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Increased Sustainability Schiphol (ISS)

Final Report

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Summary

The KDC studies Increase of Landing Capacity Schiphol (Ref. [Landing Capacity]) and Increased Ground Control Capacity Schiphol (Ref. [Ground Control Capacity]) have identified bottlenecks in the operation under low visibility conditions and good visibility conditions. The project scopes and analysed datasets, however, were too limited to draw decisive conclusions.

Due to the current economic recession and the negative impact on aviation, KDC partners stated that the focus should not be placed so much on capacity studies but on sustainability of the airport. When the results of the two earlier mentioned studies are combined, a clear conclusion about implementation steps to improve sustainability (i.e. the capacity under low visibility conditions) could not be reached. Therefore, the assignment of the current study was to identify a coherent plan to increase sustainability for Schiphol airport that could be implemented by 2012 and that builds on the two mentioned studies.

For ground control only one measure was found to be easily implementable, namely modifications in signage in critical areas. Additional research should investigate whether there are more areas that are apt for improvement and analyse the best solutions.
Three other measures are considered easily implementable which are all related to runway occupancy and therefore landing capacity. These are an extension of the yellow-green alternate centre line lighting indicating the ILS Sensitive Area until the aircraft has clearly left the area (meaning until it has reached the centre of a parallel taxiway), a campaign for ILS Sensitive Area awareness including awareness regarding the yellow-green centre line lighting, and finally a training bulletin addressing additional runway controller instructions to effectively continue to use Auto-QSY in BZO-B and worse conditions.

Apart from abovementioned easily implementable measures (i.e. awareness campaigns and ILS SA lighting), there are several additional measures which are more challenging and more difficult to implement. They concern a revision of difficult exits and a consequential change in operations, the implementation of RET indicator lights helping the pilot identify high-speed exits in time to safely vacate the runway, and changes in ILS technology. All mentioned measures may result in large infrastructure reconstruction efforts.
Another more challenging measure that considers ground control would be the deployment of a third ground controller in BZO-A and BZO-C. Research in the form of real-time simulations and a cost-benefit analysis was recommended before considering this option.

The earlier mentioned training bulletin for runway controllers would eliminate the need to abolish Auto-QSY from BZO-B on, so this measure was discarded. The same goes for the use of standard taxi routing. It is questionable whether the measure will have a large effect as most routing is already standard.
As to the use of 2+1 runway combinations in off-peak no clear indication of the deeper causes of a capacity shortfall in marginal conditions with 1+1 runway usage could be found. Finally, a change in marginal visibility criteria was also discarded as it was deemed that the effect was too small to outweigh any related operational or safety issues.

Several of the abovementioned measures to reduce ROT will consequently lead to reducing final approach spacing and improving sustainability. During BZO-C benefits are expected to be larger and likely to be accomplished more easily than for BZO-B.

Within LVNL the process of considering a reduced separation during BZO-C is already ongoing. Data presented in this study should be used to explore possibilities as there is strong evidence that a reduction is feasible.
Current ROT data suggest that additional measures are not a prerequisite for reducing the spacing during BZO-C. It is, however, recommended to implement the most promising ones mentioned above in order to reduce the probability that aircraft need extra attention from runway and ground controllers.

To be able to reduce the spacing during BZO-B, one or more of the presented measures for reducing ROT are a prerequisite.

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Abbreviation	Description
AAA	Amsterdam Advanced ATC
ALARP	As Low As Reasonably Practicable
APP	Approach controller
APV	Approach with Vertical Guidance
ARR	Arrival controller
ASAS	Airborne Spacing Assurance System
ATCO	Air Traffic Controller
ATIS	Automatic terminal information service
BZO	Low Visibility Conditions (*Dutch: Bijzonder Zicht Omstandigheden)*
CDA	Continuous Descent Approach
CLB	Cloud base
CONOPS	Concept of Operations
CRDA	Converging Runway Display Aid
DA/H	Decision Altitude/Height
DTW	Downwind Termination Waypoint
EDA	En-route Descent Advisor
FAF/FAP	Final Approach Fix/Final Approach Point
FDR/DCO	Feeder / Departure controller
FPA	Flight Path Angle
FMS	Flight Management System
GBAS	Ground-Based Augmentation System
GP	Glide path
IAF	Initial Approach Fix
IFR	Instrument Flight Rules
ILS	Instrument Landing System
LDA	Localizer Directional Aid
LOC	Localizer
LPV	Localizer Performance with Vertical guidance
LVC	Low Visibility Conditions
MDA/H	Minimum Decision Altitude/Height
MLAT	Multilateration
MLS	Microwave Landing System
MMP	Mens-Machine Procedure *(Dutch: Human Machine Procedure)*
NOZ	Normal Operating Zone

NTZ	No-transgression zone
OPD	Optimised Profile Descent
PBN	Performance Based Navigation
PRM	Precision Runway Monitor
PTC	Precision Trajectory Clearance
(P-)RNAV	(Precision-) Area Navigation
RC	Runway Controller
RF	Radius to a Fix (ARINC coding leg type)
RNP	Required Navigation Performance
RNP APCH AR	RNP Approach Authorisation Required
RNP SAAAR	RNP Special Aircraft and Aircrew Authorization Required
RPAT	RNP Parallel Approach Transition
R/T	Radiotelephony
RVR	Runway Visual Range
RWY	Runway
SBAS	Space-based Augmentation System
SOIA	Simultaneous Offset ILS Approaches
SPL	Schiphol
SUP	Supervisor
STAR	Standard Terminal Arrival Route
STCA	Short Term Conflict Alert
TA	Tailored Arrival or Transition Altitude
TAR	Terminal Approach/Area Radar
TMA	Terminal Control Area
TOD	Top of Descent
VCR	Visual Control Room
VDV	ATC Operational Procedures Handbook (*Dutch:Voorschriften Dienst Verkeersleiding*)
VEMER	Safety Efficiency Environment Impact Report (*Dutch: Veiligheid Efficiency Milieu Effect Rapportage)*
VFR	Visual Flight Rules
VMC	Visual Meteorological Conditions

1 Setting the Scene

This chapter outlines the project objectives and aim of the document and provides essential background information.

1.1 Background

The studies Increase of Landing Capacity Schiphol (Ref. [Landing Capacity]) and Increased Ground Control Capacity Schiphol (Ref. [Ground Control Capacity]) have identified bottlenecks in the operation under limited visibility conditions and good visibility conditions. The study Increase of Ground Control Capacity Schiphol primarily analysed Schiphol ground capacity for 2+2 runway use under good visibility conditions while the study Increase of Landing Capacity Schiphol focussed on single runway capacity under low visibility condition (BZO) C. Runway 27 proved to be the most limiting as far as runway occupancy times are concerned. But the analysed dataset was too limited to draw decisive conclusions.

Due to the current economic recession and the negative impact on aviation, KDC partners have stated that less priority should be given to capacity studies. The focus should now be placed on increasing the sustainability of the airport. When the results of the two studies mentioned are combined, a clear conclusion about implementation steps to improve sustainability (i.e. the capacity under limited visibility conditions) to be taken could not be reached. The assignment of the current study will be to identify a coherent plan to increase sustainability for Schiphol airport, building on the results of the studies Increase of Landing Capacity Schiphol and Increase of Ground Control Capacity Schiphol.

1.2 Assignment and Usage of the Project Result

Analyse the results of the studies Increase of Landing Capacity Schiphol and Increase of Ground Control Capacity Schiphol and bring the results into a coherent plan to further develop sustainability. Capacity shortfalls which were not sufficiently addressed in mentioned studies should be analysed and the study thereof is part of the new assignment.

The development of an initial implementation step is a key element of the assignment.

1.3 Objective of this Document

This document is the final result of the project and informs KDC, project members and other relevant stakeholders of the steps taken to find solutions for improving operational sustainability at Schiphol, and the further analysis that has been taking place to evaluate these solutions and define initial implementation steps.

1.4 Project Objectives

Short-term objective:
Identify implementation steps to increase operational sustainability at Schiphol Airport outside nominal conditions (good visibility inside UDP) and develop the first step.

Long-term objective:
Ensure that capacity at Schiphol Airport meets the demand under all visibility conditions.

1.5 Project Scope

This project focuses on the short term (feasible to implement before the year 2012) measures to increase operational sustainability at Schiphol Airport outside nominal conditions (good visibility inside UDP). This project addresses issues related to visibility, not wind. Within this scope, an increase of sustainability is translated into two separate parameters:

1. Increase of runway system capacity;
2. Increase of deployability of runways and runway combinations.

Due to this timeline, the use of present day technology is assumed. Foreseen improvements are therefore most likely related to:

- Procedures and regulations
- Infrastructure

It should be noted that systems and technology will be considered in bottleneck search and solution generation. However, it is expected that due to the implementation constraints, ranking will be lower as compared to improvements feasible in short term.

The prioritisation of the visibility conditions to be considered in this project will be done by means of a “non-performance cost” analysis.

The implementation process for the resulting selected measure(s) will be initiated within the scope of this project. In practice, this will mean timely co-ordination and alignment of the project result with relevant stakeholder processes to start implementation. For clarity, the actual implementation is outside the scope of this project.

In a next stage, after this project, to provide a more complete view on potential sustainability increase measures, the scope may be broadened to address the other (lower priority) measures as identified in this project.

In this study the focus is on:

- Schiphol operations
- Inbound traffic
- Marginal and BZO phases A to D
- Implementation feasible in 2012 or before

1.6 Project Approach

This project builds on the results of previous projects and includes:

1. [Landing Capacity]
2. [Ground Control Capacity]
3. [Runway Capacity]
4. [TUD 2009.TEL.7390]
5. [Improved Forecasts]

Potential solutions from Ref. [1], [2] and [4] are listed in Annex I. Potential solutions listed in Ref. [3] are already contained in Ref. [4].

The results of these projects are analysed so as to capitalize on the knowledge built up in the projects, identify open issues that need further investigation and to enable the project team to address landing capacity and ground handling in a more integral and coherent way.

Building on aforementioned analysis, the following activities are performed:
1. BZO prioritisation based on non-performance cost analysis

Then, for the selected BZO condition(s) as a result of the first activity:
2. Identification of causes of reduction of capacity and/or deployability
3. Definition of potential measures to increase capacity and/or deployability
4. Operational analysis of potential measures
5. Cost-benefit analysis of potential measures
6. Selection of priority measure(s) and initiation of the implementation process

In a next stage (to be discussed, currently outside project scope), the steps mentioned above may be repeated for the lower priority visibility conditions.

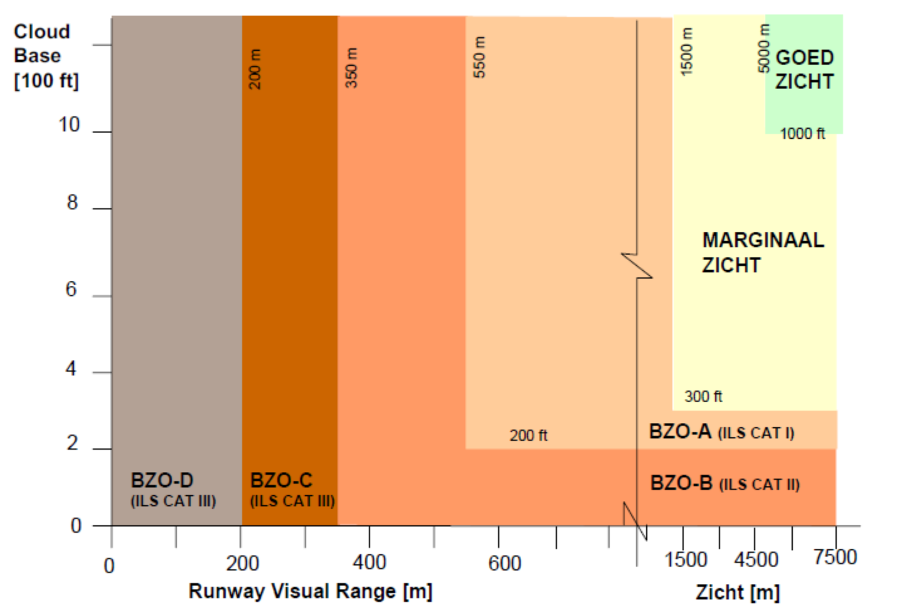
The ATM operation is an integrated chain of ATM components. When solving e.g. a RWY bottleneck, it could move the bottleneck up- or downstream in the chain. If this occurs, the relevant issues are documented.

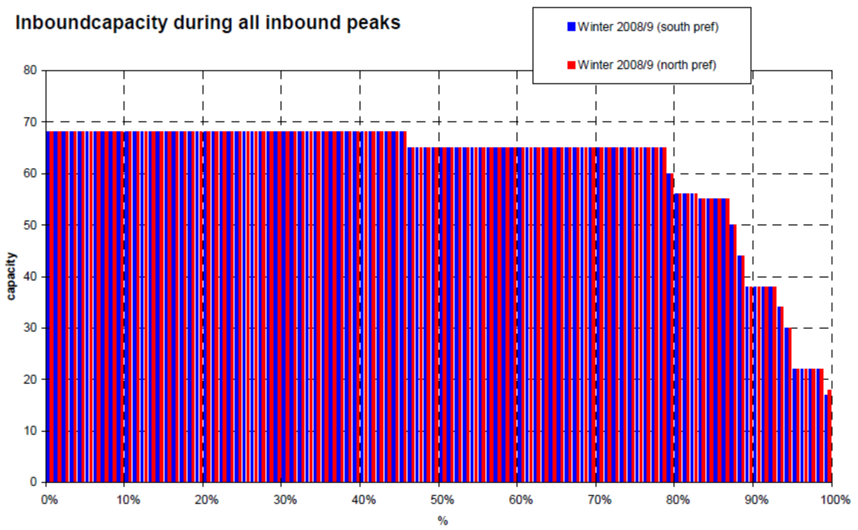
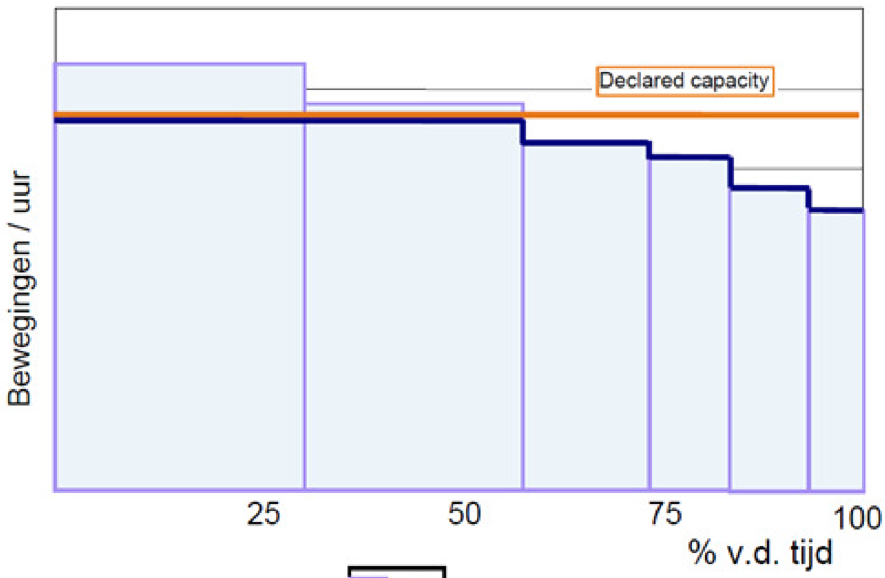
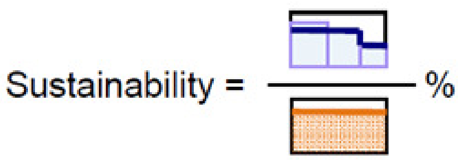
2 Bottleneck Analysis

2.1 Definitions

In this study the following definitions are used:

Table 2-1: Overview of Definitions

Item	Description
RVR	The range over which the pilot of an aircraft on the centre line of a runway can see the runway surface markings or the lights delineating the runway or identifying its centre line.
Visibility	The ability, as determined by atmospheric conditions and expressed in units of distance, to see and identify prominent unlighted objects by day and prominent lighted objects by night.
Low visibility	**7.12 PROCEDURES FOR LOW VISIBILITY OPERATIONS** **7.12.1 Control of aerodrome surface traffic in conditions of low visibility** *Note.— These procedures apply whenever conditions are such that all or part of the manoeuvring area cannot be visually monitored from the control tower. Additional requirements which apply when category II/III approaches are being conducted are specified in Section 7.12.2.* **7.12.2 Procedures for control of aerodrome traffic when category II/III approaches are in use** 7.12.2.1 The appropriate ATS authority shall establish provisions applicable to the start and continuation of precision approach category II/III operations as well as departure operations in RVR conditions less than a value of 550 m.
LVNL classification Good, Marginal BZO A/D	

Declared capacity	The declared capacity is a capacity value that is applied for the strategic airport slot allocation process and agreed upon with the sector partners. It is the (average) capacity which can be accommodated by LVNL per hour during nominal conditions.
Operational runway capacity	For slot allocation purposes, the operational runway capacity for the summer season 2010 has been determined as follows: Arrival peaks: 106 IFR movements per hour (three 20-minutes blocks), with a maximum of 68 arrivals and 38 departures. The movements should be evenly distributed over the 20-minutes blocks.
Sustainability	   The sustainability relates to the percentage of time that a requested number of movements per hour can be realised.

Manoeuvring area	That part of an aerodrome to be used for the take-off, landing and taxiing of aircraft, excluding aprons.
Movement area	That part of an aerodrome to be used for the take-off, landing and taxiing of aircraft, consisting of the manoeuvring area and the apron(s).
Uniform Daylight Period (UDP)	The period between 15 minutes before sunrise and 15 after sunset.

2.2 Standards, Recommended Practices and Local Regulations

The following regulations apply with regard to low visibility operations:

ICAO Doc 4444	PANS-ATM
ICAO Doc 9365	Manual of All Weather Operations
ICAO Doc 9830	Advanced Surface Movement Guidance and Control Systems (A-SMGCS) Manual

LVNL internal regulations are laid down in e.g. [VDV] and QRH/QRC25/QRC09.

- The phase "BZO" becomes effective at Schiphol when either one of the following conditions takes place:
  - Visibility falls below 1500m and/or the cloud base falls below 300ft.
  - One of the runways in use is no longer visible from the TWR-VCR.
- Terminology reduced visibility versus low visibility
  When visibility falls below 1500m, parts of the manoeuvring area at Schiphol (runway and taxiways) can no longer be visually monitored from TWR-C. According to ICAO, this would then be categorised as a low visibility condition. At Schiphol, however, the term <u>reduced visibility</u> is applied at Schiphol when 550≤RVR≤1500m and/or 200ft ≤ cloud base ≤ 300ft (BZO-A). The actual <u>low visibility phase</u> starts when 350m ≤ RVR < 550m and/or cloud base < 200ft (BZO-B).

2.3 General Characteristics Regarding Marginal and BZO A-D Conditions

The accuracy and reliability of forecasting the beginning and end of BZO phases directly affects the runway configuration, hence capacity. Other projects (e.g. KDC-LVP) have dealt with this issue and significant improvements in this area are not expected to take place prior to 2012.

Based on LVNL data from the years 2005 to 2009 that contained amongst others BZO times, durations, and runway combinations, a general analysis was performed in terms of characteristics of marginal and BZO conditions.

