Advances in Simulation for
Production and Logistics Applications
Markus Rabe (ed.)
Stuttgart, Fraunhofer IRB Verlag 2008

De-peaking Lufthansa Hub Operations at Frankfurt Airport

De-peaking des Lufthansa-Hub-Betriebs am Flughafen Frankfurt

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Abstract: In the past, limited runway capacity at Frankfurt Airport (FRA) has been a major issue for Deutsche Lufthansa AG. A simulation model mapping the idea of de-peaking, i.e. the idea of balancing the use of capacities better over the entire day, resulted in significant improvements and cost savings for Lufthansa's operation. To evaluate the positive effect that a depeaked schedule has on the flight times, an iterative fast time simulation approach has been used. In the first run the original schedule was evaluated with respect to the approach delays. This result was used to modify the schedule regarding the expected number of arrivals and the arrival times of the aircraft at the hub FRA. The newly generated schedule gives a different level of overdeliveries that itself has a different behaviour in the arrival delay. After several iterations this schedule converges to the expected arrival delay of the airport. A comparison is made to an alternative schedule with a different peak structure.

1 Introduction

Frankfurt Airport is one of the major airports in Europe with a traffic volume of approximately 480.000 flights each year. Deutsche Lufthansa AG uses Frankfurt as its main intercontinental airport in a Hub-and-Spoke System that connects a large number of European destinations to the intercontinental flights. As a result of this Deutsche Lufthansa AG holds 60% of the traffic share at Frankfurt and is highly dependent on a reliable and punctual operation to satisfy the connecting passenger flows.

One of the biggest problems Deutsche Lufthansa AG is encountering at Frankfurt is that of limited runway capacity. The airport has a runway system consisting of 3 runways, all of which can be used as departure runways while only two of these are usable for arrivals (fig. 1). The problems of infrastructure are due to:

- Dependent parallel runway (25L/25R - 07L/07R) for departure & arrival operation and one departure runway 18,

- Arrival Process: (1) Staggered approaches during peak times; (2) Handling of demand variations by dynamic tromboning (i.e. the flexible use of different transition lengths by the means of extending the downwind) during approach; (3) Exceeding demand is handled through holding or GDP at departure station,
- Departure Process: (1) six departure routes for r/w 18; (2) two departure routes for r/w 25,
- High level of dependability of arrivals and departures on parallel runway and between runways.

***Figure 1**: Frankfurt Airport from the Bird's Eye View*

The result consecutively is an arrival capacity deficiency. In previous years this generated significant Air Traffic Control Delays, generated through a Ground Delay Program (GDP) at departure stations for flights inbound Frankfurt, as well as an additional holding of aircraft in the Frankfurt Terminal Manoeuvring Area (TMA). In comparison with other major hubs in Europe FRA accumulated the largest portion of ATC-Delay with up to 950.000 minutes per year (in 2002), which is the equivalent of the production of 5 medium-haul aircraft on European routes (fig. 2 and 3).

As a part of the delay is airborne holding the scheduling department tries to account for this proactively, such as to provide customers with feasible and reliable connections through the hub-airport. The 'blocktime' specifies the time that an aircraft is in motion from the moment it leaves the gate at the origin until it arrives at the gate at its destination. In the light of the aforementioned, airlines have taken on the approach to calculate scheduled blocktimes in terms of quantiles of actual blocktimes flown in the previous period. Thus they are accounting for a constant and structural airborne delay with prolonged blocktimes.

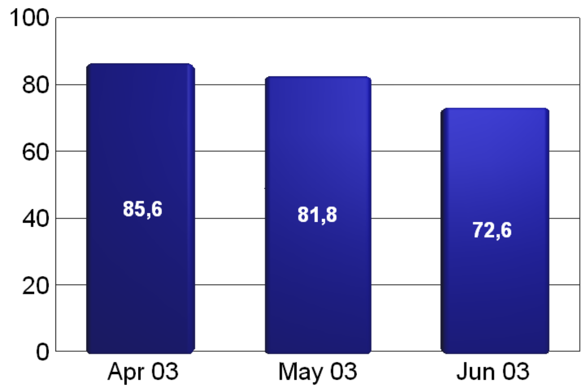

Figure 2: *Share of all Regulated Lufthansa Flights inbound Frankfurt Airport, Affected by a Regulation of Arrival Sector FRA (Source: Lufthansa)*

