Airport Modelling:

Capacity Analysis of Schiphol Airport in 2015

by

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Abstract

The NLR has recently conducted a study into the expected airport capacity of Amsterdam Airport Schiphol in 2015 in The Netherlands. The primary objective of the study was to investigate whether the capacity of the airport and the expected demand would balance in the year 2015 and if not, which measures should be necessarily taken to accomplish this.

The study has been performed using the fast time simulation model TAAM (Total Airspace and Airport Modeller). TAAM is a very easy to operate model, so the study was completed in a relative short time.

First results of the study showed excessive delays (on average more than one hour), resulting from a complete mismatch of capacity and demand. Then 5 different measures to reduce the observed delays were investigated. One of them was to use more runways at the same time. It is evident that this leads to a significant reduction of delays. Other less trivial measures proved also to be able to produce significant reductions of delays. Amongst them were intersection take−off’s and segmentation of arrivals based on wake turbulence category.

During the seminar more details of the study and a detailed specification of the simulated capacity enhancing measures will be presented (see the accompanying viewgraphs). Also some preliminary results of a follow−up study will be indicated. This follow−up study comprised the comparison of four different possible extensions of the layout of Schiphol Airport in relation to two different developments of the airline schedules (traffic distribution). In this new study the airport layouts were more closely matched to the demand as dictated by future planned airline schedules, resulting in a significant reduction of the calculated delays.

1. Introduction

As the cost of air travel continues to decrease, the number of people flying across the planet climbs inexorably: according to the latest IATA Passenger Forecast, the number of international scheduled passengers will reach 522 million in the year 2000, and 800 million in 2010. When domestic traffic is included as well, the figures increase dramatically: the total number of scheduled passengers will reach 1.725 billion for the whole world by the year 2000.

How can they all be carried in safety, punctually and at a profit when there is already a major problem with congestion and delays, both on the ground and in the air?
Whilst there is no simple fix for the world’s aviation congestion the incentives are clear. The Air Transport Action Group (funded by Airbus Industrie, Boeing Commercial Airplane Group and IATA, but with a much wider general membership) has noted that "The results of infrastructure constraints are major delays which cause fuel waste and increase engine emissions", consequently there is not only a direct economic cost associated with delays, there are also environmental and political issues which cannot be neglected.

The scale of the problem is huge: in 1990 Lufthansa alone claimed that it experienced approximately 12,000 hours of holding time due to inefficient air traffic control, and the total cost of congestion has been estimated at $5 billion per year in Europe, and a further $5 billion in the United States.

In order to try to solve or at least alleviate these problems, three fundamental approaches are possible:

1. Increase the number of passengers per aircraft −> larger aircraft

2. New ATM−procedures, e.g. to reduce separations and to make the traffic streams more efficient (~ constant streams with less variation) and better coordinated between ATC−centres

3. Expand present airports in such a way that their capacity increases, reducing ground and airborne delays or build new efficiently laid out airports (parallel runways!)

Before investing large amounts of money in implementing these approaches, it is obviously wise to carry out extensive research beforehand. A very efficient and cost−effective way to do this research is to perform simulations, fast−time as well as real−time. Both simulation techniques have their own strengths and weaknesses, requiring to tailor a research programme to the tools available. For fast−time simulations in the field of ATM, NLR has purchased TAAM (Total Airspace and Airport Modeller) from "The Preston Group", Melbourne, Australia. For real time ATM−related simulations, NLR has developed NARSIM (NLR ATC Research Simulator). This paper will concentrate on recent research NLR has carried out using TAAM.

Also at Amsterdam Schiphol Airport the problems are becoming more and more urgent with present and forecasted traffic growth. The present annual traffic growth rate is more than 10%, which implies that the officially allowed maximum number of 44 million passengers (presently ~28 million) will be reached much sooner than the forecasted year 2015. Therefore, the national carrier KLM has commissioned NLR to investigate the impact of traffic growth on the capacity of Schiphol Airport and study the effects of certain measures to alleviate the possible bottlenecks.