Figure 2-1 shows the months during which BZO conditions occur over the period 2005-2009. Marginal visibility (as shown in the first figure in Annex III) has its maximum frequency between October and March. For BZO-A and BZO-B the winter months are most frequent whilst for BZO-C February and March, September and October, as well as December show a maximum likelihood (for more detail in BZO conditions, have a look at the second figure in Annex III).

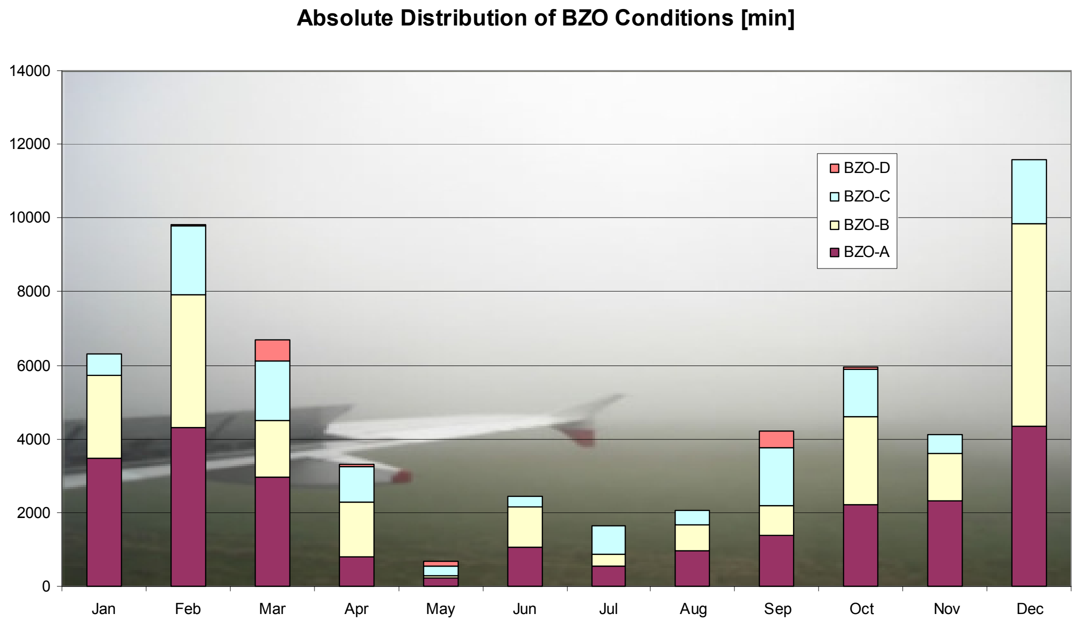


Figure 2-1: BZO Occurrences per Month between 2005 and 2009

Figure 2-2 shows the time of day of marginal and BZO conditions. Marginal visibility may occur at all times during the day and BZO phases predominantly occur during the early morning as a result of e.g. sunrise. The occurrence of BZO-D is scarce and it appears that BZO-C and BZO-D are not very likely to occur at noon (for more detail in BZO conditions, have a look at the third figure in Annex III).

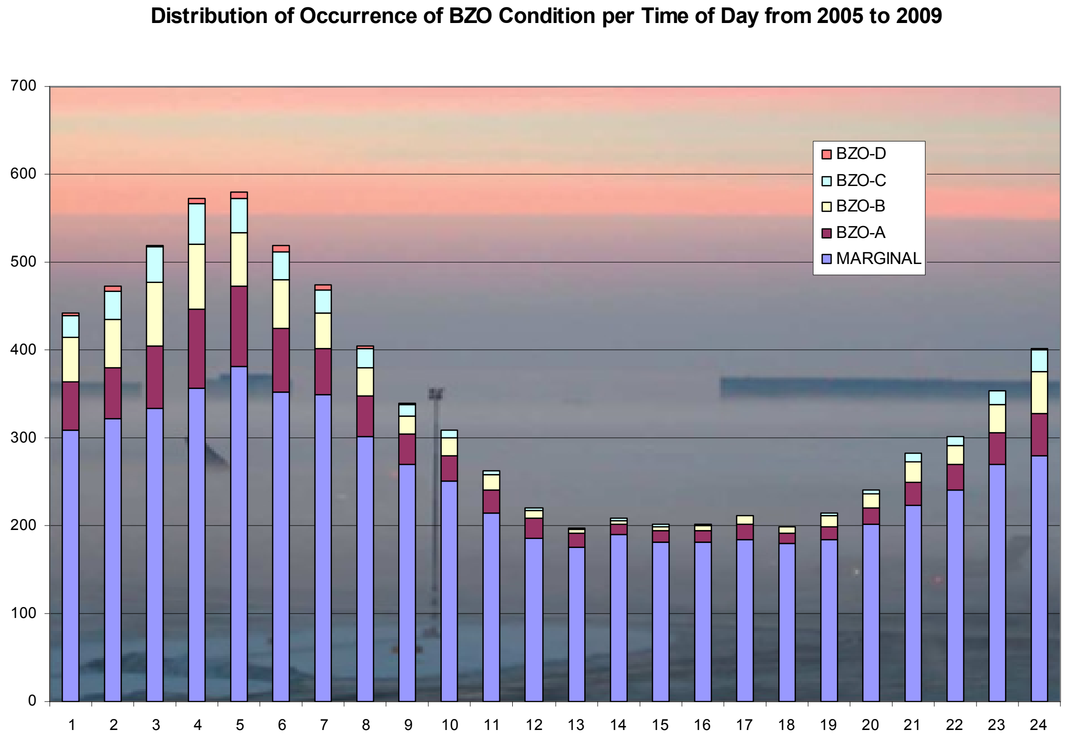


Figure 2-2: Time of Day of BZO Occurrences between 2005 and 2009

For the same period a brief analysis of the duration of BZO conditions was performed. It shows that marginal conditions frequently last long (>5 hours). Although the runway capacity slightly drops during marginal conditions it lasts for a long time and therefore affects runway sustainability. Generally, about 50% of BZO conditions last shorter than 40-60 minutes (see Figure 2-3).

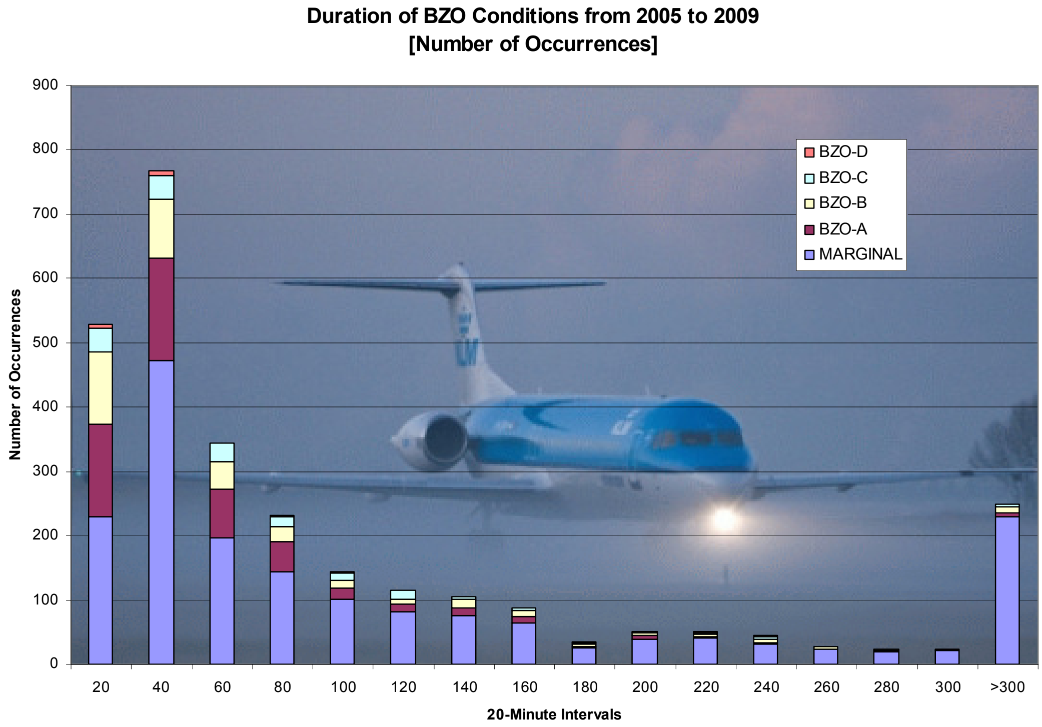


Figure 2-3: Duration of BZO Occurrences between 2005 and 2009

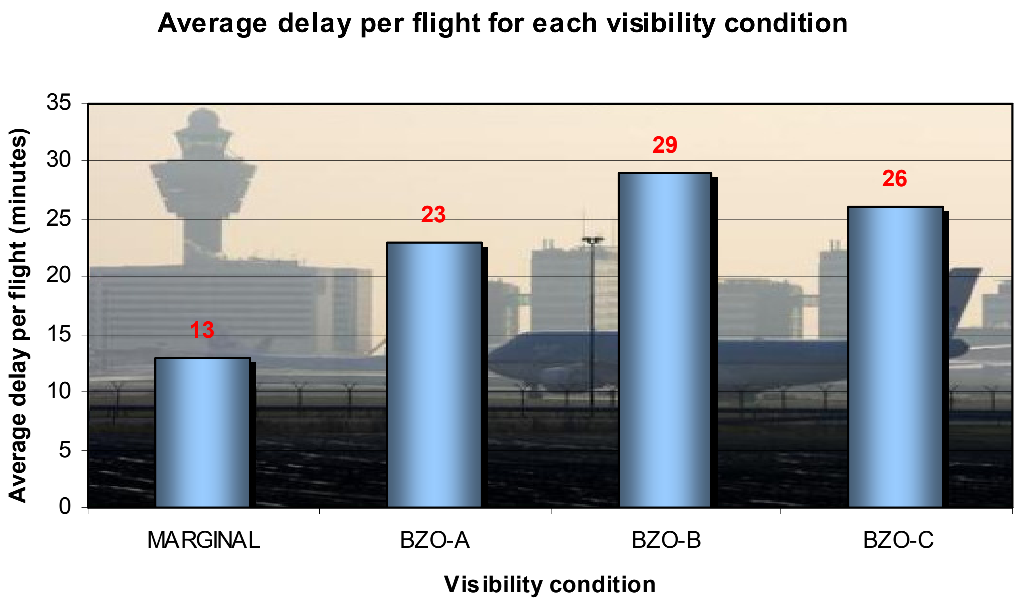


Figure 2-4: Delay per Flight for BZO Occurrences between 2005 and 2009

Given the average delay per flight shown in Figure 2-4, BZO-B results in the largest delays per flight (29 minutes), as opposed to marginal conditions (13 minutes). However, the smaller delays encountered during marginal conditions apply to much more traffic so that more flights are affected.

In terms of non-performance costs for airlines it is expected that marginal conditions are ranked as number one.

2.4 Marginal Visibility Conditions

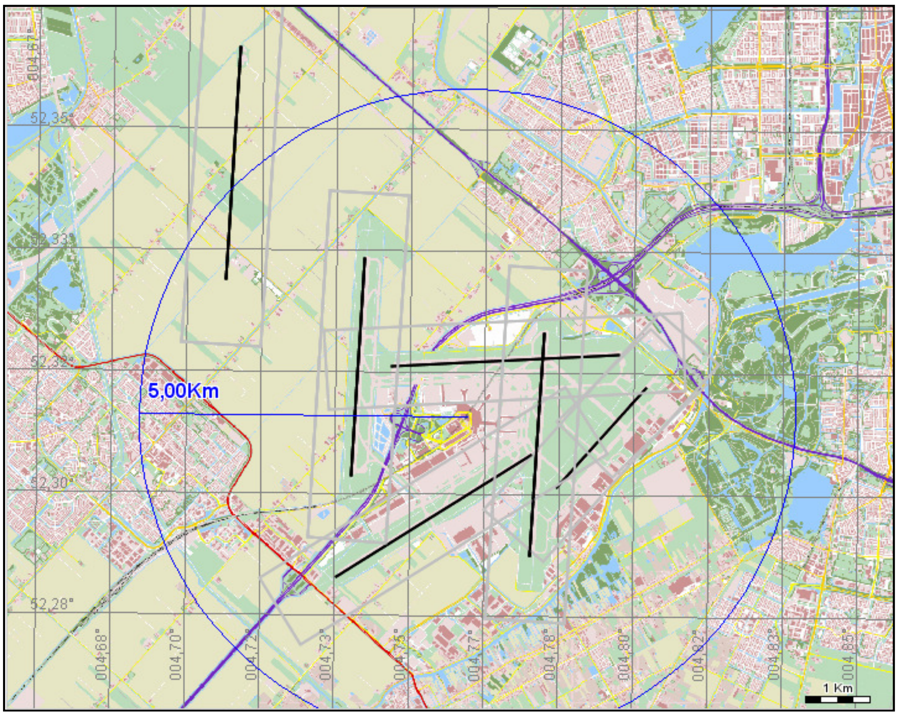
2.4.1 Characteristics

2.4.1.1 Impact on Visual Monitoring

Marginal visibility conditions are activated at Schiphol when 1500m < visibility ≤ 5000m and/or 300ft < cloud base ≤ 1000ft.

RC		RC has a reduced ability to apply visual separation since some runway thresholds can not be observed and first turns during departure cannot be observed. When the cloud base falls below 1000ft missed approaches cannot be visually separated.
GC		GC has visual on taxiways and aprons.
Pilot		Pilot has sufficient visual cues to follow markings/lighting.

According to ATCOs, the value of 5000-1500 metres is based on the distance between runway thresholds and the VCR-TWR/C. The visual range from the VCR is shown below:



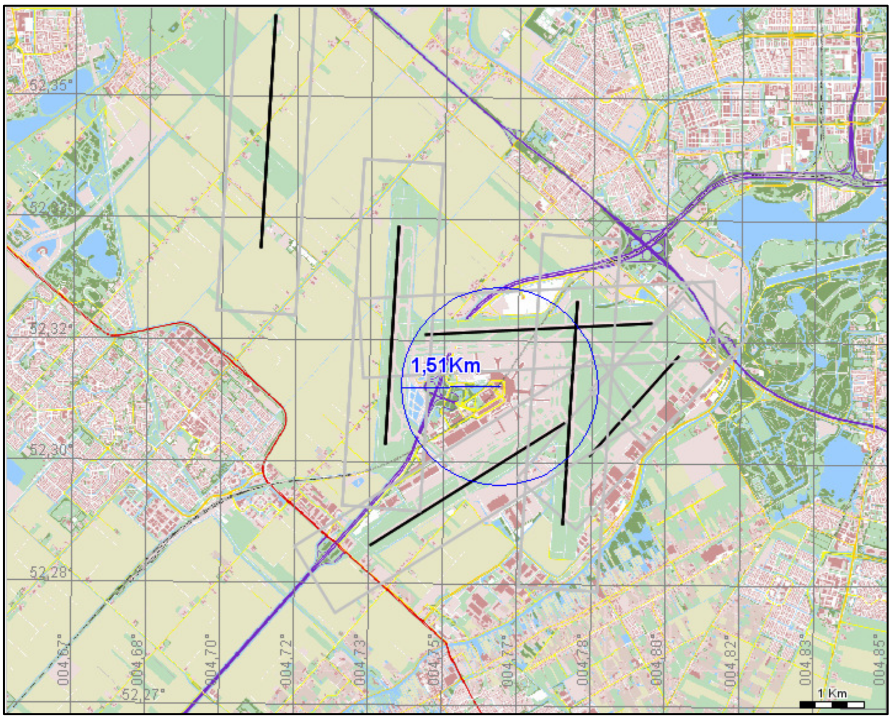


Figure 2-5: Visual Ranges from the VCR-TWR/C

Also, the value of 5000m is considered to be required for visually monitoring double missed approaches and to verify the first turn during departures.

2.4.1.2 Frequency of Occurrence and Capacity

Marginal visibility conditions have occurred on average 840 hrs[1] per year which accounts for 9.6% of the time on an annual basis.
There may be a discrepancy between the reported weather and the actual condition declared by LVNL but it is assumed that this does not have a significant effect.

During marginal visibility conditions, wind will more likely determine the selection of runways as opposed to less or no wind during BZO phases.

ATM Component	↓	↑	Total	Difference ↓ (Good Visibility)
Runway	65-68	30-35	103	0 to -3
Ground	-	-	>103	

The runway capacity in good visibility during inbound peak is 68↓.

2.4.1.3 Non-performance Impact for Airlines

Figure 2-6 below shows the number of delay minutes experienced by KLM during each phase[2].

[1] KNMI meteorological data during 2004-2007
[2] KLM analysis, March 2010

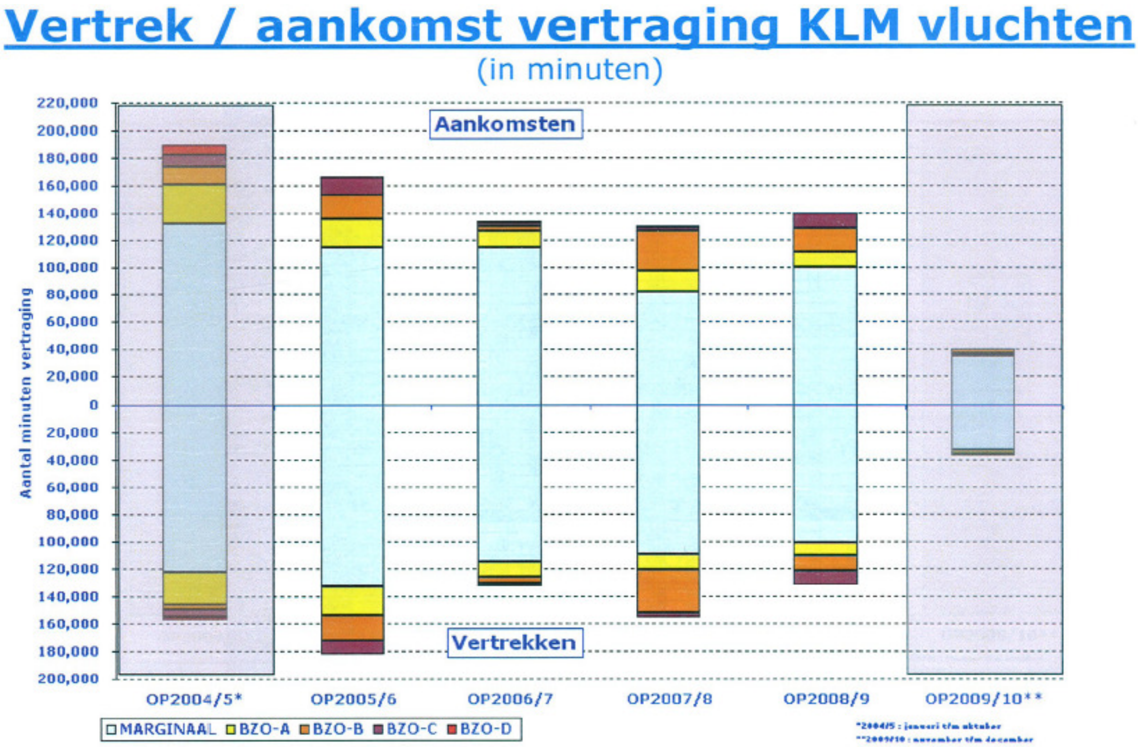


Figure 2-6: Delay Minutes of KLM Flights per LVC between 2005 and 2009

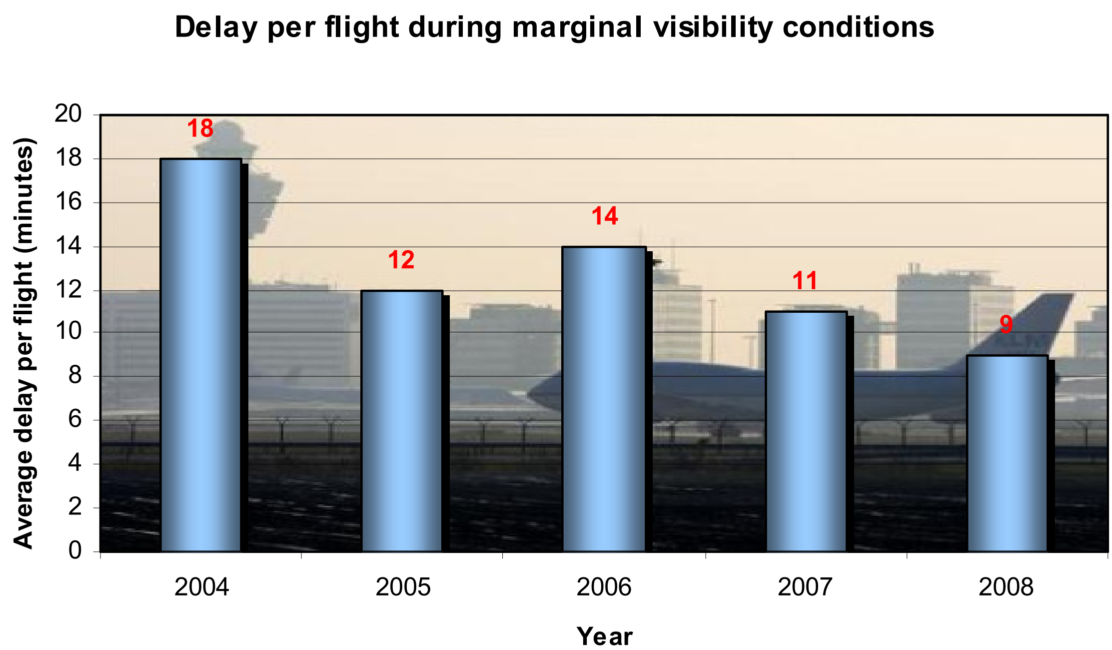


Figure 2-7: Delay per Flight in Marginal Visibility between 2004 and 2008

It clearly shows that delays are at a maximum during marginal visibility conditions. Marginal conditions occur more frequently than BZO conditions. In order to correctly interpret the numbers, it is required to have the delay figures for good visibility conditions as well.