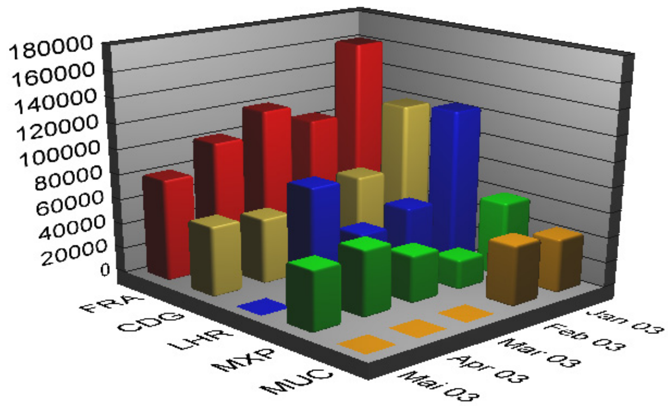

Figure 3: *ATFM Arrival-Delay at Frankfurt Airport in Minutes (all Airlines, Source: Eurocontrol CODA)*

However, if actual blocktimes show a significant spread then the mode of the flight-time is somewhat left of the quantile used for the blocktime calculation (fig. 4). This can consecutively result in overdeliveries, i.e. the number of flights filed to the ATC provider seems higher than the number of flights scheduled in the same period of time (due to the fact that aircraft tend to arrive somewhat ahead of schedule). If this difference becomes too large, ATC is forced to protect sectors/airports from overloads by the means of a Ground Delay Program (GDP). As this GDP is a very imprecise and crude tool for dealing with overloads the interference may still lead to airborne holding at the destination station which then in the long run causes yet another increase in blocktime.

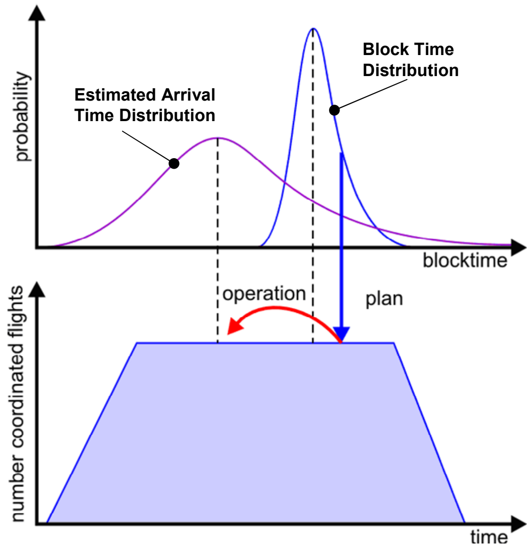

***Figure 4**: Difference between Block and Flight Times*

2 The Idea of De-Peaking

When looking at how the airport/airspace infrastructure is being used in several banks of arrivals and departures in a hub-system, it becomes obvious that while at times the scarce capacities are used above their limits, at other times these capacities are slack. Thus the idea was to balance the use of the capacities better over the entire day. While in previous years the maximum number of scheduled arrivals peaked at 45 per hour this number was reduced in the de-peaking process to 42 arrivals per hour (fig. 5), the excess movements where then used filling up the trough between two peaks.

With this the load on the scarce resource 'arrival runway' could be reduced thus leading to less airborne holding. As described above, in the long run this would mean a decrease in blocktime. Yet as this was to be expected, the intention was to already anticipate the magnitude of delay reduction and decrease the blocktimes by this amount proactively, thus breaking the vicious circle of blocktimes and ATC interference described above.

Although there is a broad body of research done on runway capacity analysis utilizing various types of numerical queuing models (Stolletz 2008) it was decided to model such a complex system such as the airport/airspace infrastructure at FRA in a commercial off-the-shelf discrete event simulator.