2. TAAM

The Total Airspace and Airport Modeller (TAAM) is a large scale fast−time simulation model, designed to simulate very realistically all possible aspects of the handling of air traffic, on the ground as well in the air, in the TMA as well as en−route. It simulates the behaviour of aircraft in all phases of flight, as well as the rules of airlines and air traffic controllers alike. It is a tool enabling the user effectively to simulate total air traffic from gate to gate. It has been under continuous development since 1987 and presents the state−of−the−art in fast−time ATM modelling. After proper training, it can be set up in a relatively short time. One of its strong points is that it is highly visual with unlimited zooming possibilities: you can easily follow the traffic flow in all its aspects, making it easy to pinpoint problem areas down to small details as well as to present a general picture of what is going on in modern ATM to higher management.

TAAM consists of a generic shell which interfaces its 4 main modules:

1. The main simulation mode (SIM)
2. An interactive data input module (IDIS)
3. A special CAD−tool for editing of graphical objects (GTOOL)
4. A reporting module for presenting and analysing of the results (REPORT) The setup of a basic TAAM−project (see figure 1) consist of:

1. The environment: maps, sectors, runways, taxiways, etc.
2. The general procedures: SID's, STAR's, taxiway usage, etc.
3. The aircraft performance data (tabular data for the parametrised aircraft performance model)
4. The ATM Rulebase for the specific usage of the airport, sectors, etc. In TAAM very complex traffic handling rules can be setup easily.
5. The traffic sample or −schedule
6. Running the simulation(s)
7. Analysing the TAAM output (graphics and reports)

3. Capacity Analysis of Schiphol Airport in 2015 using TAAM: first study

In order to investigate the capacity of Schiphol Airport in general and in particular to determine and solve important bottlenecks in the handling of air traffic, KLM has asked NLR to carry out fast−time simulations of the expected traffic situation in 2015. After a preceding feasibility study, KLM and NLR have agreed to use the advanced fast−time simulation model "TAAM" for this purpose.

The basic scenario consists of the officially published maximum of 44 million passengers, five main runways plus limited use of the shorter runway 04−22, as well as the corresponding extension of aprons and the number of gates. The prognosis of the corresponding number of aircraft movements, as well as its distribution over the day (the so−called 6−block system), per group of airlines, and the distribution of aircraft types, has been provided by KLM.

The study has been split into 3 main phases, covering a period of 5 months:

− *Phase−1:* setup of a basic model of the expected situation in 2015
− *Phase−2*: identification of major bottlenecks in the handling of air traffic, plus determination of suitable solution strategies and analysis of the results
− *Phase−3:* reporting on the results (this report)

The work has been structured as follows:

Phase−1:

− obtaining of the correct data with respect to the layout of the new 5th main runway, the extension of aprons and number of gates, runway preferences, meteo data, new SID's and STAR's, new taxi rules. Discussions with the ATC− and airport authorities.

− conversion of meteo data and traffic prognosis (KLM) into a format suitable for TAAM. Creation of multiple time tables.

− input of data (modification airport layout, runway preferences, meteo data, taxi rules, SID's and STAR's, creation of TAAM "usage rules").

− writing of a program for a reporting function additional to the standard TAAM reports, calculating e.g. mean values, standard deviations and extreme values of delays (sequencing, taxiing and gate delays) for a year as well a group of best and worst days. No distinction is made between summer and winter periods.

− extensive testing of the model

− demonstration to KLM of the working basic model of the expected traffic situation in the year 2015 *Phase−2*:

− determination of a number of the most urgent bottlenecks impeding maximising of the airport capacity.

− determination of a number of strategies to solve these bottlenecks.

− discussion with KLM on these 2 items above.

− running of a large number of simulation runs and analysis of the results.

− demonstration to KLM of the effect of the solution strategies on the bottlenecks. *Phase−3*:

− final report

In general, the obtained simulation data have been worked out as follows.

Since it proved to be unpractical and unnecessary to run a complete year’s traffic, the contribution of the different weather conditions to the actual use and accompanying delay figures has been accounted for in the following way:

A large number of simulation runs has been performed, (at least) one for each allowed runway combination. Using TAAM’s reporting function and the additional program mentioned above, all relevant delay figures have been calculated. Then, the contribution of each run to the total annual delay figures has been determined by using a weighting factor for the relative frequency of occurrence of such a situation during the year. The latter has also been done for runs representing the best and worst conditions.