For every hour of marginal visibility, the total delay for all arriving KLM flights is approx. 2 hrs[3] per year on average.

On average the delay per flight is approx. 13 minutes (see also Figure 2-7). The runway combination which results in the largest delay is 18R/24. This is an off-peak runway combination and is frequently used (see Figure 2-8). This issue will be addressed at a later stage.

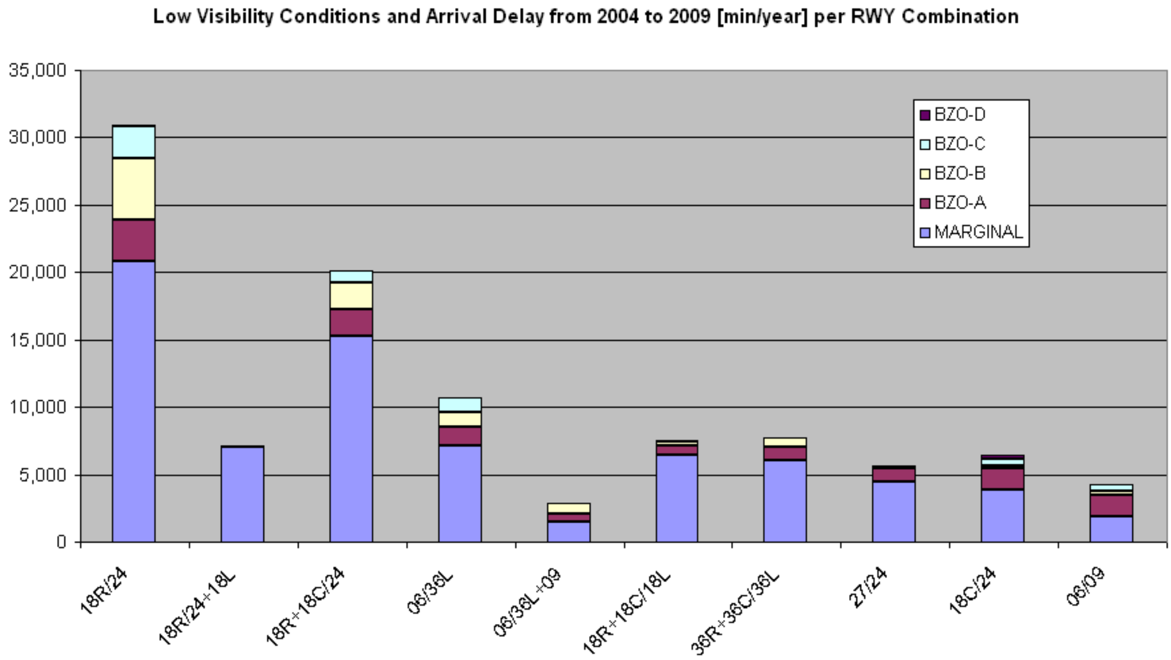


Figure 2-8: Delay Minutes per RWY Combination and BZO Phase

2.4.2 Bottlenecks and Operational Consequences during Marginal Visibility

The operational consequences (►►) when marginal visibility conditions are in effect are listed below.

1. The RC has no visual (cloud base < 1000ft) on dual missed approach paths ►► hence converging approaches are not allowed

   Effectively, this means that from the 31 possible runway combinations during an inbound peak, 16 runway combinations remain. The three runway combinations:
   - 18R+18C↓/09↑
   - 18R+18C↓/18L↑
   - 36R+36C↓/36L↑

[3] 110,000 minutes average delay during marginal visibility / average 840 hours marginal visibility per year [KLM].

can maintain the same inbound capacity as during good visibility conditions. For reasons of punctuality and preferential runway use, the use of convergent combination 06+36R is highly preferred during UDP.

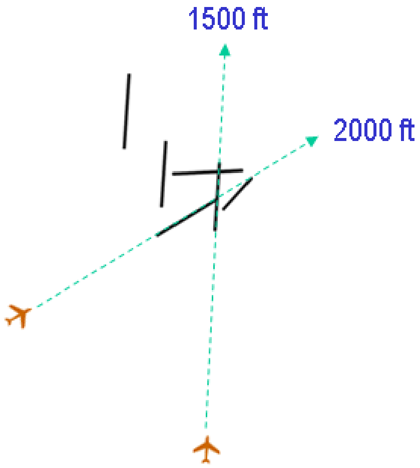


Figure 2-9: Converging Approaches on Combination 06+36R

2. Potential conflict between missed approach and departure ►► hence RC needs to time a departure with a potential missed approach, e.g. 18C↓ and 24↑. In this case an aircraft may depart from RWY24 when an arriving aircraft is at least 3 NM from the threshold of RWY18C (see Ref. [QRH SPL TWR]). Operations between RWY18R and RWY24 remain independent due to the missed approach procedure described in the AIP (Ref. [AIP Netherlands]. This is shown below.

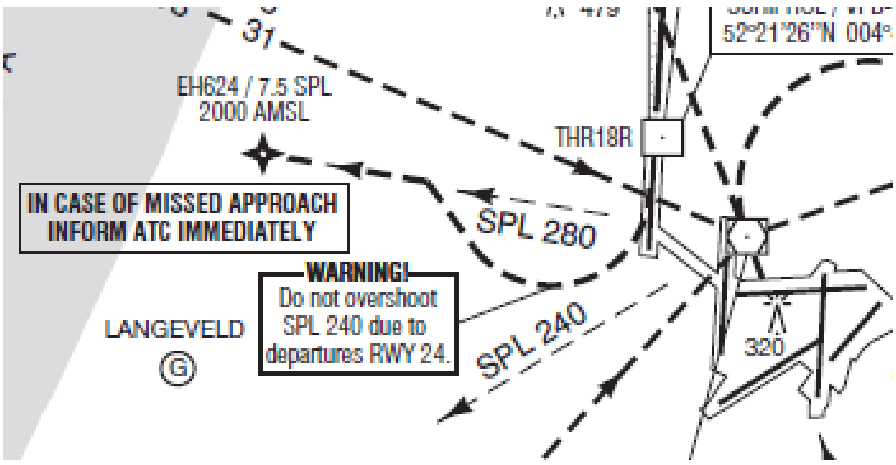


Figure 2-10: Missed Approach Procedure on RWY 18R (AD 2.EHAM-IAC-18R.1)

2.4.3 Limiting ATM Element

During marginal visibility conditions, the **RUNWAY** capacity is the limiting element. This is due to the fact that TWR ATCOs cannot visually separate traffic during potential missed approaches and between conflicting take-offs and landings.

2.4.4 Potential Solutions

During the ISS workshop, where operational ATCOs (TWR and GND) were involved, a long-list of potential solutions to increase ground and/or runway capacity was established. The solutions are listed below:

Table 2-2: Overview of Potential Solutions in Marginal Visibility Conditions

ID	Potential Solution	Remarks
M1	Investigate lowering the criteria for 1000 ft cloud base	Further analysis is needed to quantify the percentage that marginal conditions apply when lowering cloud base from 1000ft to e.g. 900ft. If this is significant, then operational consequences need to be assessed. According to ATCO lowering the cloud base below 1000ft prohibits the monitoring of missed approaches during dependent runway use.
M2	Investigate reduction of visibility criterion for marginal visibility from 5000m to e.g. 4000m.	Similar to M1; first assess how this affects the time marginal conditions would occur.
M3	Temporarily apply 2+1 during off-peak	As calculated flight delays for KLM and partners are at its maximum during 18R/24 (off-peak) runway usage, it may be advantageous to (temporarily) apply a 2+1 runway configuration. It is, however, vital to understand the reason for the delays when this runway combination is in use. Note: this operation is not in line with the current environmental framework. It may be part of a future noise regulatory system (long-term development). The issue will be addressed in a later section.

Solutions not further pursued:

Solution	Reason for Dismissal
CRDA-like tool	According to [Landing Capacity] the use of CRDA could be

	worthwhile in order to apply and maintain an accurate separation during LVP. Workload also slightly reduces because ATCO need not calculate distances by means of 2 NM tick marks on extended centreline. An LVNL study between 2007 and 2009, however, concluded that the CRDA tool would not work in the current situation which is characterised by unpredictable arrival routes and traffic flows coming in from ACC. This would result in large speed differences. Furthermore, fall-back operations were not sufficiently defined. Thus, a prerequisite for further study would be a positive change in predictability of arrival traffic flows.

2.5 BZO-A

2.5.1 Characteristics

2.5.1.1 Impact on Visual Monitoring

BZO phase A is applied when 550m ≤ RVR ≤ 1500m and/or 200ft ≤ cloud base ≤ 300ft. Note that the ATIS reports "reduced visibility procedures in progress" as opposed to BZO-B where ATIS reports "low visibility procedures in progress".

RC		RC cannot apply visual separation for missed approaches and to deconflict landings and departures.
GC		GC has limited visual on taxiways and aprons.
Pilot		Pilot has sufficient visual cues to follow markings/lighting.

RVR > 550 metres and/or visibility < 800 metres corresponds to ILS Cat I and has a decision height of 200ft. The RVR in BZO-A is based on the lowest RVR at the aerodrome.

Due to the height of the TWR-C (309ft above aerodrome), BZO comes into effect when the cloud base is below 300ft and obstructs the view from the VCR. Also 300ft is the minimum decision height for ILS Cat I approaches.

2.5.1.2 Frequency of Occurrence and Capacity

BZO-A conditions have occurred on average 105 hrs[4] per year which accounts for 1.2% of the time on an annual basis.

During BZO-A, wind is less likely to determine the selection of runways as opposed to marginal visibility conditions.

ATM Component	↓	↑	Total	Difference ↓ (Marginal Visibility)
Runway	56	24	80	-9 to -12
Ground	-	-	80	

2.5.1.3 Non-performance Impact for Airlines

The total delay during BZO-A is significantly less than during marginal visibility conditions because the frequency of occurrence of BZO-A is much lower. For indication purposes, for every hour of BZO-A visibility, the total delay for KLM inbounds is approx. 3 hrs[5] per year on average.

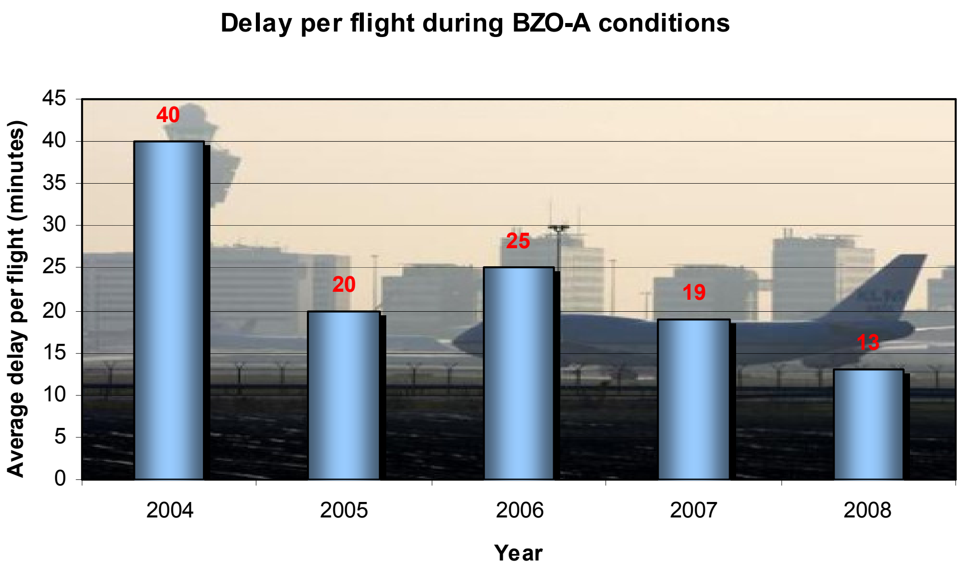


Figure 2-11: Delay per Flight in BZO-A between 2004 and 2008

Taking into account the average number of KLM flights during BZO-A conditions, the delay is approx. 23 minutes/flight.

2.5.2 Bottlenecks and Operational Consequences during BZO-A

In addition to marginal visibility the following bottlenecks and operational consequences (►►) apply for ATC:

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[4] KNMI meteorological data during 2004-2007

[5] 18,000 minutes average delay during BZO-A / 105 hours BZO-A per year [KLM].

1. RC/GC: limited or no visual reference by RC and GC ►► use of ground radar compulsory and SMR handover of aircraft. This induces extra R/T for GC and RT.

2. RC/GC: safeguarding ILS protection areas ►► departing aircraft must hold before Cat II/III holding line, however, for landing operations the ILS SA does not have to be free according to LVNL VDV/QRC. This only applies to phases BZO-B/C/D. The ILS Cat I sensitive area is located 90m from the centreline.

3. RC/GC: sub-optimal location of runway exits during low visibility, complexity of exit geometry at some runways, Auto-QSY (silent handover RC to GC) may prevent additional instructions, additional R/T to (re-)identify aircraft (position), SMR handovers. These factors lead to a slight increase in ROT ►► minimum 4 NM separation on final. This restricts the landing capacity to a maximum of 30 per hour.

4. RC/GC: no visual detection if two aircraft would be on the runway ►► take-off intersections are not allowed. The only exception is S6 on RWY24, but then S7 cannot be used.

5. Runway does not have a Cat I ILS ►► landings on RWY09/18L/24 are not allowed.

6. RC/GC: variation in taxi routes for runway crossing towed aircraft ►► only standard taxi routes from East to West (and vice versa) Schiphol are allowed.

7. RC: potential confusion ►► conditional clearances for line-up are not allowed.

8. GC: limited or no visual on aprons and taxiways ►► alternative pushbacks should be avoided.

9. RC: sufficient time for missed approach during use of mixed-mode runway ►► a departing aircraft must have started the take-off roll before an arriving aircraft is 4 NM from the threshold.

10. RC: two aircraft could be on the runway at the same time ►► aircraft line-ups are not allowed when traffic is crossing that runway.

2.5.3 Limiting ATM Element

During BZO-A the current **GROUND** capacity limits the runway capacity to approx. 80 movements per hour (i.e. 56↓ and 24↑ during inbound peak).

Note that the use of ground labels has increased the ground capacity during BZO-A from 70 to 80 movements per hour.

2.5.4 Potential Solutions BZO-A

During the ISS workshop a long-list of potential solutions to increase ground and/or runway capacity during BZO-A was established. The potential solutions are listed below:

Table 2-3: Overview of Potential Solutions for Solving Bottlenecks during BZO-A

ID	Potential Solution	Remarks
A1a	Start ILS SA awareness + ROT campaign; explain to pilot community the reasoning behind the Cat I and Cat II/III signs/markings (KLM initiative is being defined).	Easy measure to implement and enhances safety and efficiency of ground operations.
A1b	Linked to A1a is to simplify airport/runway signage for pilots in order to expedite navigation from RWY/TWY to gate.	Signs at Schiphol airport are according to ICAO Annex 14. Relatively easy measure to implement for enhancing safety and efficiency of ground operations.
A2	Apply 3rd GC. This solution could also apply to other visibility conditions in case there are staff planning issues, however, the real bottleneck is still in BZO-A.	This potential solution has been put forward in various studies but has currently not been actively pursued for a number of reasons: 1. Staffing and resource planning issues regarding 3rd GC (e.g. part or full-time function). 2. No physical space available in the VCR to accommodate a 3rd GC working position. Operational solutions and impact need to be studied in Human-in-the-loop conditions. This is out of the scope of this research. However a recommendation shall be included in the report.

Solutions not further pursued:

Solution	Reason for Dismissal
Further increase the accuracy of meteorological	Not feasible within time-frame of

information; e.g. when does BZO start and when does it end.	ISS (approx. 2012).
Allow intersection take-off during BZO-A.	Departure capacity is not an issue.

2.6 BZO-B

2.6.1 Characteristics

2.6.1.1 Impact on Visual Monitoring

BZO-B is activated when 350m ≤ RVR < 550m and/or cloud base ≤ 200ft. The RVR is in BZO-B based on the lowest RVR of the runways in use at the aerodrome.

Note that the ATIS now reports "low visibility procedures in progress".

RC		RC cannot apply visual separation for missed approaches and to deconflict landings and departures.
GC		GC has no visual on taxiways and aprons.
Pilot		More difficult to anticipate exits. "See and avoid" is still possible. Taxiing times slightly increase.

BZO-B corresponds to ILS Cat II and has a decision height of 100ft. Note that Schiphol does not have specific signs and marking for an exclusive Cat II operation. At Schiphol ILS Cat II/III markings and signs are in use.

2.6.1.2 Frequency of Occurrence and Capacity

BZO-B conditions have occurred on average 63 hrs[6] per year which accounts for 0.7% of the time on an annual basis.

