the average delays per aircraft in reference to a certain traffic demand. The Diagram shows the average delay for departures (green), arrivals (blue) and for the total movements (red).

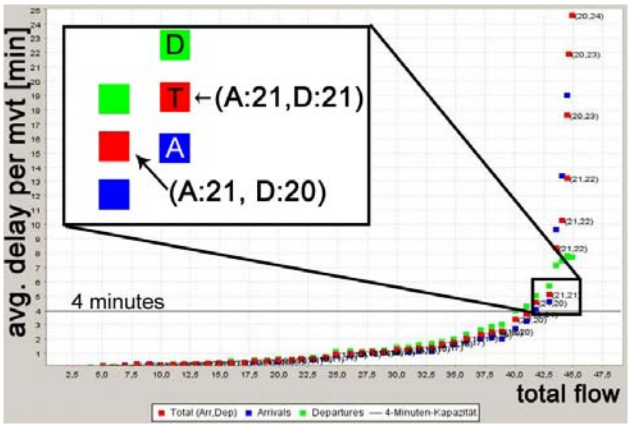

Figure 4 Screenshot ASA-Tool (Flow-Demand-Diagram)

5. EXAMPLE OF APPLICATION

The application of airside simulation and the ASA-Tool before the background of capacity analysis will be demonstrated in the following. The basis for this will be a simmod-model of Dusseldorf Airport. Different alternatives for the classification of the declared capacity can then be discussed on the ground of the simulation results. Since the focus of this paper lies on the evaluation of runway system capacity the following simplification concerning the airport model have been made:

- one direction of operation (no switching)
- maximum departure-queue length, respectively arrival prioritisation
- one-way taxi strategy

· single gate (indefinite capacity)

Afterwards various simulation runs with different proportions of departures and arrivals have been executed. The procedure was as described in chapter 3. The percentages ranged from 100% departures and 0% arrivals to 0% departures and 100% arrivals, with the proportion changing by 10% steps between the runs.

Besides the capacity which induces an average delay of four minutes per aircraft the maximum throughput capacity has been determined as well. In figures 5 and 6 the four-minute-capacity is represented by the red curves and the blue curves represent the maximum throughput capacity.

The next step would be the deduction of the declared capacity on the basis of the simulation results. An easy approach is to employ straight lines in the Gilbo diagram to find the declared capacity. Correspondingly to the three elements of the declared capacity (total capacity, maximum number of departures and maximum number of arrivals), three straight lines are set in the diagram. The one straight line that determines the number of total movements is the tangent at the point of a 50/50 proportion of departures and arrivals or at the same time the orthogonal line to the bisector subtending at 50%/50%. The straight lines corresponding to the maximum numbers of departures respectively arrivals lie orthographic to the x and y axes. There are two ways concerning the positioning of the straight lines. Either the straight lines are drawn near to the red four-minute curve as in scenario 1 (figure 5), or following the requirement that the whole area enclosed by the lines lies within the red four-minute curve as in scenario 2 (figure 6).

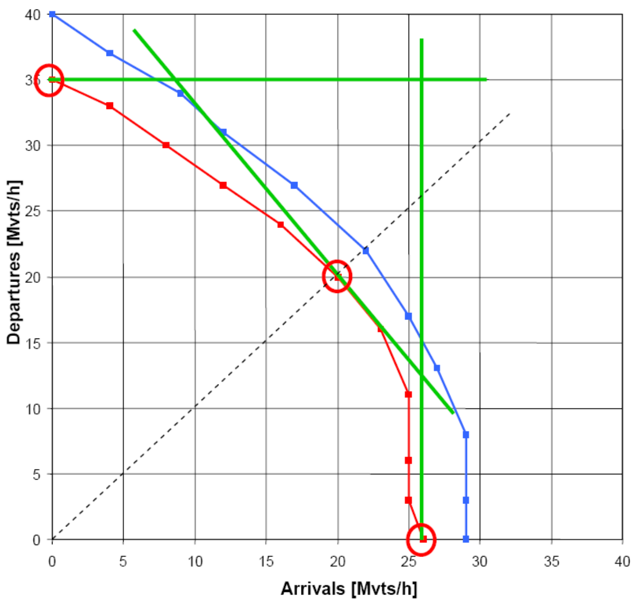

Figure 5 Scenario 1

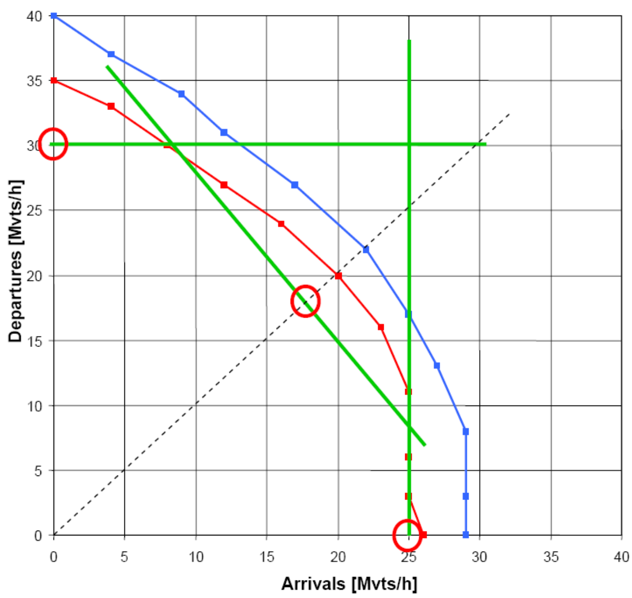

Figure 6 Scenario 2

For reasons of contrast to the two scenarios above a third scenario is illustrated which implies that the total throughput capacity is the decisive factor (figure 7).