The setup of the simulations is described in section 3.1, while the main results ˜the identified bottlenecks and its proposed solutions˜ are treated in section 3.2.

3.1 Setup of the simulations

3.1.1 Phase−1: basic scenario 2015

3.1.1.1 Input of data to the model

After discussions with the ATC− and airport authorities, the correct data with respect to the layout of the runways, taxiways, aprons and gates, as well as Standard Instrument Departures (SID’s), Standard Approach Routes (STAR’s) and taxi/pushback rules, as expected to be implemented in 2015, have been obtained and implemented in the simulation model. Apart from changes to the current SID’s and STAR’s, new ones have been added for the new fifth main runway and for full bi−directional use of the present 01L/19R runway. The following aprons have been added to the present (1996) layout: A− (mainly commuters), H− and J−apron (mainly for wide−bodies), plus a new large freight area "South East". The scenario is based on the officially agreed maximum of 44 million passengers per year.

For the weather data, the "International Station Meteorological Climate Summary", as published on CD−ROM by NCDC/NOAA, has been obtained. The relevant meteo data for Schiphol Airport have been extracted and the frequencies of the occurrence of the different weather conditions at Schiphol have been derived.

The basic prognosis of KLM of the number of aircraft movements and its distribution over the day and aircraft types has been transformed into a suitable "time table" format for TAAM. It comprised a maximum of 1460 movements per day.

Other assumptions are:
− all aircraft will be Cat III equipped.
− SMGCS will not be generally in use in 2015, implying that low taxi speeds (~5 kts) will be necessary under extreme low visibility conditions.
− maximum number of simultaneously taxiing departures of 12 per individual runway and of 20 in total for the whole airport.
− General use of MLS in 2015 (so no ILS−protection area!), implying that effectively the severe separation limits of BZO phase−D no longer apply and can be replaced with those of BZO phase−C.
− Use of DCIA ("ghost" approaches, using CRDA) until Cat. III conditions.
These two applications imply that always two parallel or two converging runways can be used for landing, without extra large separations.

The effects of other scenarios can be investigated further in possible future additional simulations.

3.1.1.2 Testing of the model

For testing of the model−under−construction many simulations have been run, enabling the fine-tuning of the apron/gate/taxiway−layout, the time tables, TAAM "usage rules" for gate usage, pushback, taxiing, runway usage, etc.

During this testing it became clear that unrealistic large gate delays for departures occurred, especially under low visibility conditions (i.e. larger separations), due to the fact that the preceding arrivals were experiencing very large sequencing delays (much larger than 1 hour), while the corresponding departures often already (unrealistically) occupied their assigned gates. This means effectively that the practical capacity of the airport is exceeded and that in real life these arrivals would have been diverted to other airports or would have been held on the ground at the airport of departure. This problem has been solved elegantly through implementation by The Preston Group (supplier of TAAM), on special request by NLR, of an extended functionality in a updated version of TAAM in the following way:

In the NLR−simulations TAAM has been set up such, that as soon as an aircraft has arrived, it is connected (linked) at its gate with a corresponding (via its registration nr.) departing aircraft from the time table. Moreover, a departure is set to appear at its gate 40 minutes before ETD as standard. If an arrival is delayed such that it cannot arrive at its gate at least 40 minutes before it has to depart again as a corresponding departure (under a different flight nr.), this corresponding departure is delayed as well. Another new functionality that has been tested is the following: if some aircraft get a large sequencing delay of say, one hour, in reality these aircraft would have diverted to another airport. This can be simulated in TAAM (via runway usage rules) by "termination" of these aircraft at the FIR−boundary. Now TAAM also correctly removes the corresponding departure from the time table. This function has been used to let flights "divert" if, at the end of a simulation "day" (04:00−04:00 hrs), they could not land before the end of the simulation "day" due to too large sequencing delays. In the latest 1997 version of TAAM this diverting of flights is fully implemented.