ATM Component	↓	↑	Total	Difference ↓ (BZO-A)
Runway	44	26-30	74	-12
Ground	-	-	74	

2.6.1.3 Non-performance Impact for Airlines

For indication purposes, for every hour of BZO-B visibility, the total delay for KLM inbounds is 4 hrs[7] per year on average.

[6] KNMI meteorological data during 2004-2007
[7] 16,000 minutes average delay during BZO-B / 63 hours BZO-B per year [KLM].

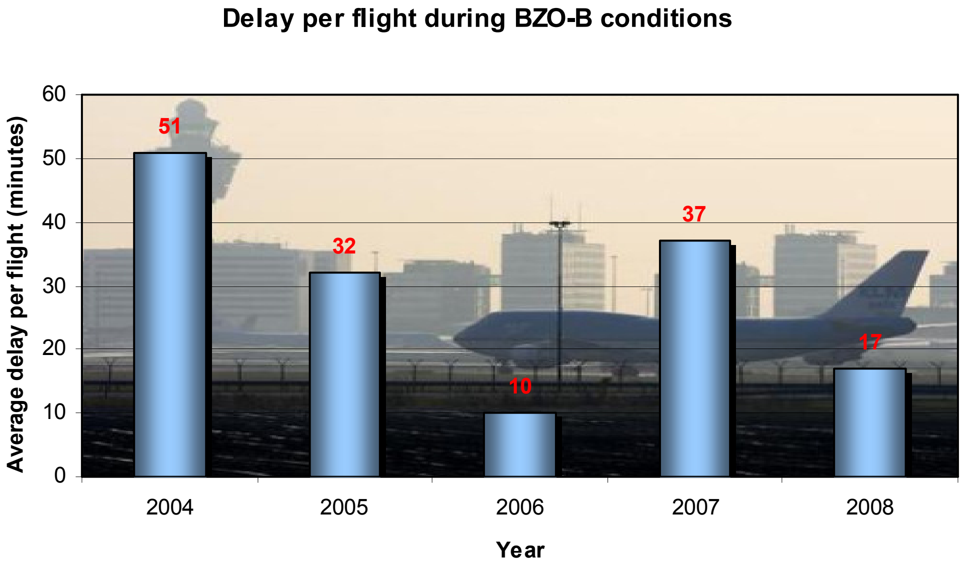


Figure 2-12: Delay per Flight in BZO-B between 2004 and 2008

Taking into account the average number of KLM flights during BZO-B conditions, the delay is approx. 29 minutes/flight.

2.6.2 Bottlenecks and Operational Consequences during BZO-B

In addition to phase BZO-A, the following bottlenecks and operational consequences apply for ATC:

1. RC/GC: safeguard ILS sensitive area ►► departing aircraft holds before Cat II/III holding line, and issuing a landing clearance is not allowed when the ILS SA is not free.

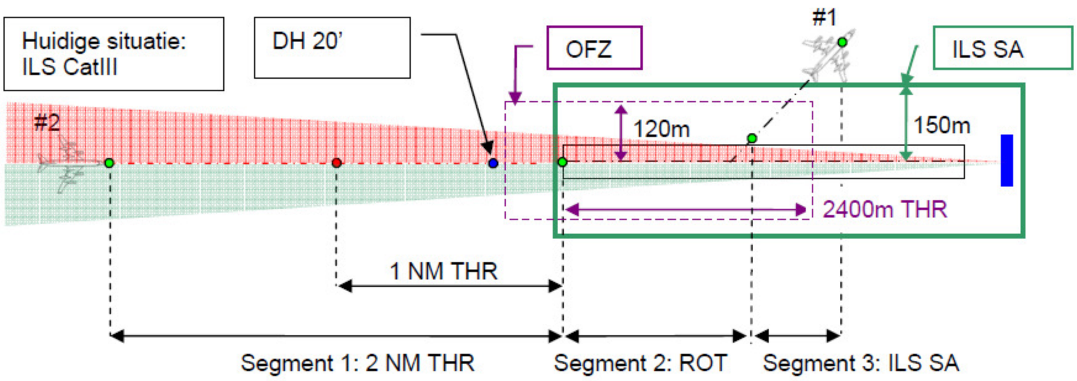


Figure 2-13: ILS CAT III Operational Situation

2. RC: it can be difficult for a RC to observe whether an aircraft has vacated the ILS SA using SMR as there is no indication of the ILS SA on the SMR display. In practice the RC considers the aircraft to be free of the ILS SA when the aircraft is on the parallel taxiway which may be conservative. Taxiing speeds are difficult to assess using the SMR ►► ROT slightly increases.

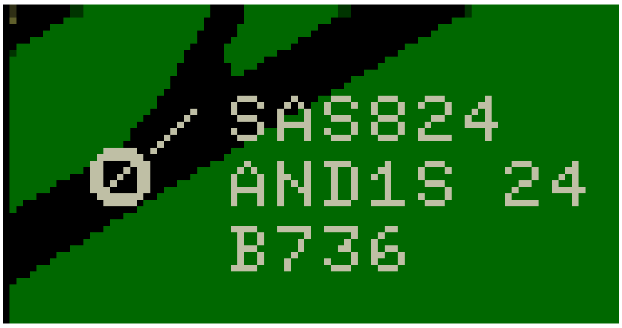
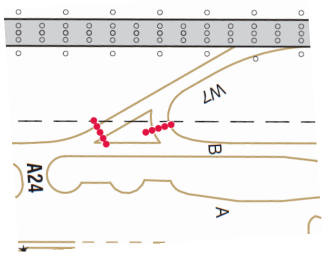


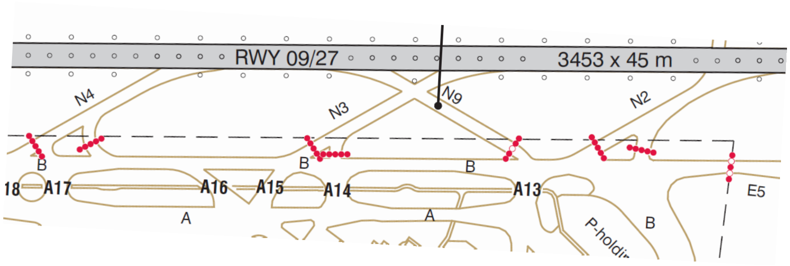
Figure 2-14: SMR Detection Issues

3. RC/GC: sub-optimal location of runway exits, complexity of exit geometry, especially N2, N3, N4 (RWY27) and W7 (RWY18C), where the taxiway has multiple exits *within* the ILS SA, Auto-QSY (silent handover RC to GC) may prevent additional instructions, extra R/T to (re-)identify aircraft (position), large variation in time to vacate ILS SA, no specific Cat II holding/signs so a more conservative Cat III holding line is used, not all exits have a Cat II/III holding line and SMR handovers. These factors lead to an increase of the ROT ►► minimum 6 NM separation on final. This restricts the landing capacity to a maximum of 22 per hour.

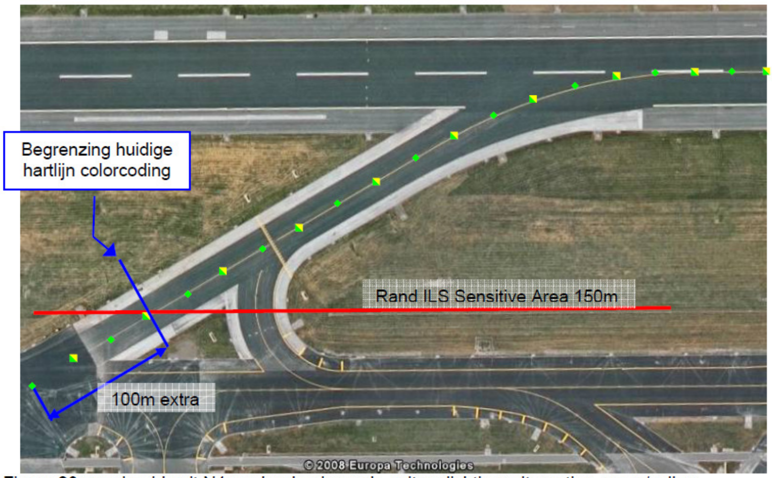
   Runway 18R: Exit W7



   Runway 27: Exit N2, N3, N4



4. RC/GC: for some (foreign) airlines the guidance cues such as markings and signs are not (exactly) followed ►► ROT increases even further.
   For example: the yellow-green centreline lighting on the exits extends to the edge of the ILS SA as a cue for pilots that the ILS SA has been vacated.



Figuur 28: voorbeeld exit N4 verder doorlopende exit verlichting: alternating green/yellow

Figure 2-15: Yellow-green Alternating Centreline Lights

5. Some runways are not equipped with Cat II ILS ►► landing on RWY04/09/22/24 is not allowed.

6. Runway incursion possibility whilst erroneously taxiing on RWY09/27 ►► departures from RWY18L are not allowed (see figure below).

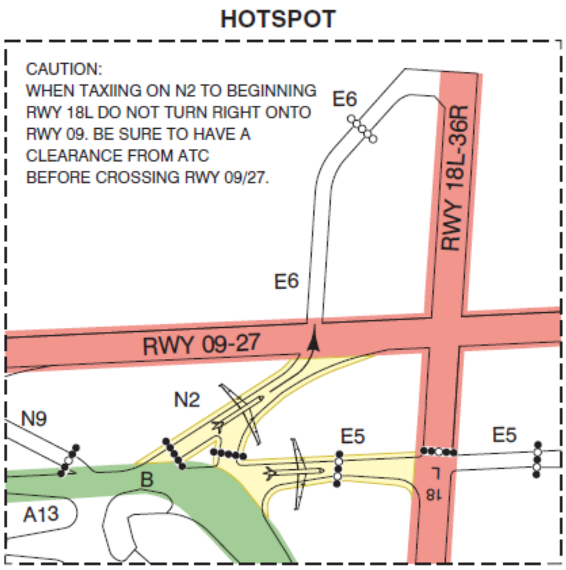


Figure 2-16: Hotspot at Crossing of RWY09-27 and RWY18L-36R

7. RC: disturbance of the ILS sensitive area ►► late landing clearance (1 NM) is not allowed. A landing clearance must be issued at least 2 NM from the threshold.

8. GC: no visual on aprons/taxiways ►► alternative pushbacks are not allowed.

9. ARR: uncertainty for controller as to what separation on final is expected due to pilot's discretion during CDA ►► RNAV transitions are not allowed.

10. GC: uncertainty regarding position ►► on request of the fire brigade, vehicles of the fire brigade are guided by means of the SMR. This increases the R/T load.

2.6.3 Limiting ATM Element

During BZO-B the current **RUNWAY** capacity limits the capacity to approx. 74 movements per hour (44↓ and 26-30↑ during inbound peak).

Note that the use of ground labels has increased the ground capacity during BZO-B from 74 to 80 movements per hour.

2.6.4 Potential Solutions BZO-B

During the ISS workshop a long-list of potential solutions to increase ground and/or runway capacity during BZO-B was established. The potential solutions are listed below:

Table 2-4: Overview of Potential Solutions for Solving Bottlenecks during BZO-B

ID	Potential Solution	Remarks
B1	Apply standard taxi routes.	QRC states "avoid deviating from the standard taxi route" and is currently a recommendation. If standard routes are enforced, it may lead to safety benefits. Efficiency might not change because a restriction in routing choices could be detrimental to the throughput.
B2	No Auto-QSY during BZO-B (and other phases) so that RC can still intervene/provide guidance if necessary.	Throughput might be enhanced by quickly leaving the runway. Note: B1+B2 can be combined as a single measure.
B3	"Difficult" runway exits within ILS SA. Applies to N2, N3, N4 and W7.	This is a direct contributor to the ROT problem. Confusion can be avoided by different measures, such as additional lighting configurations and infrastructural improvements. See B3.1 and B3.2 below.
B3.1	Infrastructural modification to avoid confusion.	
B3.2	RC issues additional instructions on exit direction in case two exit directions are possible within the ILS SA, e.g. "vacate via N3 using right turn".	Direct impact on ROT with a small operational measure.
B4	Extend yellow-green centreline lighting on runways exit beyond the ILS SA so pilots know that ILS SA	Positive effect expected in terms of leaving ILS SA more quickly. Might be more effective than additional signing/markings.

	has been vacated (also includes an awareness campaign).	Can be implemented directly as AAS has already conducted a safety assessment.
B5	Reduce influence of the ILS SA.	This can be addressed by measures B5a and B5b.
B5a	Use runway exits that interfere less with the existing ILS SAs. The shape of the ILS SA depends on the distance from ILS LOC and the dynamic/static budget allocation for ILS protection area.	It is expected that this measure complicates ATC operations (extra R/T, plan exits) and could also mean that taking a more favourable exit increases ROT.
B5b	Use alternative ILS beam characteristics (e.g. fishtail) as investigated in KDC Project [Landing Capacity] to reduce dimension of ILS SA.	NLR-CR-2008-255 suggests that antennas with a smaller beam width lead to smaller SAs. Issues to be addressed include how ATC can determine that the ILS SA has been vacated in case the ILS SA varies for each runway exit (due to the fishtail shape of ILS SA).
B6	Use Rapid Exit Taxiway Indicator Lights (RETILs) that serve as visual guidance for pilot to anticipate runway exit.	Obtain experience from airports where RETILs have been installed (e.g. Gatwick airport). Potentially initiate a cost-benefit analysis.
B7	Investigate whether current spacing on final (min. 6 NM is prescribed but appears to be based on experience from the past) could be reduced. The separation is the result of a large number of factors that contribute to a higher ROT. For this reason conduct a ROT analysis for BZO-B to identify the major contributing factor(s). Solutions to reduce ROT may include: apply brake-to-vacate, use of moving map display, braking and steering cues, higher taxi speed, eliminating the need to vacate ILS SA area by GNSS-based landings (not feasible before 2012) or reducing the dimension of the ILS SA using different ILS antenna characteristics (see B5). Solutions to increase situational awareness pilot may include an ILS SA/ROT awareness campaign for pilots (see A1a), use of moving map display and improved guidance by lighting (see also B4, B6).	Direct consequence for runway throughput. Different solutions for solving the problem can be identified and need to be investigated, such as ROT reducing measures, situational awareness increase and controller workload reduction. Thus, reducing the criterion merely is an indirect measure that depends on other potential solutions. The other solutions therefore need to be investigated first. The ISS project team has requested to conduct a ROT analysis for BZO-B. This analysis entails the quantification of the time the aircraft occupies the runway and time needed to vacate the ILS SA. It is anticipated that this analysis provides insight into whether or not the 6 NM spacing can be reduced.

	Solutions to increase situational awareness ATCO or to reduce ATCO workload may include reducing the R/T load by e.g. automatic detection of ILS SA vacated, project ILS SA lines on an A-SMGCS display or automatic routing and route clearances.	

Solutions not further pursued:

Solution	Reason for Dismissal
Allow departures from RWY18L(E5) for aircraft that are capable and other aircraft from RWY24.	Not further pursued because it complicates the ATC operation (planning and additional runway). Could be more prone to mistakes/misinterpretations especially during low visibility conditions.
Do not use RWY27 for landings during BZO.	RWY27 leads to the longest ROT during Cat II/III conditions, however operationally this is not a feasible option for ATCOs.
Stop bar on runway or alternative to protect entering RWY18L/36R via RWY09/27.	In case a stop bar would be installed on RWY27, a failure would lead to a situation where all stop bars for RWY27 would automatically be activated. RWY27 would not be available then.
Apply inset taxiway edge lighting fixtures ("verzonken randarmaturen") as a demarcation for taxi route to be taken.	Expensive measure; would be more efficient to close a particular exit direction. Measure is therefore no longer pursued.
In addition to Cat I and Cat II/III also introduce specific Cat II.	No benefits expected and several infrastructural and procedural modifications needed.
Brake-to-vacate procedure	Currently only available on A380 and cannot be used during low visibility operations.
Build more Rapid Exit Taxiways (RET).	Building or relocating RETs would require many infrastructural changes, would be comparatively expensive and take a lot of time to realise (therefore out of scope of this project). Above that, it would be difficult to exactly determine where to locate them, as different types of aircraft will have different braking distances, so that there might be no real advantages as compared to the current situation. Also, additional taxiways might introduce new problems regarding situational awareness of pilots and controllers.
GNSS based landings without sensitive areas.	GBAS Cat II/III landings not foreseen before 2020.

MLS based landings with smaller sensitive area.	Not further pursued due to lack of sufficient MLS equipped aircraft in 2012 and operational issues (mixed spacing ILS-ILS, ILS-MLS, MLS-ILS).
Reduce 2 NM "free" approach	The 2 NM spacing should provide sufficient separation between successive approaching aircraft, normally to allow the leading aircraft to land, to turn off the runway, and to clear the relevant part of the runway strip and the ILS sensitive area before the following aircraft reaches a point 2 NM from touchdown. Previous studies indicated significant concerns by ATC and pilots.

2.7 BZO-C

2.7.1 Characteristics

2.7.1.1 Impact on Visual Monitoring

BZO-C becomes active when 200m ≤ RVR <350m.

RC	✧	RC cannot apply visual separation for missed approaches and deconflict landings and departures.
GC	✧	GC has no visual on taxiways and aprons.
Pilot	✧	"See and avoid" is not possible. Difficult to distinguish markings. Taxiing times increase significantly.

This phase corresponds to ILS Cat III and has a decision height below 100ft.

2.7.1.2 Frequency of Occurrence and Capacity

BZO-C and BZO-D conditions have occurred on average 26 hrs[8] per year which accounts for 0.5% of the time.

ATM Component	↓	↑	Total	Difference ↓ (BZO-B)
Runway	34	13	47	-10
Ground	-	-	47	

2.7.1.3 Non-performance Impact for Airlines

For every hour of BZO-C+D visibility, the total delay is 6 hrs[9] per year on average.

[8] KNMI meteorological data during 2004-2007

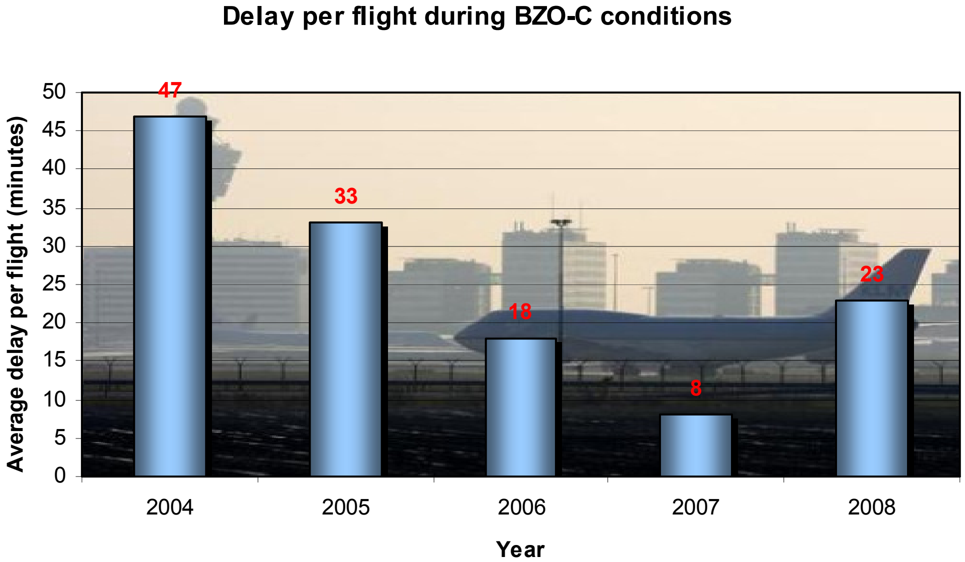


Figure 2-17: Delay per Flight in BZO-C between 2004 and 2008

Taking into account the average number of KLM flights during BZO-C conditions, the delay is approx. 26 min/flight.