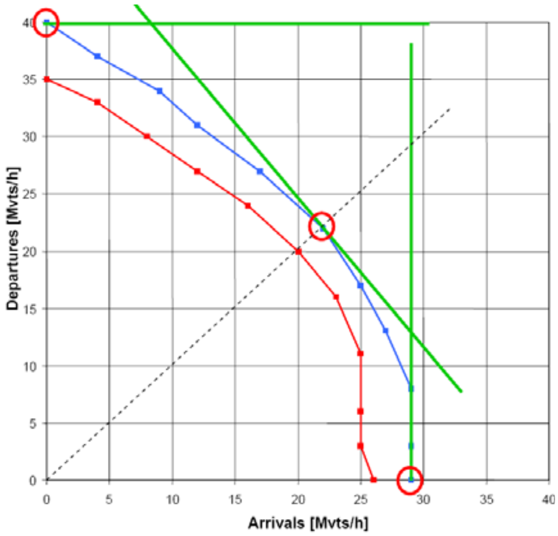

Figure 7 Scenario 3

Accordingly the declared capacities are shown in table 1. The difference between the values of total movements in each scenario to the following is 4.

	Declared Capacity [Mvts/h]		
	ARR	DEP	TOT
Scenario 1	26	35	40
Scenario 2	25	30	36
Scenario 3	29	40	44

Table 1: Declared Capacity

The declared capacities which derive from the capacity analysis will be assessed against the quality criterion in the following. For that reason schedules which include the calculated declared capacities are set up for all three scenarios. As a basis serves a coordinated schedule for Dusseldorf Airport of the summer of 2005 which has been adjusted in the following way:

- strict compliance with declared capacity
- capacity utilisation of slots: ~90%
- proportions arr/dep 50/50, light/medium/heavy 10/60/30
- evenly spread increase and reduction
- departure-peak (morning), arrival-peak (evening)

The uneven distribution of flights constitutes the quality of an authentic traffic distribution over one day.

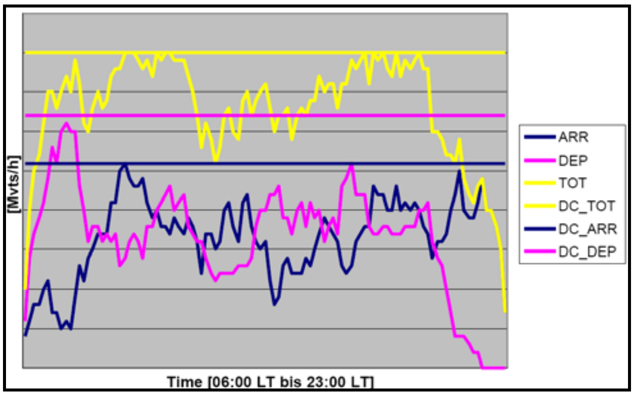

Figure 8 Distribution of Flights

Figure 8 gives an overview over the qualitative pattern of traffic demand and the respective declared capacity (DC). The schedules of all three scenarios have then been put through airside simulation (simmod). The aim was to examine whether the given quality criterion of four minutes average delay maximum per aircraft was achieved.

As a result of the simulation the following values for the three scenarios have been determined.

	Average Delay (min/aircraft)
Scenario 1	2,84
Scenario 2	2,19
Scenario 3	4,77

Table 2: Average Delay

The average delay per aircraft is 2.84 respectively 2.29 minutes for the two scenarios referring to the four-minute value as can be seen in the table 2. The average delay in scenario 3 is 4.77 minutes. These results demonstrate that the delay increases with proximity to the maximum throughput capacity. Although the differences between total movement values (table 1) are identical between 1, 3 and 2, 1 the increase in average delay is higher.

6. SUMMARY

The paper shows that the identification of the declared capacity can be supported through the methodology of capacity analysis according to Gilbo and the application of airside simulation. However this practice can only be regarded as assistance to the coordination committee, since only runway system capacities are taken into account. As has been mentioned earlier the declared capacity depends on further factors.

The application of airside simulation on the ground of capacity analysis encompasses some risks as well. The identification of simulation parameters have to be realistic. Smallest divergences may lead to a deviation of the results. In case of a deficient classification of the declared capacity either valuable infrastructure capacity is going to be wasted or delays are above the favoured level because of an overloaded runway system.

LITERATURE

[Gi93] Gilbo, E.P.: Airport Capacity: Representation, Estimation, Optimization; IEEE Transactions on Control Systems Technology, Vol. 1, No. 3; 1993

[Kö07] Kösters, D.: Study on the usage of declared capacity at major German airports; study in cooperation with the Performance Review Unit (PRU), Eurocontrol; 2007

[ON03] Odoni, A.R.; de Neufville, R.: Airport Systems – Planning, Design and Management; McGraw-Hill, New York; ISBN 0-07-138477-4; 2003

[Si04] ATAC Corporation: Simmod *Plus* Reference Manual; ATAC Corporation; Sunnyvale; 2004