3.1.2 Phase−2: analysis of bottlenecks

3.1.2.1 Determination of bottlenecks

In order to determine bottlenecks in the expeditious handling of air traffic, a large number of simulations has been run for all operational allowed runway combinations, for good as well as limited visibility conditions. Since these runs took a long time each (typical four hours or more), due to the "loading" of the airport to its capacity limits, they were often run at night and in weekends in so−called batch−mode (without graphics to speed things up), gathering large amounts of statistical data. After a "quick look" analysis of the results, the important parts (with large delays, etc.) of these simulations were re−run (with graphics switched on) during office hours, to determine visually the nature and seriousness of the possible bottlenecks.

In this manner a list of more or less important bottlenecks (section 3.2.1) has been made, which subsequently has been shown to and discussed with KLM. From this list a selection of most urgent bottlenecks has been made for which a number of solution strategies has been determined (see section 3.2.2).

3.1.2.2 Solution strategies

The main issues with respect to bottlenecks at Schiphol when operating at its capacity limits are identified as:

− aircraft movements in peak periods (total number as well as distribution over the peak periods)
− availability of "concrete": runways, taxiways, aprons
− availability of gates
− large taxi distances to/from the new 5th main runway in relation with limited taxi speeds Some of the possible solution strategies are of a purely technical nature, like reconstructing taxiways, while others, like modifying the priority rules of arrivals vs. departures, require a change of national or even international policies.

3.2 Results

3.2.1 Identified bottlenecks

Within the scope of the project and using the techniques described in section 3.1.2.1, a number of serious bottlenecks has been identified.

After demonstrations to and discussions with KLM it was decided to further analyse possible solutions (see below) to only the following most urgent problem areas.

− Situation around the head of runway 24
− Situation around the head of runway 09
− Excessive gate delays of outbound traffic
− The situation on taxiway "South" near the head of runway 01 The best solution to the last bottleneck is to construct a second parallel taxiway. However, in case this (costly) solution will not have been carried out in 2015, it is of interest which effects the use of the general solution strategies, as described below, will have on this bottleneck also.

It must be realized, that by solving some problem areas, other, closely related bottlenecks can also be solved. E.g. the improvement of the situation around the head of runways 24 and 09, optimizing of the landing queue and modification of the number of available runways, can reduce the excessive gate delays of departures, which in turn can solve the problem of the limited number of available gates.

3.2.2 Solution to bottlenecks

After consultation with KLM, the following solution strategies have been further analysed:

1. Flexible procedures for taxiing on the main "inner tracks" and "outer tracks", instead of the current strictly one−way traffic rules. TAAM can often solve such situations dynamically.
2. Allowing intersection take−off’s for all runways (non−heavies only), if the departure queue for the normal entries exceeds a certain value, using special TAAM "usage rules".
3. Construction of an extended taxiway south east of runway 06−24, from the new freight area "South East" to the head of runway 24 (see figure 4). Although the active runway has to be crossed, this extra taxiway could be used for the whole departure queue for runway 24, no longer blocking the arrivals.
4. Continuous use of so−called 2/2 runway combinations (two departure runways and two arrival runways available simultaneously) from 7 to 23 hours daily. Also the possible use of 3/2 combinations will be investigated.
5. Optimisation of the landing sequence per runway: as much as possible similar traffic on one runway (e.g. medium traffic only to one runway, while all heavy traffic to another runway, with additional medium traffic if necessary).
6. All strategies simultaneously.

Although not being a part of the present study, it may be wise to analyse in an extended study the effects of the combination of some pairs of solution strategies, e.g. nr. 1 and 3. In this example it has been observed that sometimes a row of arrivals from Rwy 19/19R, taxiing on the outer track of Rwy 24, were blocked by a small number of departures crossing Rwy 24 towards the southern entry. If a more flexible use of taxiways is allowed, this situation is alleviated.

N.B. In order to limit the absolute number of simulation runs as much as possible, it has been decided that in the context of this study the delay figures belonging to limited visibility conditions (= BZO) will be represented by BZO phase−C only. On a yearly basis limited visibility conditions (all BZO−phases) occur in ca. 5% of the time. It has been chosen to let the delay figures for BZO phase−C be representative for these 5%.