2.7.2 Bottlenecks and Operational Consequences during BZO-C

In addition to phase BZO-B the following bottlenecks and operational consequences apply for ATC:

1. RC/GC: sub-optimal location of runway exits, complexity of exit geometry especially N2, N3, N4 (RWY27) en W7 (RWY18C) where the taxiway has multiple exits *within* the ILS SA, Auto-QSY (silent handover RC to GC) may prevent additional instructions, extra R/T to (re-)identify aircraft (position), large variation in time to vacate ILS SA, and SMR handovers. These factors lead to an increase of the ROT ►► minimum 8 NM separation on final. This restricts the landing capacity to a maximum of 17 per hour.

   Recent studies (Ref. [Landing Capacity]) have shown that RWY27 yields the highest ROT times and largest variation during BZO-C conditions.

2. Runway incursion possibility whilst erroneously taxiing on RWY09/27 ►► landing on RWY36R is not allowed.

3. GC: potential confusion where vehicle is located or headed ►► active control is applied by the GC to all vehicles which results in extra R/T.

4. Runway configuration ►► only 1+1 runway use is allowed. Two exceptions currently exist: 18R+18C/09 and 18R+18C/24.

[9] Average 9000 minutes delay during BZO C+D per year / average 26 hours BZO-C+D per year [KLM].

2.7.3 Limiting ATM Element

During BZO-C the current **GROUND** capacity limits the runway capacity to approx. 47 movements per hour (34↓ and 14↑ during inbound peak). LVNL has announced that they will start a trial from mid July 2010 to increase the ground capacity from 47 to 57 movements per hour. The extra capacity will be used for accommodating outbound movements initially.

2.7.4 Potential Solutions

An LVNL internal project is currently being defined to address GND capacity issues during BZO-C. Initially, the project team decided to de-scope BZO-C from Project ISS. However, given the fact that potential solutions for phases BZO-A and, in particular, BZO-B are also applicable for BZO-C, and considering that it was possible to obtain BZO-C data for further ROT analysis, it was decided to consider BZO-C issues as well. Thus, results from the ISS Project may complement the LVNL internal study during BZO-C and vice-versa.

2.8 BZO-D

2.8.1 Characteristics

2.8.1.1 Impact on Visual Monitoring

BZO-D becomes active when RVR < 200m.

RC	✧	RC can not apply visual separation for missed approaches and deconflict landings and departures.
GC	✧	GC has no visual on taxiways and aprons.
Pilot	✧	"See and avoid" is no longer possible. Difficult to distinguish markings. Taxiing times increase significantly.

This phase corresponds to ILS Cat III and has a decision height below 100ft.

2.8.1.2 Frequency of Occurrence and Capacity

BZO-C and BZO-D conditions have occurred on average 26 hrs[10] per year which accounts for 0.5% the time on an annual basis.

ATM Component	↓	↑	Total	Difference ↓ (BZO-C)
Runway	16	20	36	-18
Ground	-	-	47	

[10] KNMI meteorological data during 2004-2007

2.8.1.3 Non-performance Impact for Airlines

For every hour of BZO-C+D visibility, the total delay is 6 hrs[11] per year on average.

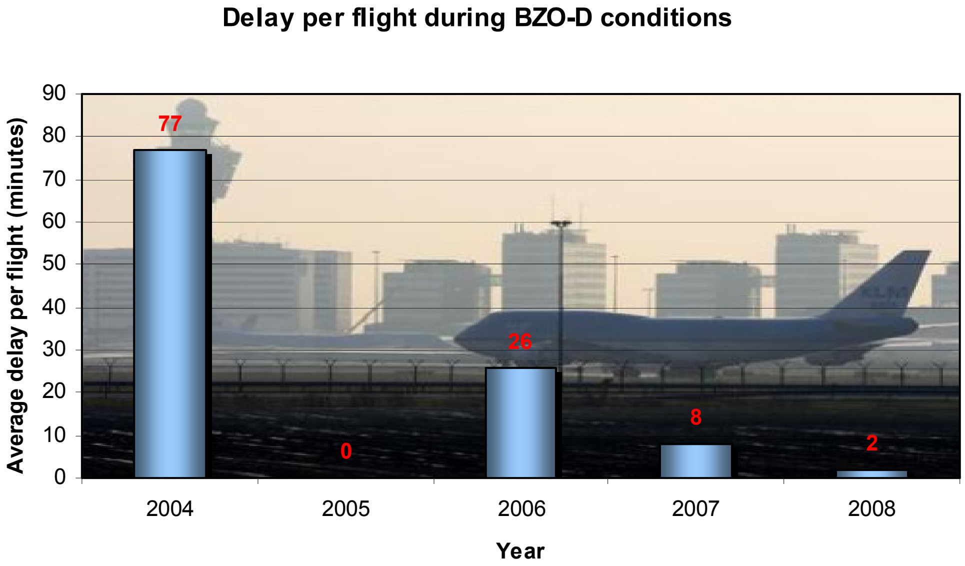


Figure 2-18: Delay per Flight in BZO-D between 2004 and 2008

The delay per flight could not be calculated because the annual delay figures vary too much.

2.8.2 Bottlenecks and Operational Consequences during BZO-D

In addition to the items specified in phase BZO-C, the following bottlenecks and operational consequences apply for ATC in BZO-D:

1. RC/GC: sub-optimal location of runway exits, complexity of exit geometry especially N2, N3, N4 (RWY27) en W7 (RWY18C) where the taxiway has multiple exits *within* the ILS SA, Auto-QSY (silent handover RC to GC) may prevent additional instructions, extra R/T to (re-)identify aircraft (position), large variation in time to vacate ILS SA, and SMR handovers. These factors lead to an increase of the ROT ►► minimum 9 NM separation on final. This restricts the landing capacity to a maximum of 16 per hour.

   Recent studies (Ref. [Landing Capacity]) have shown that RWY27 yields the highest ROT times and largest variation during BZO-C conditions.

2. Runway configuration ►► only 1+1 runway use is allowed.

3. GC: potential confusion where vehicle is located or headed ►► apply active control to all vehicles.

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[11] Average 9,000 minutes delay during BZO C+D per year / average 26 hours BZO-C+D per year.

2.8.3 Limiting ATM Element

During BZO-D the current **GROUND** capacity limits the runway capacity to approx. 36 movements per hour (16↓ and 20↑ during inbound peak).

2.8.4 Potential Solutions

Due to very low occurrence of BZO-D (on average 5 hrs per year during the last 5 years) it is considered out of scope of Project ISS.

2.9 Final Selection of Potential Measures

The following table provides a summary of the identified measure per visibility condition, based on the results of earlier studies as well as the workshops organised as part of the project. Furthermore, the actions that are based on the identified measures are specified and a prospective end date for the activities is given. These measures will be detailed in Chapter 3.

Table 2-5: Overview of Potential Measures

#	Potential Measure	VC	Action	Finished
1.	Change Visibility Criteria for Marginal Conditions	M	Assessment finalised: it is doubtful whether benefits can be achieved given the amount of time that certain conditions persist. Above that there are operational reasons for the specified limits. (actionee: LVNL and NLR)	June 7
2.	Change Runway Use	M	During the prioritisation workshop, an initial KLM analysis of delay minutes showed a special increase for off-peak runway use. Causes for delays are unknown: KLM would have to deliver more data (delays per aircraft and during good visibility) and LVNL should indicate why a certain runway use would lead to an extensive amount of delay minutes; if the problem is identified, a possible solution should be brought to the Alders consultation board. LVNL indicated that the current working method actually foresees 2+1 runway use	KLM data will not be available within the time frame of the project. Causes for delays remain unknown.

			except for night conditions. The data or the conclusion might not be correct. (actionee: KLM, LVNL, NLR)	
3.	ILS Sensitive Area Awareness Campaign	A (B, C)	Establish implementation plan: first steps were taken by KLM. Campaign will also focus on yellow-green centreline lighting at Schiphol. (actionee: KLM en AAS)	It is expected that the actions will be carried out within the time frame of the project.
4.	Simplification of Signage	A (B, C)	Assessment of main criticism in terms of operations and cost. (actionee: AAS)	Assessment cannot be finished within project time frame.
5.	3rd Ground Controller	A (B, C)	Large-scale Human Factors research will be necessary. In preparation, operational and organisational issues can be discussed with operational experts (controller interviews). The larger Human Factors activities cannot be part of this project and need to be assessed in a separate project. Recommendations will be given. (actionee: LVNL en NLR)	Interviews carried out on July 5 and 15.
6.	Standard Taxi Routes and No Auto-QSY	B (C)	An early assessment with controllers regarding operations, costs and training should be carried out. According to controllers standard routes are already used whenever possible and RC will give instructions on how to quickly vacate the runway. Removing Auto-QSY would lead to additional rules that might add operational confusion. (actionee: LVNL en NLR)	Interviews carried out on July 5 and 15.
7.	Difficult Exits within ILS Sensitive Area	B (C)	CBA for alternative measures to reduce confusion should be carried out. RC will already give instructions in such cases. All other alternatives (remove, paint, extra	Operational question discussed during interviews on July 5 and 15. AAS results not

			lighting) need to be assessed regarding their costs. (actionee: LVNL en AAS)	available yet.
8.	Extension of Yellow-Green Centreline	B (C)	Is currently implemented: an implementation plan needs to be written giving indications on how this will be handled (in phases or instantly). Will a CBA be necessary? Has AAS carried out a CBA already? (actionee: AAS)	AAS started work on this measure. Planning should be part of the final report.
9.	Rapid Exit Taxiway Indicator Lights (RETIL)	B (C)	Study results from Gatwick and Prague must be consulted. What were the options for a possible no-go? A CBA for Schiphol needs to be initiated. (actionee: AAS)	AAS did not give any information on this, yet.
10.	Changes in ILS Sensitive Area Shape	B (C)	Operational assessment and CBA should be carried out. What are the benefits in terms of aircraft movements (see KDC report)? Which runways will benefit the most and what are the costs of the antennas? (actionee: LVNL)	Operational question discussed during interviews on July 5 and 15. No cost data available yet.
11.	Reduce 6NM (BZO-B) and 8NM (BZO-C) Final Spacing	B, C	ROT assessment. This assessment should lead to the identification of bottlenecks during either BZO-B or BZO-C and should give indications on the benefits in terms of aircraft movements per critical area. This will eventually lead to a reduction in final spacing. (actionee: NLR)	Assessments will be finished at the end of July.

3 Solutions Pursued

3.1 M1: Modify Cloud Base and Visibility Criteria for Marginal Visibility

3.1.1 Aim of Measure

Lower the criteria for visibility and/or cloud base that set marginal conditions so that the visibility condition "marginal" occurs less frequently and the capacity and preferred runways during "good" visibility can be maintained.

3.1.2 Applicable Phases

This measure applies to the marginal visibility condition only.

3.1.3 Analysis

Based on actual data for 2008 and 2009, the contribution of visibility and cloud base during marginal visibility conditions was determined.

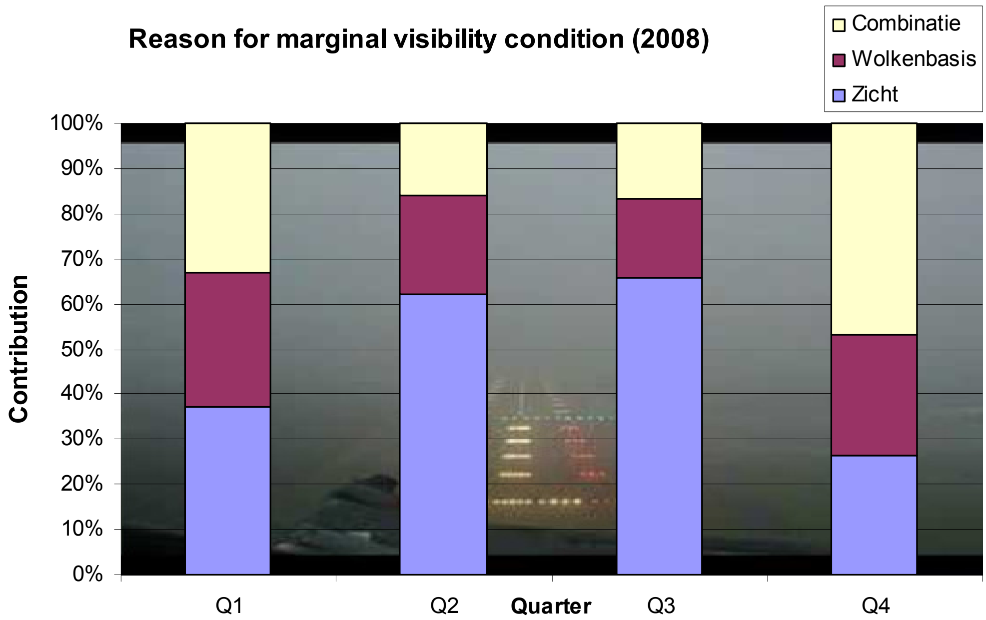


Figure 3-1: Reasons for Marginal Visibility in 2008

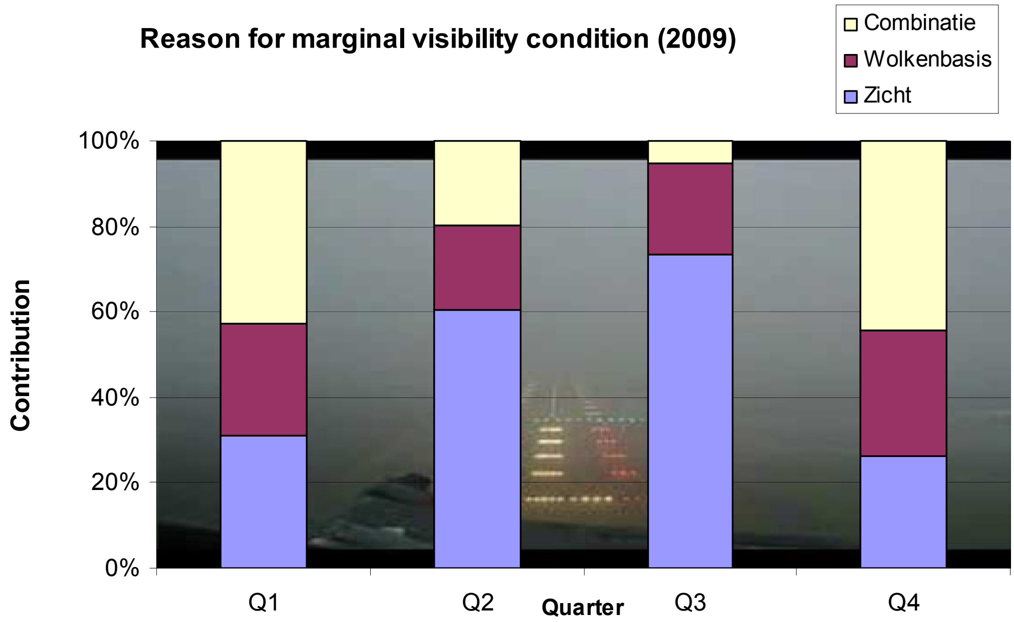


Figure 3-2: Reasons for Marginal Visibility in 2009

From the above figures for 2008 and 2009, a distinction can be made between summer and winter period. During summer the visibility determines that the marginal condition is set for 65% of the time and during winter the visibility and cloud base are more or less equally restraining.

Also, an inventory was made to determine how often the marginal condition would be set when the criteria for cloud base and visibility were reduced (see below).

Table 3-1: Visibility and Cloud Base Occurrence

Visibility (metres)	Cloud Base (ft)	% of time (2008)	% of time (2009)
1500-5000	**>=1000**	**3.7**	**3.8**
1500-4000	>=1000	2.5	2.3
1500-3000	>=1000	1.3	1.2
>=5000m	**300-1000**	**3.9**	**4.3**
>=5000m	300-900	3.4	3.7
>=5000m	300-800	2.7	3.0

From the values above it appears that the percentages for visibility are more sensitive to lowering the criteria. When for example the criteria 1500-5000m is modified to 1500-3000m (Figure 3-3) then the marginal visibility condition (2009) can be postponed by approx. 3.8%-1.2%=2.6%. This means effectively that the number of hours with marginal visibility conditions decreases from 995 hrs (for OP2008/9) to 969 hrs (-26 hrs).

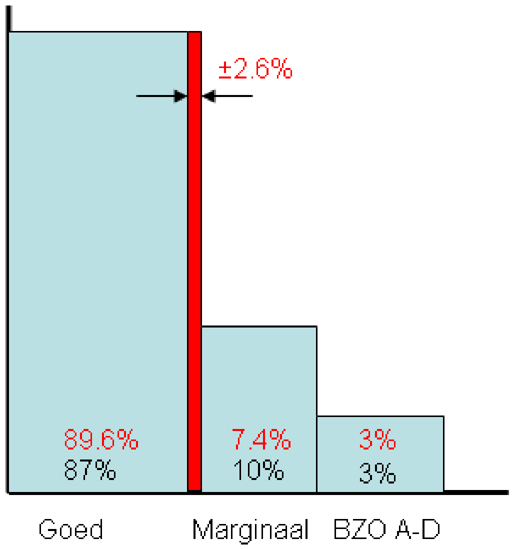


Figure 3-3: Change of Visibility Criterion and Marginal Condition Reduction

However, during marginal visibility conditions it is still possible to utilise the main North-South/South-North runway combinations which yield the same inbound capacity as achieved during good visibility conditions (see table below):

Table 3-2: Preferred Runway List for Inbound Peak (Ref. [QRC])

Inbound peak
0600 – 0820 UTC
1020 – 1220 UTC
1340 – 1520 UTC
1720 – 1900 UTC

- Windroos: inbound peak (UDP of not UDP).
- 2+1 baangebruik tijdens pieken, na afloop 2ᵉ baan niet meer gebruiken.
- 2+2 baangebruik tijdens overgangen toegestaan.
- Met reden propellervliegtuigen op/van andere baan.
- Convergerende naderingen buiten UDP:
  - zie QRH APP, 3.02, blz. 5
  - zie QRH TWR, 3.02, blz. 3

	Pref	LND-1	LND-2	STR	Vereist zicht / CLB	
X	1 *	06	36R	36L	≥ 5 km / ≥ 1000 ft	~~34+34/40 (68↓)~~
	2 **	18R	18C	24	RVR ≥ 200 m	35+30/30 (65↓)
	3	18R	18C	18L	RVR ≥ 550 m / CLB ≥ 200 ft	34+34/35 (68↓)
	4	36R	36C	36L	RVR ≥ 350 m	34+34/35 (68↓)
X	5	27	18R	24	≥ 5 km / ≥ 1000 ft	
X	6	27	36C	36L	≥ 5 km / ≥ 1000 ft	
	7	18R	22	24	RVR ≥ 550 m / CLB ≥ 200 ft	35+30/35 (65↓)
	8	18R	22	18L	RVR ≥ 550 m / CLB ≥ 200 ft	35+20/30 (65↓)
	9	Zie off-peak				

* Buiten UDP bij noordelijk baangebruik en bij verkeersaanbod > 58, preferentie 4 toepassen i.p.v. preferentie 1.
** Als 550 m ≤ VIS < 5 km en 200 ft ≤ CLB < 1000 ft, preferentie 3 toepassen i.p.v. preferentie 2.