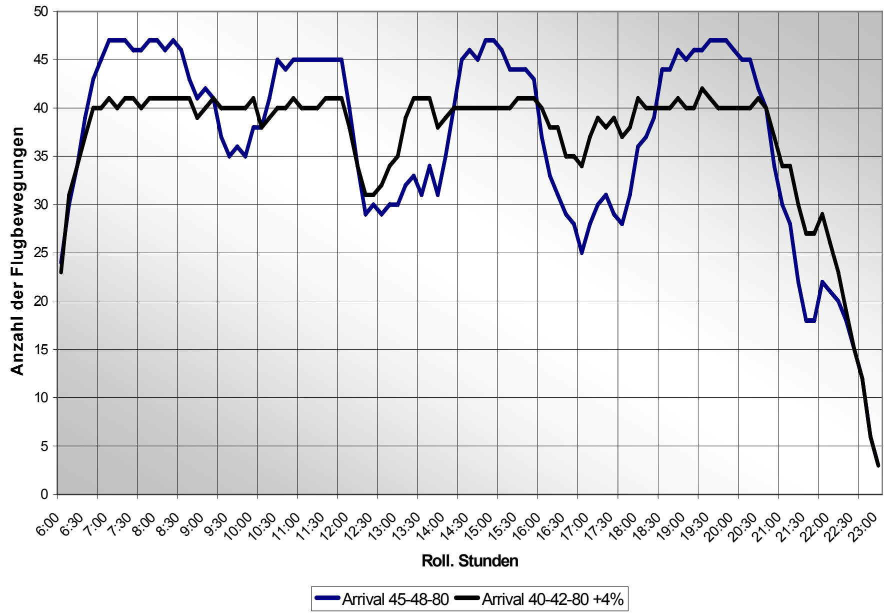

Figure 5*: Number of scheduled Arrivals throughout the Day*

In order to evaluate this right amount of blocktime reduction, a highly flexible simulation tool was necessary that enabled modeling of complex, interdependent queues as well as large numbers of multiple runs (fig. 6) and, also, provided the flexibility in using various statistical distributions for the different processes involved. In this context Rockwell Software's *Arena*® provided by *SAT Simulations- und Automations-Technologie AG* (Freiburg, Germany) could satisfy all the requirements mentioned above and hence was chosen by Deutsche Lufthansa AG as the appropriate tool for this simulation.

Iterative simulation was used as a new approach to overcome the task at hand (fig. 7). Under real live conditions a change of the structure of a schedule does not only result in a different arrival delay, it also has an impact on the overdeliveries that appear in the ATC-System. This may not be seen independent of each other. Hence the simulation has to account for this. For each of the simulated schedule options the following procedure was established. In a first run the original schedule was evaluated in a step of multiple simulation runs with respect to the approach delays over the daytime curve. This approach delay was subtracted from the flight time according to the time of its appearance in order to generate a more realistic expected arrival behaviour and in consequence the expected magnitude of the overdeliveries (cf. fig. 4). With this method the generated new schedule was then again simulated and the above procedure was iterated until the schedule converged in terms of approach delay and overdeliveries. The same procedure was performed on the alternative schedule leading to comparable results of the quality of the schedules with respect to its behaviour and robustness against arrival delays. The difference in the arrival delay of both scenarios was then taken as the average delay that was expected to be reduced by changing the bankstructure of the schedule. This was taken as the number of minutes the scheduled blocktime could proactively be decreased by upon generating the schedule.