For the analysis of the capacity of Schiphol Airport, the following sets of simulations have been run twice, once for good visibility, and in principle, a second time for BZO phase−C conditions:

Set nr.	**Arrival ˜ Departure Runways:**				**Solution strategies:**					
	arriv. peak	**depart. peak**	**off−peak/night**	**Basis**	1	2	3	4	5	all
01	19/19R˜24	19R˜24/19L	19R˜24	x	x	x	x	x	x	x
02	01R/06˜01L	06˜01L/01	06˜01L	x	x	x		x	x	x
03	19/19R˜19L	19R˜19/19L	19R˜19	x	x	x		x	x	x

04	06/09˜09	06˜09	06˜09	x	x	x		x	x	x
05	24/27˜24	27˜24/27	27˜24	x	x	x	x	x	x	x
06	01/01R˜01L	01R˜01L/01	01˜01L	x	x	x		x	x	x
07	06˜09	06˜09	06˜09	x	x	x				x
08	27˜24	27˜24	27˜24	x	x	x	x			x
09	01˜01L	01˜01L	01˜01L	x	x	x				x
10	27˜27	27˜27	27˜27	x	x	x				x
11	09˜09	09˜09	09˜09	x	x	x				x
12	24˜24	24˜24	24˜24	x	x	x	x			x
13	06˜06	06˜06	06˜06	x	x	x				x
14	04/06˜01L	06˜01L/01	06˜01L	x	x	x		x	x	x
15	27/06˜01L	06˜01L/01	06˜01L	x	x	x		x	x	x

N.B. When discussing the results in the following sections, reference is made to the simulation set numbers and solution strategy numbers mentioned above.

With respect to runway preferences the peak−, off−peak and night hours are defined as:
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3.2.2.1 Delay analysis summary

In this section the solution to these bottlenecks are summarized by solution strategy:

1) Flexible use of taxiways:

− no significant change of delays around the head of runway 24
− much less delay around the head of runway 09
− less delay on taxiway"South" near the head of runway 01
− no significant change of gate delays for departures
− much less diverted flights **2) Intersection take−offs:**

− decrease of sequencing delays of departures
− increase of departure flow
− less diverted flights
− much less gate delays
− increase of delays around the head of runway 24. The complex situation her with nearby aprons and gates introduces an extra bottleneck
− increase of delays around the head of runway 09 if this runway is in use, introducing an extra bottleneck. However, allowing intersection take−offs on other runways improves the general flow of taxiing traffic, also that near the head of runway 09

3) Use of new taxiway south of runway 24 for take−off 24

− solves the bottleneck around the head of runway 24 effectively

4) Use of double (or even triple) sets of runways in daytime (7−23 hrs)

4.1) Always 2 arrival− and 2 departure runways available ("2om2")

− decrease of delays around the head of runway 24
− decrease of sequence delays of arrivals in most cases. No significant effect in those cases where the actual runway combination was already favourable for landings
− strong reduction of gate delays for traffic to runways that are only used for departures
− increase of gate delays and sequencing delays for traffic to runways that are used in mixed mode => increase of number of aircraft unable to depart in time => increase of number of arrivals finding no free gate upon landing

4.2) Always 3 arrival− and 2 departure runways available ("3om2")

− even further reduction of sequence delays of arrivals

5) Optimum runway assignment according to wake turbulence category

− decrease of delays around the head of runway 01
− reduction of sequence delays of arrivals
− increase of sequence delays of departures from runways used in mixed mode => increase of number of aircraft unable to depart in time => increase of the number of arrivals finding no free gate upon landing

6) All solution strategies together

− reduction of gate delays for traffic to two independent departure runways
− reduction of sequence delays of arrivals contributed by solution: "Always 2 arrival− and 2 departure runways available ("2om2")" and "Optimum runway assignment according to wake turbulence category"
− alleviation of bottleneck around the head of runway 24 through solution: "Use of new taxiway south of runway 24 for take−off 24", but this positive effect is reduced through solution: "Intersection take−offs"
− increase of the number of aircraft unable to depart in time and thus of the number of arrivals finding no free gate upon landing, if runways are used in mixed mode. This is caused by the contribution of solution: "Always 2 arrival− and 2 departure runways available ("2om2")" and "Optimum runway assignment according to wake turbulence category", when runways are more utilised in mixed mode, where arrivals have priority on departures
− the bottleneck on taxiway "South" near the head of runway 01 is reduced
− the bottleneck near the head of runway 09 is reduced, except when intersection take−offs are used runway 09