X = not to be used during marginal visibility conditions.

There are, however, consequences for the outbound capacity. These are not considered as the ISS project focuses on inbound capacity/sustainability only.

3.1.4 Pros and Cons

Benefits:
1. Slightly longer time that good visibility conditions can be maintained, but similar capacity figures can also be maintained using other runway configurations during marginal visibility conditions. The sustainability is therefore not expected to increase.
2. Can be implemented before 2012 at relatively low cost.

Drawbacks:
1. Change in ATC procedures and operations required.
2. Potential safety issue because visual observation of double missed approaches is hampered when lowering the criteria from 1000ft to e.g. 800ft.
3. Potential safety issue because visual observation of runway thresholds and/or first initial turn during departure can not be visually observed when lowering the criteria from 5000m to e.g. 3000m.

3.1.5 Conclusion

Reducing the visibility or cloud base criteria does not significantly impact the period of time that a marginal visibility condition has to be applied. Moreover, in most cases the inbound capacity can be the same as during good visibility conditions since several other runway combinations (non-converging) are available yielding similar capacities. For this reason, ATCOs have not been consulted to provide feedback in terms of operational feasibility.

3.1.6 Recommendation

Weighing up safety of the ATM operation against the potential increase in runway capacity does not warrant the implementation of the proposed measure.

3.2 M2: 2+1 Runway Usage during Off-peak

3.2.1 Aim of Measure

Provide extra runway capacity and reduce delays through 2+1 runway use during situations where 1+1 runway usage may (not certain at this stage) result in large delays.

3.2.2 Applicable Phases

The applicable phases are marginal conditions and BZO A/B.

3.2.3 Analysis

Following the delay analysis by KLM, it was concluded that the majority of delays was caused during marginal visibility conditions. The figure below shows the average delay per year for each runway combination and visibility condition.

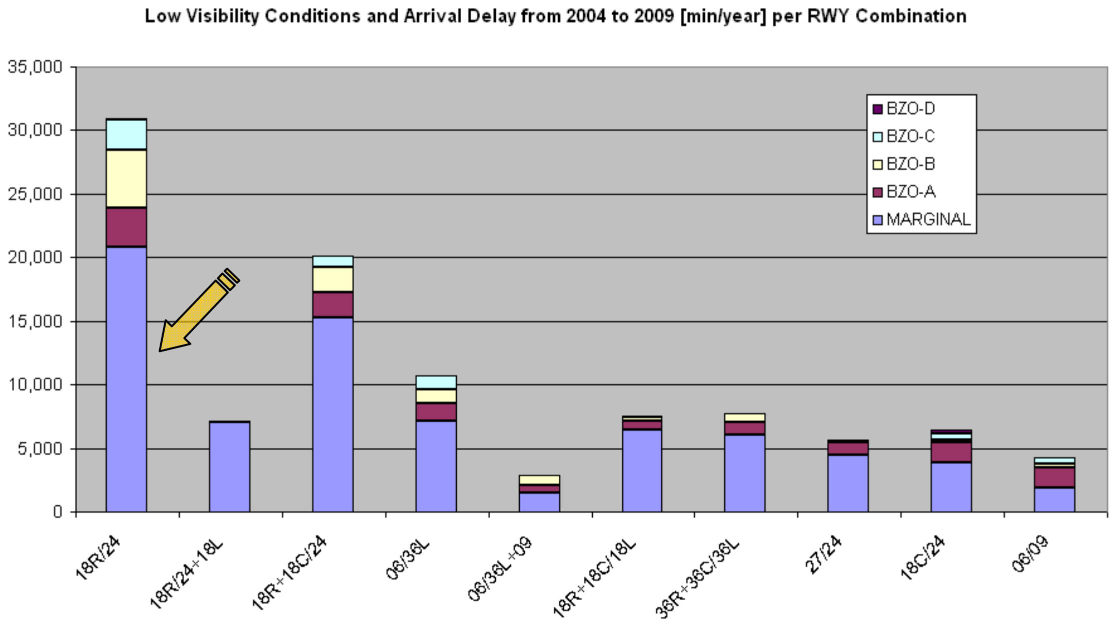


Figure 3-4: LVC and Arrival Delay from 2004 to 2009 per RWY Combination

Particularly when the 18R↓/24↑ runway combination is used, the delays are significant. This is an off-peak combination and has a capacity of 38↓/35↑ during marginal visibility conditions[12].

Based on the cumulated delay figures only, it is not possible to assess the source of the delays during off-peak runway combinations. This has a number of reasons:

1. The use of runway 18R results in longer taxi-times. When longer taxi-times are not accurately anticipated in schedules (taxi routes are based on average figures) then this would automatically introduce delays.
2. It is not known whether the total delay is caused by many flights multiplied by small delay figures. There is a need for delay figures per flight or a comparison between delay figures during good visibility conditions and marginal visibility conditions.
3. ATCOs have indicated that 2+1 runway usage is applied during off-peak when needed and ATCOs do not have the impression that off-peak runway combinations lead to significant problems or delays.

Depending on the source of the delays, it may be beneficial to (partially) operate a 2+1 runway configuration during an off-peak. This question was also raised during a WG-Air meeting.

Since the measure relates to the future noise enforcement system it is a long-term measure. Generally speaking, 2+1 runway usage during an off-peak is not in line with the principles of the future noise enforcement system which has recently been published (Ref. [NNHS]) and will most likely be effectuated at the end of 2010.

[12] When TWR-W is not active then de landing capacity of 18R is restricted to 30 aircraft per hour.

3.2.4 Pros and Cons

Benefits:

1. Difficult to quantify since the reason for the delay is not known at this stage.

Drawbacks:

1. A change in the noise enforcement system would be required and such a change is not likely to be effectuated prior to 2012.
2. 2+1 during off-peak requires ATC resources.

3.2.5 Conclusion

Given the comments of the ATCOs, it is important to assess whether 1+1 runway usage does result in an operational and economic problem or whether the delay analysis only confirms that the use of runway 18R leads to long taxi-times which cannot be anticipated in the KLM schedules and hence result in delays.

3.2.6 Recommendation

Detailed delay analysis is to be conducted before taking further steps that deal with a (future) noise preferential system.

3.3 M3: Awareness Campaign for ILS Sensitive Area

3.3.1 Aim of Measure

Pilots need to be aware that they occupy the runway as long as they are not clear of the ILS sensitive area. This area may extend beyond the first holding position at the end of a runway exit, meaning that pilots are tempted to hold before entering the taxiway system, thereby still occupying the runway area. Thus, valuable time that is needed for additional instructions is lost in such cases and runway capacity is reduced. To further complicate matters, these cases usually occur at a time when handover processes are underway, so that it might not be clear from the start whether runway or ground controller should give further instructions.

Only if pilots are aware of that fact as well as the special markings and lights indicating the boundaries of the ILS sensitive area, it will be possible to see a reduction in runway occupancy time and an improvement in runway capacity. An awareness campaign will help pilots improve an understanding of the situation and contribute to a more efficient service on the ground.

3.3.2 Applicable Phases

The ILS sensitive area comes into play in BZO-A, which is an ILS CAT I low visibility condition. However, Cat II/III conditions are also expected to benefit.

3.3.3 Analysis

Although runway capacity is not seen as a limiting factor in BZO-A, air traffic controllers during interviews noted that runway occupancy time would increase due to problems in handover from runway controller to ground controller and extra time spent on the frequency. This is mainly due to pilots not being aware that they are still occupying the runway when not entirely clear of the ILS Sensitive Area. This area may extend beyond the first holding position at the end of a runway exit and is marked with a yellow line for both CAT I and CAT III positions.

The specified measure is supposed to raise awareness among pilots that the ILS sensitive area needs to be cleared as soon as possible and that Schiphol indicates that area in accordance with [ICAO Annex 14], paragraphs 3.12.3 and 5.3.16.7, with both runway-holding position markings and alternate taxiway centre line lights that show green and yellow from their beginning near the runway centre line to the perimeter of the ILS sensitive area. For that purpose, the International Federation of Airline Pilots' Associations (IFALPA) will be asked by the Dutch Air Line Pilots Association (VNV) to take action. Furthermore, the topic will be addressed during a meeting of the International Air Transport Association (IATA), and KLM will start a SkyTeam Alliance internal awareness campaign.

A detailed ROT analysis was conducted for BZO-B and BZO-C based on actual ground-radar track data gathered by LVNL. This track data corresponds to the time period of January 2008 to March 2010 and 50 hours of BZO-B (1025 tracks) and 21 hours BZO-C (654 tracks) have been analysed. Annex II contains details with regard to determining ROT and ILS SA times.

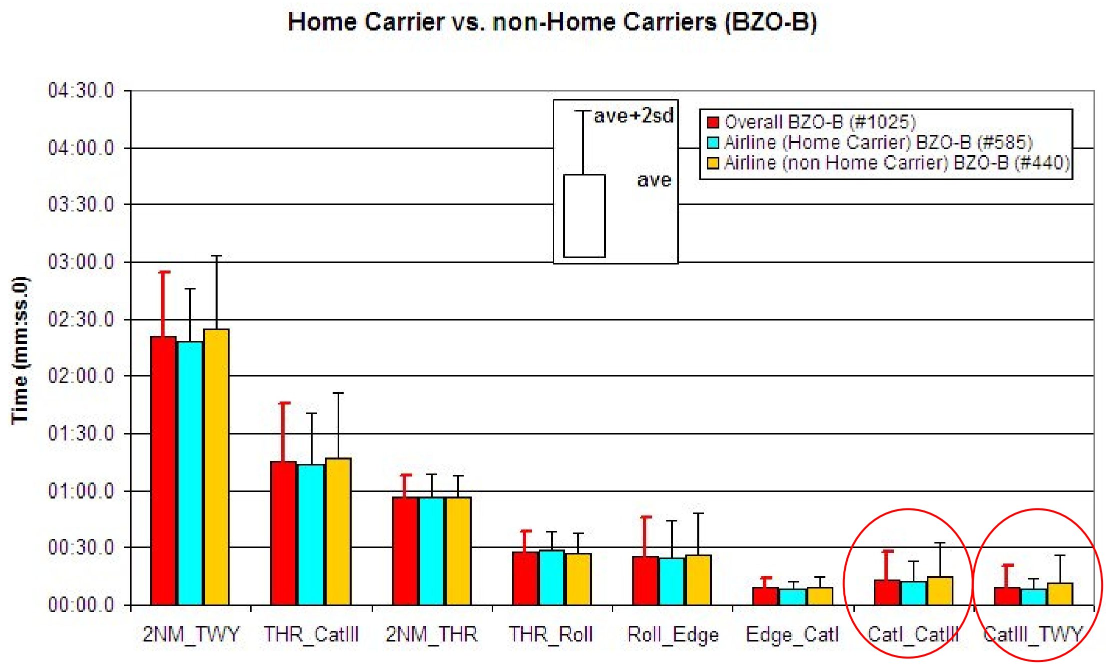


Figure 3-5: ROT Analysis Results for Home vs. Non-home Carrier in BZO-B

Based on the data above, one may conclude that non-home carriers have a slightly large ROT due to longer time to leave the ILS SA. Data confirms that they need approx. 20 seconds more during BZO-B and BZO-C. An ILS awareness campaign may aid in reducing the time for non-home carriers to leave the ILS SA.

3.3.4 Pros and Cons

Obviously, the benefits of this approach can be rather large as compared to the costs of this measure. While all the earlier mentioned actions are free of charge, additionally posters and leaflets might need to be printed.

3.3.5 Conclusion

The mentioned measure aims at reducing runway occupancy time by raising awareness among pilots that they need to leave the ILS sensitive area, indicated by abovementioned markings and lights, as quickly as possible. Several actions will be taken that will address the awareness campaign on an international level (IFALPA has already been contacted) and internally within KLM and SkyTeam.

3.3.6 Recommendation

Runway occupancy times should be monitored on a regular basis in order to find out about trends regarding pilot awareness. Based on the monitoring results, an awareness campaign should be repeated. Special attention should be given to the fact that Schiphol (AAS) is planning to extend the green and yellow alternate taxiway centre line lights up to the taxiways where applicable (see also Measure 8). This should specifically be addressed during the awareness campaign, and there should be an official announcement to IATA, IFALPA and the airlines after installation of the lights.

3.4 M4: Simplification of Ground and Runway Signage

3.4.1 Aim of Measure

Signs are provided on an airport mainly to convey a mandatory instruction or information on a specific location or destination. In particular, the latter is of importance for efficient guidance and taxiing operations. According to Schiphol (AAS), the signage is in agreement with the standards and recommended practices put forward by Annex 14, however, there have been instances in which pilots were confused by the complexity of the different signs in particular areas of the airport. Improving signage and reducing complexity of navigation indications is therefore a contributor to improved efficiency of ground operations.

3.4.2 Applicable Phases

Signage concerns all those phases in which pilots are still able to clearly detect the messages provided by the signs in time. Obviously, there can be no exact definition for such a phase, as circumstances might be different at different parts of the airport. However, a general understanding is that starting from BZO-C it will be difficult for pilots to see and avoid other traffic or distinguish markings and signs on the airport surface. From this understanding, it can be assumed that the applicable phases concern good and marginal conditions as well as BZO-A and BZO-B conditions.

3.4.3 Analysis

According to operational experts and pilots there are particular areas at Schiphol airport where the signage is confusing due to its complexity, especially when being confronted with it for the first time. One of the critical areas mentioned was the end of taxiway Q in the direction of the Y-apron (entry into A27). Another structural problem noted is the taxiway layout around the P holding area, which could be confusing to pilots.

Generally, it was confirmed by Schiphol (AAS) that there were plans to re-evaluate the signage and indicate areas for improvement. A possible solution could be to improve indications on the ground using paint. Changing a complete signpost (including electricity for illumination) could cost up to ten-thousands of Euros according to AAS. Changing just the sign itself (but not its frame structure or cabling) could be achieved for about €1000. Changing a sign would not require a NOTAM. It was also noted by AAS that changing ICAO principles for improving signage, if deemed necessary in the identified case, would be possible but should be initiated by ICAO.

3.4.4 Pros and Cons

From the positive side, this measure is easy to accomplish and enhances safety and efficiency of ground operations. However, it still means that a formal investigation into current shortcomings and areas for improvement has to be made under the involvement of pilots. Also, it might not be feasible to solve all problems due to the complexity of the taxiway layout and the limited space for placing signs.

3.4.5 Conclusion

Schiphol (AAS) has already considered starting an initiative that will re-evaluate the signage in critical areas on the airport. Although some improvement in terms of safety and efficiency of ground operations can be expected, it is hard to specify an exact figure as an analysis would have to consider expected pilot behaviour. Furthermore, it is not clear yet whether improvements are really feasible since possibilities for placing signs are always limited by the taxiway layout. Nevertheless, the mentioned measure seems to be very effective for ground operations in terms of navigation capabilities within the time frame of the project (before 2012).

3.4.6 Recommendation

It is recommended to start the planned initiative on re-evaluation of Schiphol (AAS) signage, as it is expected that it is the only measure that could be introduced easily and within the envisaged time frame in order to improve situational awareness of pilots when navigating on the taxiways. From the benefit side, it will be hard to draw any conclusions without monitoring data relating to the critical areas and without ideas on how pilots would react to changes. In that regard, the identified measure seems to be a measure that simply needs to be done, because it can be achieved comparatively easily.

3.5 M5: Introduce Third Ground Controller

3.5.1 Aim of Measure

The introduction of additional human resource (3rd GC at TWR-C) is expected to increase the ground capacity.

3.5.2 Applicable Phases

BZO-A and BZO-C are the applicable phases since the ground capacity is currently limiting in these LVC phases at respectively 80 and 47 movements per hour. Also other phases may benefit due to a more equal distribution of GC workload. Already a need exists to utilise a 3rd GC at TWR-C due to increased workload during de-icing activities when specific runway combinations are used. For this reason, marginal and good visibility conditions would also benefit.

3.5.3 Analysis

The GC is responsible for air traffic control in the manoeuvring area excluding traffic on runways in use and the main tasks include:

1. Issue pushback and taxi instructions
2. Co-ordinate with AAS towing control, RC, SUC/DEL or other GC
3. Dealing with flight strips

During an inbound/outbound peak two GCs on TWR-C are active. TWR-W also has a separate GC position but this is out of scope of this study. The current workload is GC is at its maximum and can a further increase is highly undesirable, if not unacceptable. The current area of responsibility of GND is depicted below. Note that the boundary between GC North and GC South is flexible and depends on the runways in use, traffic volume and whether de-icing is required. However, the Auto QSY frequencies are always the same (Figure 3-6).

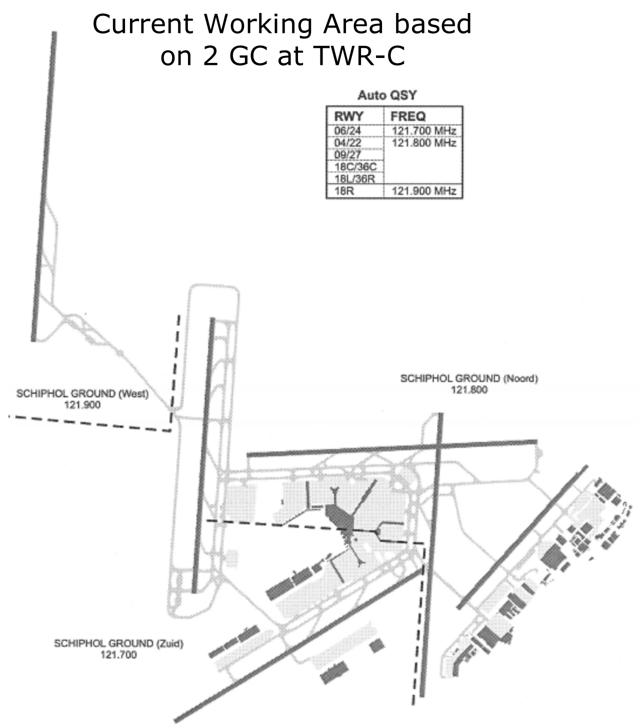


Figure 3-6: Current Working Area with Two Ground Controllers at TWR-C

Additional workload is created by towing activities where the RC and Schiphol Tow Control have to co-ordinate with one another, for example when runways have to be crossed. In the past this has led to the proposal to transfer full responsibility of towing to LVNL or alternatively to let Schiphol Tow Control and LVNL be physically located next to each other.

The introduction of a 3rd GC raises several issues that would have to be resolved (Ref. [Ground Control Capacity]) including:

- What is the net effect on workload of other GCs when introducing a 3rd GC given the fact that a subdivision of a sector amounts to more co-ordination between GCs?

- What is the task of the 3rd GC: is this a dedicated sector (third working area) or does the task involve co-ordinating with other positions (maintain the current two working areas)?
- At what moment in time is the introduction of a 3rd GC necessary? This depends on the growth of air traffic at the airport, transitioning from 108 to 120 movements per hour at Schiphol, the transition from 2+1 to 2+2 runway use, etc.
- At what moments of the day is a 3rd GC required? Only during first morning peak or during all peaks?
- How does the 3rd GC interact with other projects such as: introduction of electronic flight strips, CDM, Departure Management (DMAN) / Collaborative Pre-departure Sequence Planning (CPDSP) and possible re-design of the working positions on TWR-C, etc.