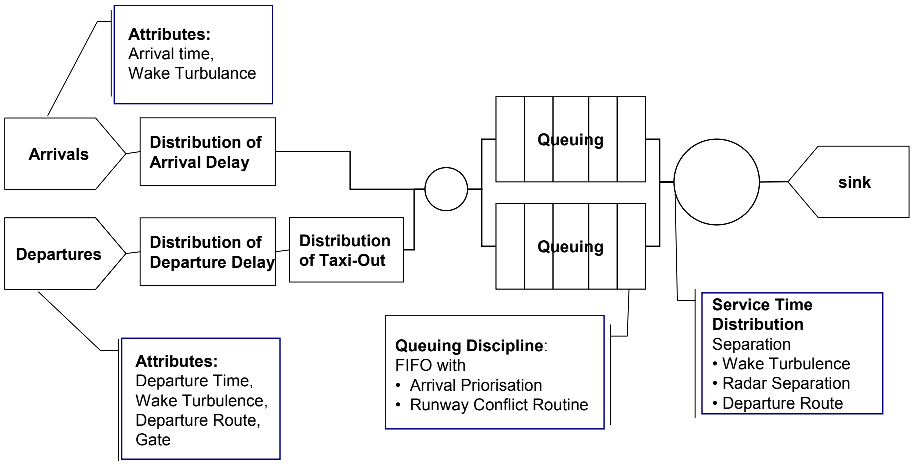

Figure 6: *Scheme of the Queuing System*

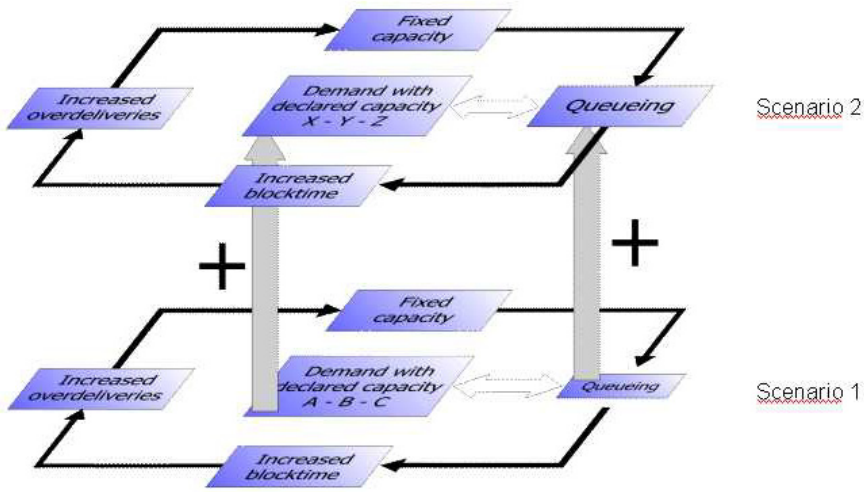

Figure 7: *Concept of the iterative Simulation; Convergence of the Iteration is Guaranteed for the Stationary Case*

3 Simulation Results

As a result of the entire process in summer 2004 Deutsche Lufthansa AG could on the one hand reduce the blocktimes inbound Frankfurt by around 5 Minutes per flight inbound; on the other hand it was possible to increase the overall traffic into FRA by approximately 5% while maintaining the same level of punctuality (Klempert et al. 2005). Overall the magnitude of delay was reduced by approx. 5 Minutes per flight accumulating in more than 10.000 delay-hours per year. In addition, more than 50.000 tons of jet fuel were saved per year. Overall this means total savings in the range of 20 to 30 Million Euro per year for Lufthansa operations.

The idea of de-peaking, in sum, lead to substantial cost savings (Klingenberg 2004; Cezanne 2005) also with regard to:

- Since arrivals and departures at Frankfurt Airport could be de-peaked, corresponding cost reduction could also be obtained for passenger services (Check-in, Boarding) as well as aircraft services (Loading, Catering, Cleaning, Fuelling),
- The peak staffing and equipment could be reduced by up to 10%,
- Utilization of gates and irregularity costs could be improved,
- Cost for flying holding patterns were significantly reduced.