3.3 Conclusions

Basic assumptions:

The air traffic prognosis of KLM for 2015 at Schiphol Airport as used in this study, is based on 44 million passengers. The groundside extension of Schiphol, comprising the construction of a **5th main runway (01L/19R)** plus construction of new aprons A, H and J, a new freight area "South East", extension of aprons D, E and some buffers, is based on the same amount of passengers (variant−3 as given in Ref. 1). See figure 1 and 2 for the layout and runway naming system as used in this study. The expected average daily traffic demand amounts to **1460 movements per day in a 6−block system.**

Results:

a) Good visibility conditions.:

In general, the results of the simulations show clearly that, if the growth of air traffic at Schiphol Airport will continue in the future at the expected rate, leading to the amount of traffic and its distribution over the day and its distribution over aircraft types according to the prognosis of KLM, Schiphol will approach or even exceed its capacity limits under good visibility conditions.

Arrivals:

In case of the basis situation, on average 646 of the 730 daily arrival flights (88%) have some imposed delay at the airport of departure (waiting for a landing slot at Schiphol) with an average of 40.6 minutes, while 146 (20%) have a delay of more than one hour. When only one runway is available, 88 aircraft (or 1.6% weighted average) will even not be able to land at Schiphol and will have to divert. Also, on average 55 arrivals (8%) find no free gate upon arrival, since these are still occupied by delayed departures.

Departures:

In case of the basis situation, the mean gate delay per aircraft for departures amounts to 62.4 minutes and 7.4 aircraft will not be able to depart (mainly when only one runway is available).

b) Low visibility conditions:

Under low visibility conditions (BZO phase−C), the airport capacity will be far exceeded, leading to very large number of scheduled inbound aircraft which have to be diverted to other airports or to be held on the ground at the airport of departure.

Arrivals:

In case of the basis situation, on average 540 of the 730 daily arrival flights (74%) have some imposed delay at the airport of departure (waiting for a landing slot at Schiphol) with an average of 4 hours 49 minutes, while 446 (61%) have a delay of more than one hour. Moreover, a mean number of 190 arrivals (26%) have to divert. Also, on average 291 arrivals (40%) find no free gate upon arrival, since these are still occupied by delayed departures.

Departures:

In case of the basis situation, the mean gate delay per aircraft for departures amounts to 131.2 minutes and 272 aircraft will not be able to depart before 04:00 hrs the next morning.

N.B, Due to very long delays, a large number of aircraft will arrive/depart after 23:00 hours. This will have serious consequences for the associated noise contours.

c) Bottlenecks:

Four main bottlenecks in the handling of air traffic at Schiphol have been analysed in this study:

− Situation around the head of runway 24
− Situation around the head of runway 09
− The situation on taxiway "South" near the head of runway 01
− Excessive gate delays of outbound traffic   For the **serious situation around the head of runway 24**, which occurs very often each year, the best solution is the construction of a new extra taxiway south of runway 24, to be used for all departures from runway 24. This reduces its (weighted) contribution to the daily total taxi delays from 2179 to 1077 minutes.

The **situation around the head of runway 09** does not occur very often annually,which is reflected in the relatively low weighted delay figures. But if it occurs, it is a serious bottleneck! Then the best solution is the flexible use of taxiways. This reduces its (weighted) contribution to the daily total taxi delays from 109 to 40 minutes.

For the **situation on taxiway "South" near the head of runway 01** the best solution is the construction of an extra parallel taxiway. If this is not feasible, the best solution is the use of intersection take−offs. This reduces its (weighted) contribution to the daily total taxi delays from 1162 to 300 minutes.

The best reduction of excessive gate delays of outbound traffic (from ~60 to ~40 minutes per aircraft) is found in the use of double sets of departure runways.