In the LVNL De-icing POD (Ref. [ICEPOD]) a number of the issues mentioned above have been addressed. The tasks of the 3rd GC would be equal to those of the current ground controllers with the exception that the working area for each ground controller at SPL-C changes (see figure below) and the corresponding co-ordination.

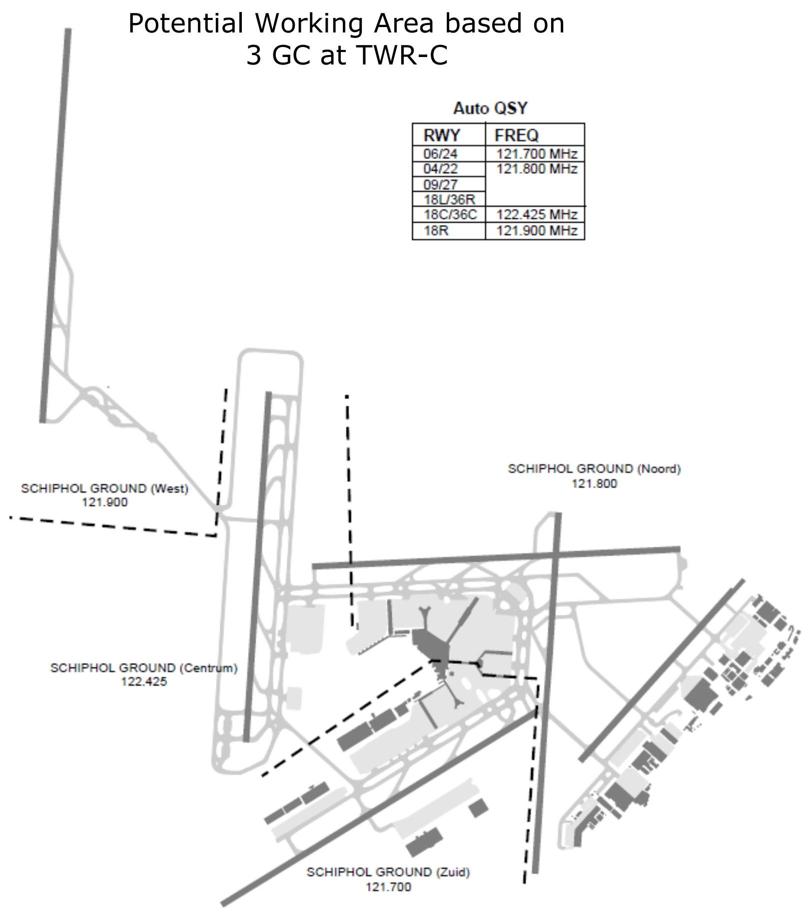


Figure 3-7: Potential Working Area with Three Ground Controllers

3.5.4 Pros and Cons

Benefits:

1. Increased overall ground capacity and particularly during de-icing on the J-apron when traffic is concentrated around RWY09 and taxies via taxiway Y.
2. More equal distribution of GC workload.
3. The increase in ground capacity is an enabler for increasing the runway capacity which increases the sustainability during BZO. The increase in ground capacity has not been quantified at this stage since it requires a more detailed study.
4. Potentially also increases safety because workload is more balanced and less prone to errors and/or larger buffer to respond to unforeseen conditions.

Drawbacks:

1. Measure has been frequently mentioned in previous studies but was never implemented. This is partially due to all the issues that need to be resolved, such as ATC resources, scheduling the utilisation of 3rd GC (part-time, full-time function) and difficulties in realising a 3rd working position in TWR-VCR.
2. Revision of ATC procedures (e.g. how to divide the movement area; functionally, operationally, transfer amongst GCs, etc...).
3. System modifications (e.g. GAREX).
4. ATC training required.
5. Amendments in VDV.
6. To exploit the increase in the ground capacity, the runway capacity also has to be increased.

3.5.5 Conclusion

The effect on the workload, ground capacity and safety cannot be assessed at this stage. Given the current need for additional GC support during specific conditions (de-icing and RWY09 utilisation) benefits are foreseen. A detailed study involving real-time simulations based on the proposed procedures described in the LVNL POD are needed to quantify effects on safety, workload and associated capacity levels. Since a significant change in MMP is required, a detailed cost-benefit analysis is also needed.

3.5.6 Recommendation

In order to investigate the implementation issues mentioned above, real-time (human-in-the loop) simulations are required to assess, in particular, the controller workload. A detailed cost-benefit analysis should be carried out to account for the significant MMP change.

3.6 M6: Apply Standard Taxi Routes and No Auto-QSY

3.6.1 Aim of Measure

In BZO-B the use of standard taxi routes is recommended in the QRC. The expert group suggested that enforcing the use of standard routes might lead to additional safety. Furthermore, Auto-QSY is currently used to automatically transfer flights from runway to ground controller thereby making that process more efficient. It was suggested by controllers that Auto-QSY should not be permitted for BZO-B conditions (and worse conditions) to prevent untimely handovers and allow the runway controller giving extra instructions to the pilot for vacating the runway as quickly as possible. According to controllers, there had been cases where aircraft could not be reached for further instructions on the runway frequency and had to be transferred back by the ground controller first.

3.6.2 Applicable Phases

The applicable phase for both measures is BZO-B and worse conditions, as in these conditions safety and efficiency enhancing measures concerning handover issues and thereby runway occupancy time will become increasingly important. This is caused by pilot behaviour as pilots will roll out slower on the runway in order not to miss an exit and will act more reserved regarding taxiing operations.

3.6.3 Analysis

The suggestions regarding improvement of handover procedures by enforcing standard routes and disallowing Auto-QSY were meant to help controllers by providing more safety during taxiing operations and more efficiency and safety when giving instructions to pilots on the runway in the handover phase.

Schiphol controllers were confronted with these suggestions during interviews and doubted the contributions of both methods to safety and efficiency. Standard routing was in fact already used whenever possible. Restricting the choice of routes to only standard routes, however, would also reduce flexibility of finding solutions in unusual situations, thereby possibly leading to unsafe or even inefficient situations. A less conservative possibility, however, was to enforce the standard routes on arriving traffic only. This would allow controllers to keep a certain degree of flexibility while at the same time leading to less uncertainties and more robustness in the taxi flow to the gate.

Regarding Auto-QSY, it was stated that a change in cockpit procedures from one visibility condition to another could potentially worsen the situation in terms of safety and efficiency, especially when the pilot was unsure about the visibility condition. Thus, disallowing Auto-QSY for a certain condition could lead to even more confusion in both the cockpit and the control tower. Instead, it was considered that proper training for runway controllers to give additional instructions early enough during roll out on the runway would mitigate the situations described in document [Landing Capacity]. Besides, this approach was already controller practice. Most importantly, the runway and ground controllers are situated next to each other and can quickly deliberate as to what action is to be taken.

3.6.4 Pros and Cons

As described during the controller interviews, the solutions for circumventing problems with Auto-QSY were already addressed in daily practice. Disallowing that procedure for certain visibility conditions could lead to unsafe situations. Thus, keeping Auto-QSY and training controllers to give extra instructions about leaving the runway from BZO-B on, is considered the safer option.
Standard taxi routes are currently given in BZO-B. Enforcing this recommendation, though, is seen as removing flexibility from the process with a potential for inefficient or even unsafe situations. In order not to completely remove any flexibility, the standard routing could be applied for incoming aircraft only. This could potentially lead to a more robust taxi flow to the gate and reduce uncertainties.

3.6.5 Conclusion

As for Auto-QSY, it seems that a circumventing solution to the problem detected in document [Landing Capacity] has already been found so that Auto-QSY can still be used in visibility condition BZO-B and worse.
The approach to enforcing the use of standard taxi routes under bad visibility is considered more restraining than helpful, since it was stated that controllers were already using the standard taxi routes and would deviate from this procedure only in cases that were obviously detrimental to efficiency or safety. However, the option to only enforce standard routes on incoming traffic could improve the taxi flow to the gate while maintaining a certain degree of control flexibility.

3.6.6 Recommendation

In how far the solution for avoiding the Auto-QSY problem is efficient, could only be assessed by analysing monitored data on transfer conditions before and after the implemented solution. As a first step, it could be investigated whether the mentioned problem still exists at all and, if it does, how grave the problem is in terms of reduced number of movements, percentage of occurrences in BZO-B and so forth.

Regarding the use of standard taxi routes, an investigation could look into the number of deviations and the underlying reasons as well as the question whether any deviation has actually led to unsafe situations during bad weather. The question whether the enforced use of standard taxi routes would also lead to better efficiency due to better pilot confidence remains a hypothetical question as useful answers could only be given if that confidence could be established and measured in terms of faster taxi times, i.e. after introduction of the change.

An additional topic for investigation should be the enforcement of standard routes for incoming traffic only and the comparison of both operational options in terms of safety (flexibility of control operations) and efficiency (taxiing times from runway exit to the gate).

Judging from the diverse possibilities and open operational and benefit questions, it seems more appropriate to first have a look at other measures that might be reducing runway occupancy time in the handover phase, such as measure 3 and measure 8. It was suggested to bring the mentioned issues under the attention of controllers by means of an LVNL Training Bulletin aimed at operations during the upcoming winter season.

3.7 M7: Reduce Complexity of Exits within SA

3.7.1 Aim of Measure

The measure seeks to remove confusion of choice of exits by means of:

1. Infrastructural modification: physically removing the second option for vacating the runway or apply lighting to indicate correct runway exit
2. Operational modification: RC applies extra instruction to indicate correct runway exit

The aim is to vacate the ILS sensitive area more quickly. This reduces the time to vacate the runway and may lead to a reduction in the buffers that determine the required spacing on final. Ultimately, this may slightly increase the runway capacity.

3.7.2 Applicable Phases

Applicable phases are visibility conditions BZO-B/C/D.

3.7.3 Analysis

In this section runway 18C is specifically addressed[13]. According to Figure 3-8, the time needed to vacate via W8 deviates from the other two exits. However, the small amount of tracks does not warrant deriving any conclusions.

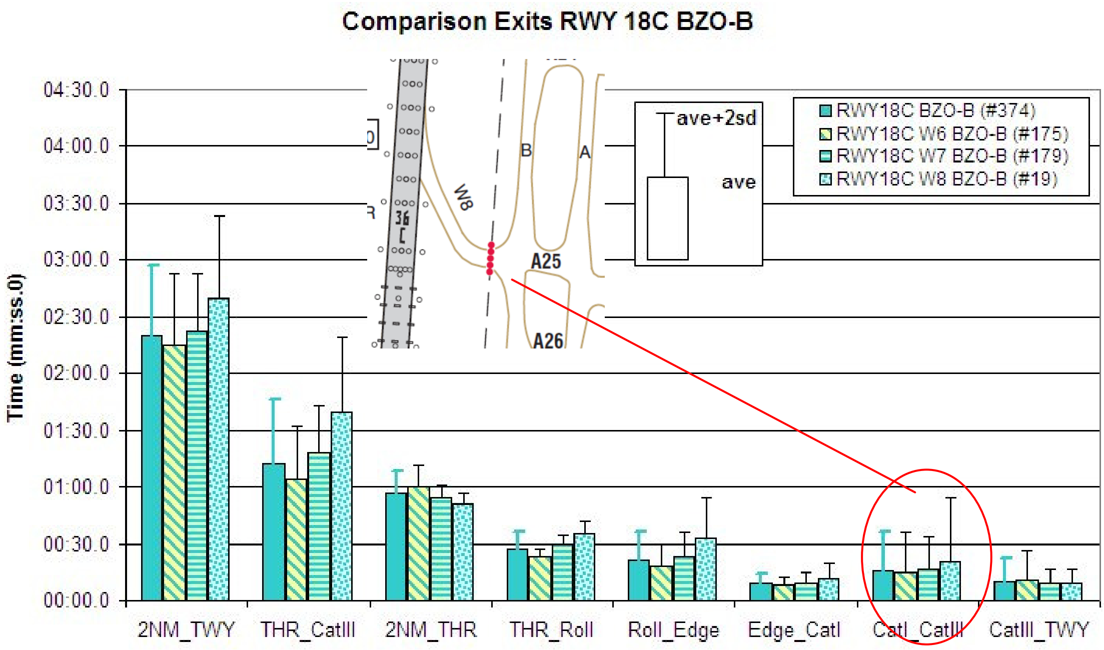


Figure 3-8: ROT Analysis Results for Complex Exits in BZO-B

From Figure 3-9 it appears that aircraft during BZO-C that vacate via W7 need additional time to traverse from the Cat I to Cat III line. This could be caused by the fact that aircraft can enter the Bravo track either clockwise or counter-clockwise whilst situated in the ILS SA. If the confusion is removed, the time is expected to be similar as observed at W6 and W8 and would save approx. 15-20 seconds.

Another situation mentioned during controller interviews concerned the proximity between the N exits of RWY09-27 and the E/F/G aprons, especially the problem with pushbacks at the F apron onto taxiway A. Initially, this problem was not looked at because RWY27 was not in use during BZO-B and BZO-C in recent years. However, there are plans to use it again in the future. Since there is no clear operational solution for this problem yet, its consequences will only be dealt with in the recommendations.

[13] There is insufficient BZO data for runway 27 during 01/2008-03/2010 partly because runway 27 is not preferred and also not used during BZO.

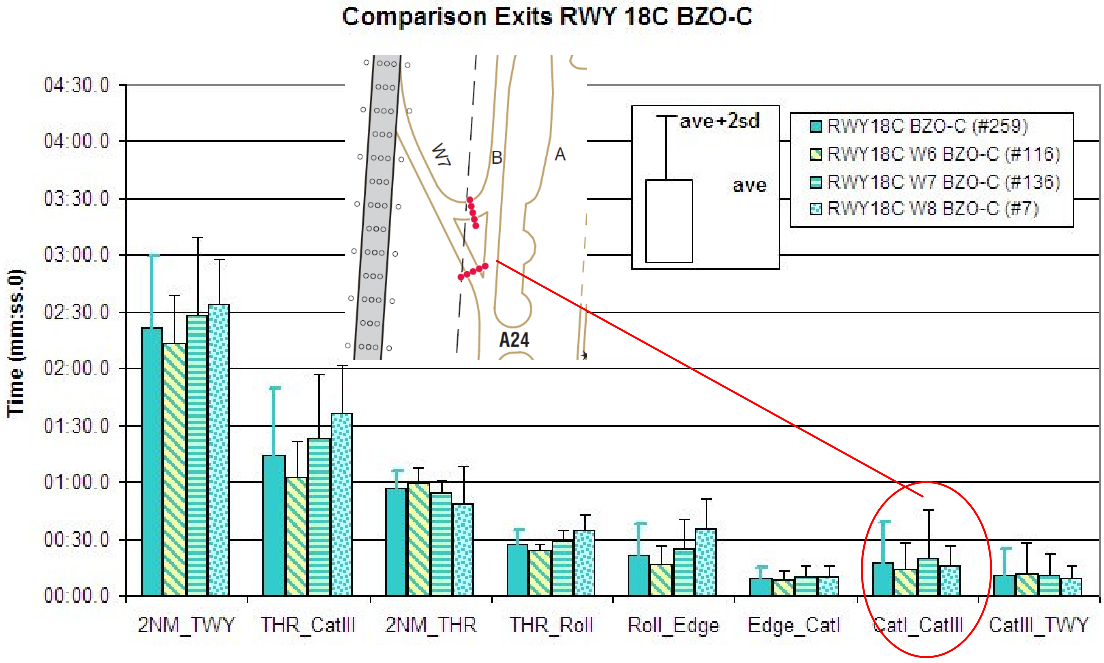


Figure 3-9: ROT Analysis Results for Complex Exits in BZO-C

3.7.4 Pros and Cons

Benefits:

1. Generally, there are low cost measures to remove the possibility of a left-hand turn on W7 which are easy to implement.
   Painting the surface would amount to about €1500 per exit. Completely removing the surface could cost up to €50,000.
   A more expensive solution would be to add special lighting at the taxiway edges, which could lead to costs between €150,000-200,000 according to AAS, mainly due to costs regarding electricity and switching, and cutting into the asphalt.
2. Based on the ROT analysis, this measure may reduce ROT time with approx. 15-20 seconds.
3. May also reduce traffic flow complexity on Bravo track.

Drawbacks:

1. There are no known operational drawbacks when the possibility of a left-hand turn on W7 is removed as W7 is not used for intersection take-off.

3.7.5 Conclusion

Choice for exit direction at W7 within the ILS SA leads to confusion and increased time to vacate the runway.
Pushbacks at F apron might lead to dangerous situations in the future (i.e. when RWY27 is used in BZO-B/C again).

3.7.6 Recommendation

Decommission W7 left-hand turn by physically restricting access either by removing exit or placing a barrier. It is advised to compare ROT results prior to and after decommissioning the exit to assess the benefits.
Since difficult exits and multiple traverses between A and B track and vice-versa also applies during good visibility conditions it is recommended to analyse these areas as well.

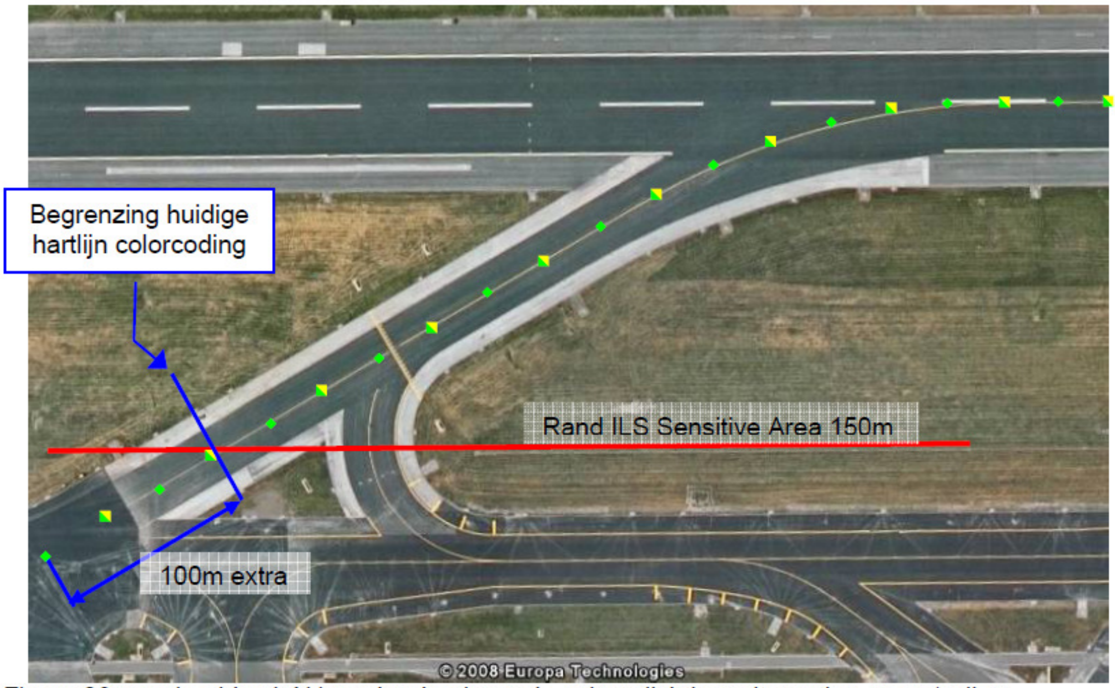
Finally, LVNL intends to start using runway 27 again during BZO-B/C conditions; i.e. 18R+27/24 during inbound peaks. Previous studies have shown that this runway exhibits the largest ROT. It is therefore recommended to also evaluate a modification of exits N2, N3 and N4.