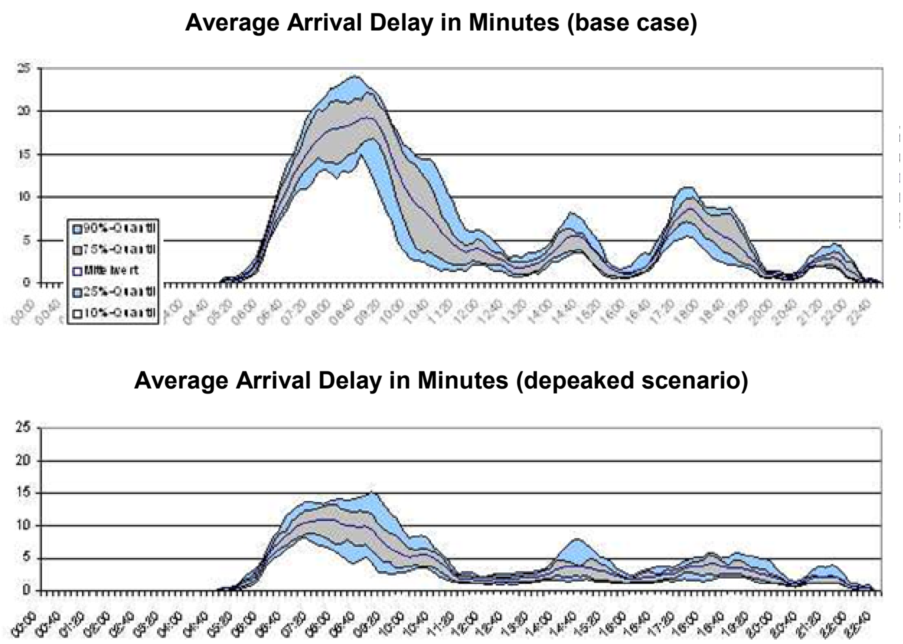

__Figure 8:__ Simulation Results for Reduction of Average Delay per Movement for the Day

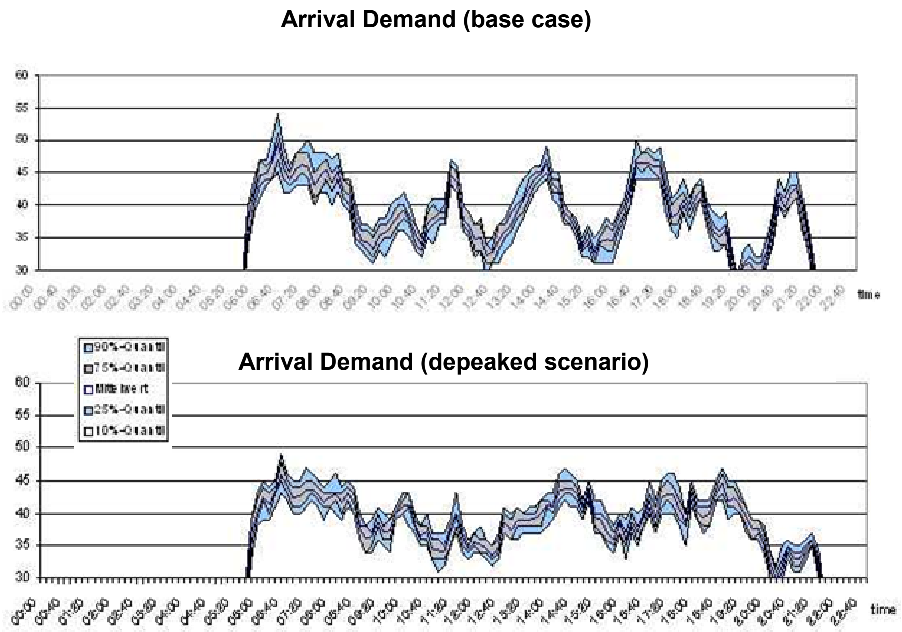

Figure 9: *Simulation Results for Demand for Base Case Scenario and De-Peaked Scenario*

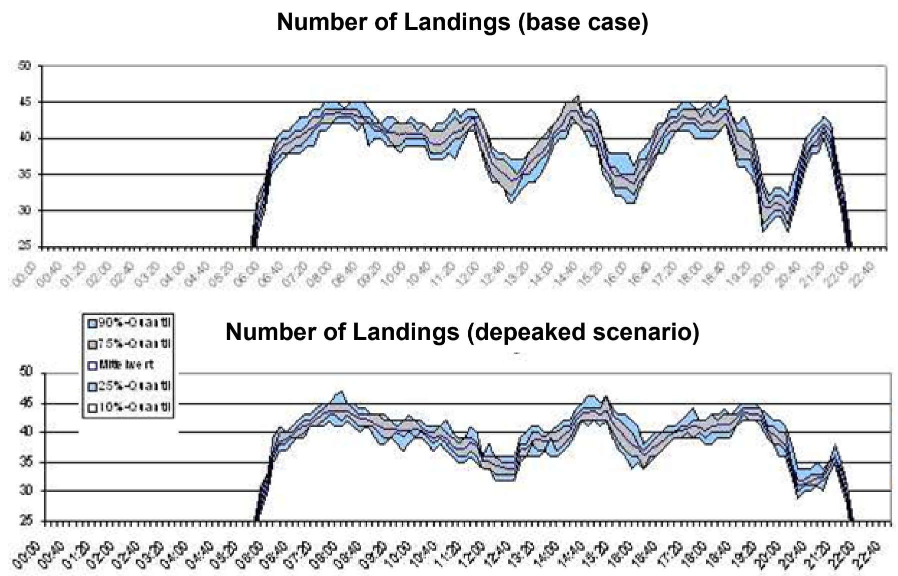

Figure 10: *Simulation Results – Effects of De-Peaking on Number of Landings*

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