General observations:

With respect to the new 5th main runway (01L/19R), it can be observed that crossing of the active runway 01/19 (the present runway 01L/19R) of arrivals on runway 19R does not occur very frequently. The planned extra taxiway "North" is used mostly in such circumstances because the "penalty" for crossing an active landing runway is larger than the extra taxi time using taxiway "North". On the other hand, departures heading for runway 01L will frequently cross the departure runway 01/19, since this is by far the shortest route, despite the (smaller) penalty caused by crossing an active departure runway.

It also has become clear that taxi times to/from runway 01L/19R (not counting possible delays) can become very large (~15 minutes), even using 30 to 40 kts taxi speed on the new long taxiways and 20 kts as standard on other taxiways, as used in the simulations.

The distribution of air traffic over the arrival/departure peaks has a significant influence on the efficient handling of the traffic. The prognosis of KLM implies that 60% of the total number of arrivals of each arrival peak land in the second half of these peaks and 60% of the total number of departures of each departure peak are scheduled to take off in the first half of these peaks. This has been done to reduce the occupancy time of gates. Nevertheless, this seems unfavourable, because the resulting clusters cause too much delay. A more favourable distribution is a uniform one, because fewer delays will occur. Further research is required to confirm this.

4. Capacity Analysis of Schiphol Airport in 2015 using TAAM: follow−up study

Under a joint contract with KLM and the airport authorities AAS (Amsterdam Airport Schiphol), NLR has recently carried out a new simulation study as a follow−up to the study described above. Although the final report has not yet been published, some interesting results are indicated below.

The object of this study was to compare four different possible extensions of the layout of Schiphol Airport in relation to two different developments of the airline schedules (traffic distribution), a high−peak and a low−peak scenario. In this new study the airport layouts were more closely matched to the demand as dictated by future planned airline schedules, resulting in a significant reduction of the calculated delays. The study had to be completed in a very short time frame (3½ weeks) and consequently only comprised 1 simulation run per runway combination for each variant, so the statistical value of the results is rather limited.

The initial delay figures which emerged from this new study are rather small in most cases. These rather different results can be explained from the rather different scenario and different starting points on which this study has been based compared with the previous study. The main differences are:

− Different characteristics of the used time tables: peaks are lower now and the distribution within the peaks are different. This has a very pronounced effect.
− The separations used are lower now than in the previous study.
− The airport layouts are better tuned to the traffic prognosis: accurate measured layouts with a optimised

distribution of the gates (qua location and aircraft category).
− The runway combinations used are more favourable now for low delays: low preference runway combinations, giving the largest delays have not been considered in this study.
− No low visibility conditions are simulated now, while these formed an essential part in the previous study.
− Introduction of three "stand−off" (holding) positions in the new study produced favourable results.
− Sequencing delays for arrivals, have not been taken into account in the new study.
− Contrary to the previous study, intersection take−off’s (effectively reducing ground delays) have been used in this study for all runways in all simulation runs.
− In all layout variants a double taxiway "South" is used now.
− In this study 2+2 runways are also used during the transit periods between departure and arrival peaks.

Remarks:

As already mentioned, the main objective of the study was to find out which variant of the four airport layouts, combined with a high peak vs. a low peak scenario, produces the most favourable results with respect to ground traffic handling as indicated by taxi times and ground delays. The first results indicated that the mutual differences are not large. However, no definitive conclusions may be drawn from these initial results, since due to time constraints, they are based on a single simulation run for each variant + runway combination. Also, no towing traffic has yet been simulated (although the number of aircraft to be towed have been calculated). A more detailed analysis, comprising more simulation runs in order to produce statistically more reliable results, including the realistic simulation of towing traffic as well as an in depth analysis of bottlenecks, is recommended as a follow−up.

5. Conclusions

In the two years NLR is using TAAM, it has proved itself to be a, although not perfect, very practical tool to simulate and analyse into great detail the handling of air traffic in all its aspects in present and future planned ATM environments. It is especially suited to provide relatively quick answers to complicated what−if questions in airport and airspace design, preventing possible costly mistakes.