Regarding the pushback problems close to RWY27 at the F apron, an additional study should be defined looking into flow issues (e.g. fast-time study) when RWY27 is to be used again in low visibility (from BZO-B).

3.8 M8: Extend Yellow-green Centreline

3.8.1 Aim of Measure

One way of showing the pilot that the aircraft is still occupying the runway when it is not clear of the ILS sensitive area is by installing alternate taxiway centre line lights that show green and yellow from their beginning near the runway centre line to the perimeter of the ILS sensitive area in accordance with [ICAO Annex 14], paragraphs 3.12.3 and 5.3.16.7. Currently, these lights are installed at Schiphol.



Figuur 28: voorbeeld exit N4 verder doorlopende exit verlichting: alternating green/yellow

Figure 3-10: Yellow-Green Alternating Centreline Lighting

However, in some cases, to be really certain that an aircraft has actually left the ILS sensitive area, these lights need to be extended to the centreline of the adjoining taxiway. This would reduce the chance of pilots being tempted to hold before entering the taxiway system, thereby still occupying the runway area and leading to the accompanying problems mentioned for Measure 6. This also means that pilots need to be aware of the meaning of the lights. The latter problem is addressed by Measure 3.

3.8.2 Applicable Phases

This measure is mainly directed at BZO-B and BZO-C, thus CAT II/III conditions, since only in these circumstances the sensitive area will reach out across the CAT III holding position.

3.8.3 Analysis

According to Schiphol (AAS) plans have been made to extend the current alternate lighting. The only open question would be how to organise the transition, i.e. whether to introduce lighting changes per runway or at all runways at the same time.

Regarding operations, nothing would change as aircraft leaving the runway should not be obstructed by taxiway traffic and would be confronted with green taxiway centre line lights anyhow. Above that, the aim of reducing runway occupancy time is to get aircraft onto the taxiway system as quickly as possible. Thus, no special safety investigations in this regard seem to be necessary. As to the monetary aspects all would come down to changing a number of lights, which would not really amount to large costs as it is expected that additional lights are on stock, so only the work to exchange lights and note the change in the AIP would be necessary steps.

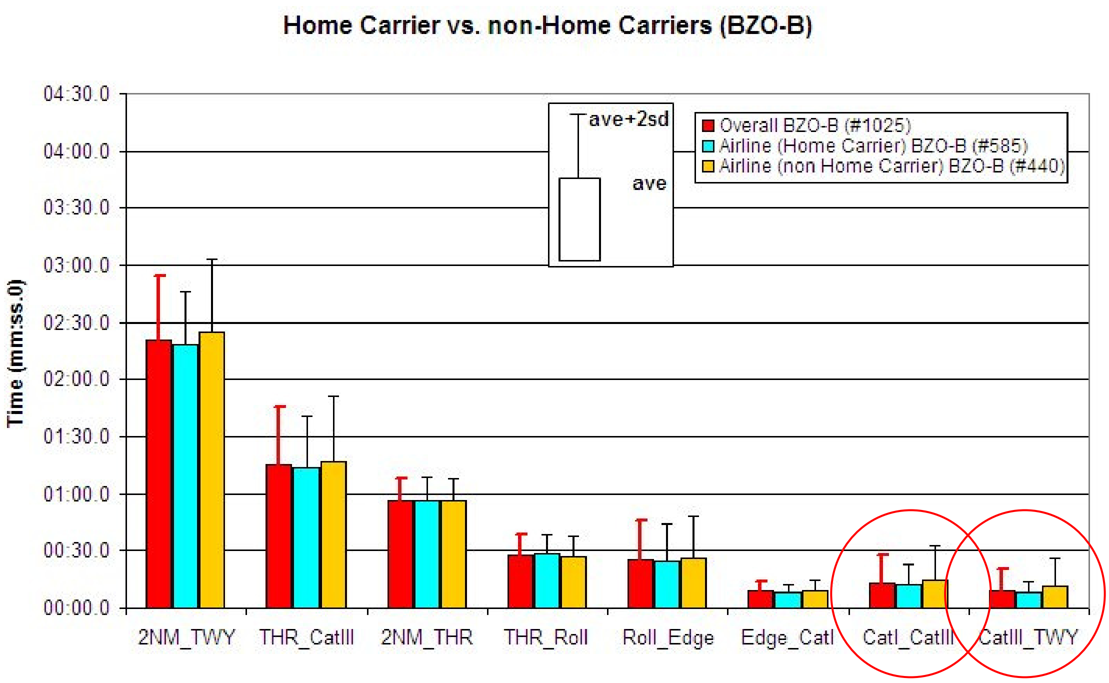


Figure 3-11: ROT Analysis Results Home vs. Non-home Carrier in BZO-B

3.8.4 Pros and Cons

Neither from the point of operations nor from the point of costs does this measure seem to have any negative effects. This means that it can be implemented easily and it is assumed that it has a positive effect on runway occupancy times once pilots are properly educated about the meaning of the lights (see also Measure 3). Currently, the safety case for extending the lighting until the centre of taxiway B has been investigated and presented to the ministry. If the previously mentioned planning is agreed upon, it should be possible to start exchanging the lighting by the beginning of 2011.

3.8.5 Conclusion

The measure will be carried out by Schiphol (AAS) in the near future as no negative effects on operations or costs are expected and the measure is assumed to reduce runway occupancy time and improving the handover process, or rather the transition from the runway onto the taxiway system.

3.8.6 Recommendation

Schiphol (AAS) is encouraged to initiate this measure together with Measure 3 to improve the handover process and expedite the vacating of the runway thereby reducing the runway occupancy time. Schiphol (AAS) has already made plans to initiate the measure.

3.9 M9: Apply Rapid Exit Taxiway Indicator Lights (RETILs)

3.9.1 Aim of Measure

The purpose of RETILs is to provide pilots with distance-to-go information to the nearest Rapid Exit Taxiway (RET) on the runway (Ref. [ICAO Annex 14], §5.3.14).

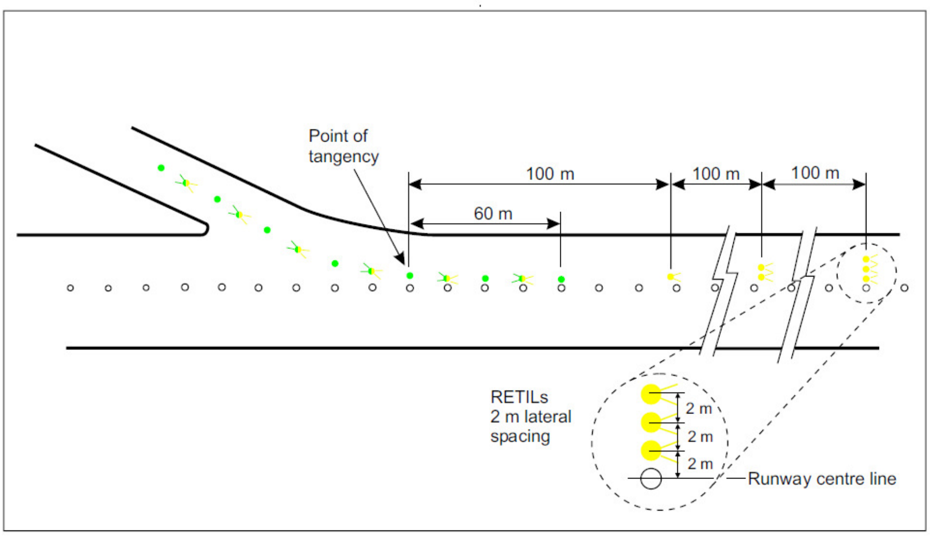


Figure 5-23. Rapid exit taxiway indicator lights (RETILS)

Figure 3-12: RETILs as Described in ICAO Reference Documentation

RETILs can enhance the situational awareness in low visibility conditions and enable pilots to apply braking action for more efficient roll-out and runway exit speeds. By reducing the probability that an aircraft "misses" the runway exit, the ROT can be significantly reduced. This in turn increases the runway capacity.

3.9.2 Applicable Phases

Applicable phases are BZO-B/C/D.

3.9.3 Analysis

RETILs have been implemented at some European airports including Prague and London Gatwick.

Prague Airport
In the context of the Eurocontrol Airport airside Capacity Enhancement (ACE) Methodology, RETILs have been installed at exits D and L of Runway 06/24.

Gatwick Airport (Ref. [AIP-UK], AD2-EGKK-1–1, 11-Feb-2010)
Rapid exit from the runway enables ATC to apply minimum spacing on final approach that will achieve maximum runway utilisation and will minimise the occurrence of go-arounds. Additional paint markings are provided on Runway 08R and 26L to assist pilots in judging distances to Rapid Exit Taxiways. Markings will be provided for the first and second 08R and 26L Rapid Exit Taxiways only and will consist of 3 sets of count-down markings placed at 300m, 200m and 100m from the intersection of the runway centreline with the RET centreline.

In addition, the preferred exit points for Runway 26L are published (Medium/Heavy aircraft via Rapid Exit Taxiway FR and Light/Small aircraft via Rapid Exit Taxiway E). Also aircraft are instructed not to stop on any Rapid Exit Taxiway awaiting instructions from Ground Movement Control. Similar statements could be included in the ILS SA/ROT awareness campaign (see Measure 3).

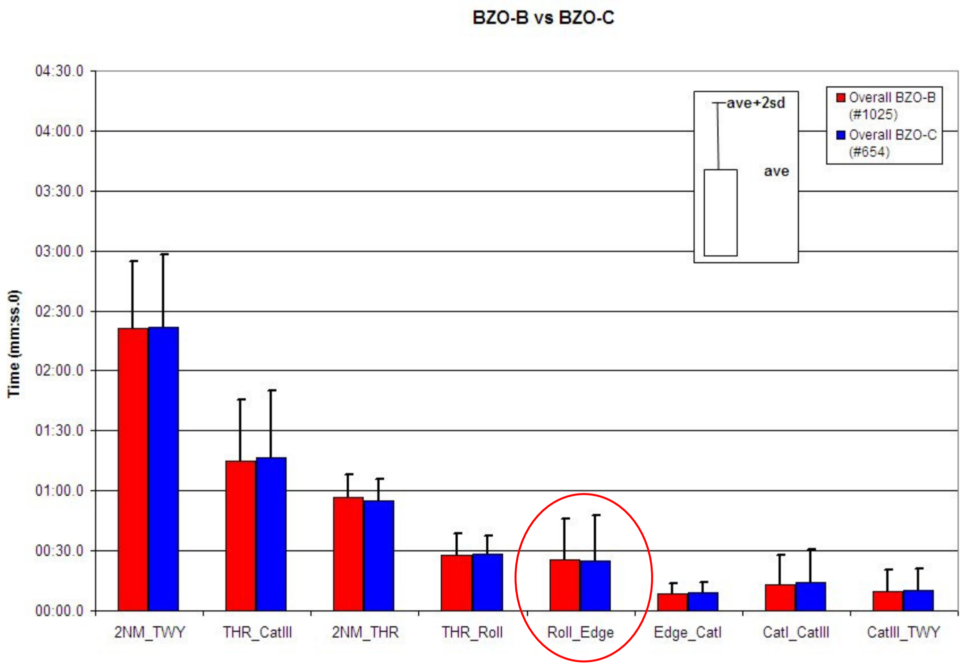


Figure 3-13: ROT Analysis Results for BZO-B and BZO-C

For the ROT analysis performed at Schiphol Airport the parameter Roll_Edge shows a large dispersion during BZO B/C and may be an indicator that RETILs can aid in anticipating an exit, thereby reducing the ROT.

A more detailed look at different runways in Figure 3-14 shows a particular effect for RWY18R.

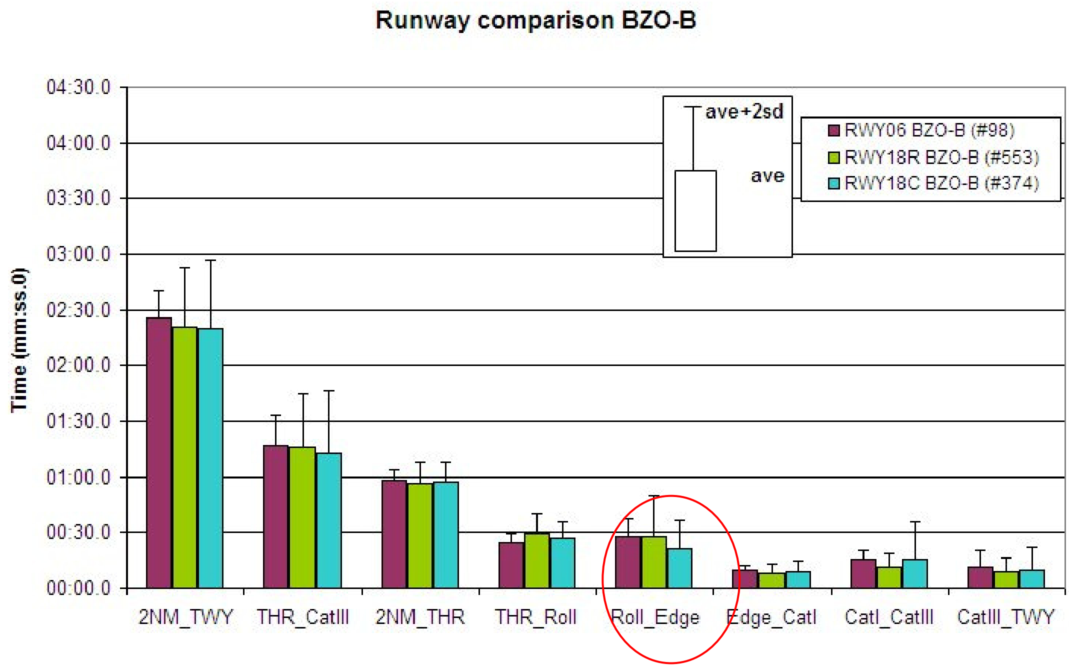


Figure 3-14: ROT Analysis Results for RWYs 06/18R/18C in BZO-B

The data set for RWY06 is much smaller than for the other two runways because RWY06 was not used much during BZO-B/C. It appears that RWY06 exhibits the smallest time needed during BZO-B to traverse from the 2 NM threshold to the taxiway.

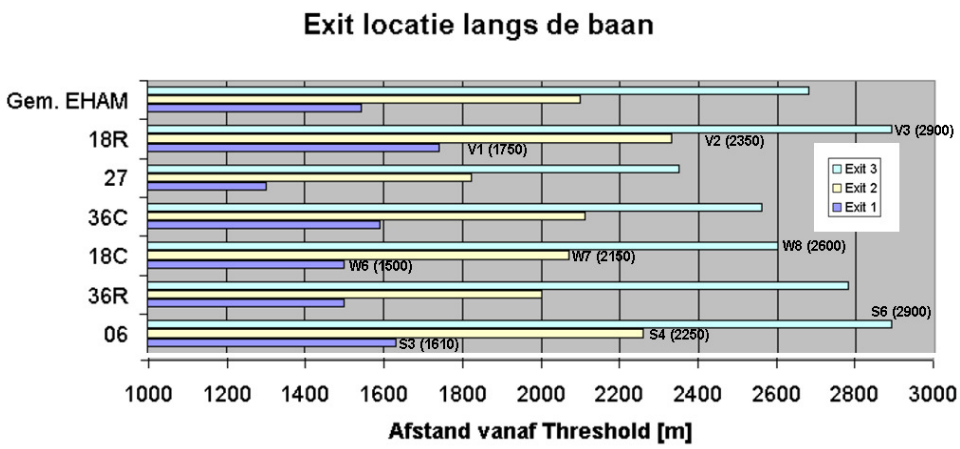


Figure 3-15: Exit Locations for Runways

Runway 18R has its first two exits further away from the threshold than RWY18C and RWY06 and this may contribute to the larger "Roll Edge" figures seen for RWY18R.

During BZO-B/C the following exits were used:

Table 3-3: Runway Exit Usage for Runways 18R/18C/06

Exit	BZO-B	BZO-C
V1	51 %	49 %
V2	36 %	43 %
V3	13 %	8 %
W6	47 %	45 %
W7	48 %	53 %
W8	5 %	2 %
S3	30 %	Not enough data
S4	57 %	
S6	13 %	

The data suggest that during BZO-C more aircraft use V2. This could be caused by the fact that V1 could not be timely anticipated by the pilot.
Assuming a taxi speed of 40 kts during BZO-B then the segment V1 to V2 would take approx. 30 seconds. In order to aid the pilot in anticipating exit V1, the application of RETILs could be beneficial.

Also V3 is used frequently during BZO-B. This exit was used by medium (28 aircraft) and heavy aircraft (18 aircraft) during the analysis period. V3 is obviously preferred by airlines because it directly leads to taxiway Victor and saves making an extra turn. It is likely that V3 was used during low traffic levels where capacity is not an issue.

3.9.4 Pros and Cons

Benefits:

1. Reduction of ROT and increase in runway capacity is expected, however, it could not be quantified at this stage. Based on the ROT analysis, when exit V1 instead of V2 is used, this would save approx. 30 seconds.
2. Experience at London Gatwick has shown that RETILs serve their purpose. As is stated in the replies to comments by member states on the recommendations of the fourteenth meeting of the Visual Aids Panel for ICAO Annex 14 (AN-WP/7880): "The RETILs are now in operational use at Gatwick. The main purpose of the use of RETILs is to provide useful indications for roll-out in low visibility conditions, thus decreasing aircraft runway occupancy times. Meanwhile, it has been advised that the trials in the UK have shown

the added safety benefits of RETILs in low visibility conditions as well as at other times, helping pilots to determine the distance to a rapid exit taxiway."
3. Can be implemented prior to 2012.

Drawbacks:
1. Infrastructural (runway lighting) investment required (comparable to earlier mentioned RET edge lighting, yet, probably even more expensive due to capacity shortfall during construction).
2. Amendment AIP and, potentially, revised ATC procedures required depending on the way RETILs are combined with expected runway exits for aircraft types.

3.9.5 Conclusion
RETILs have the potential to reduce the ROT.

3.9.6 Recommendation
Perform a more detailed cost-benefit analysis for installing RETILs on runway 18R. Assess the feasibility of vacating the runway at the expected exits during BZO-B and BZO-C to reduce ROT.

3.10 M10: Reduce Impact of ILS SA

3.10.1 Aim of Measure
Document [Optimisation ILS SA] has shown that with the currently used antennas, the actual shape of the ILS sensitive area is somewhat smaller near the localizer antenna than the rectangular shape that is used as a reference over the whole area of the runway. Using a different antenna (Watts Model 201) the shape would be the same but its size would be even smaller. This means that there would be an operational measure to reduce the sensitive area on exits in the vicinity of the localizer antenna (runway end) either with minimal changes to the infrastructure (runway holding positions) or with extensive changes to the infrastructure (new localizer antennas and runway holding positions). In both cases runway occupancy time would be reduced, in the second case somewhat more than in the first case.

3.10.2 Applicable Phases
CAT III conditions will certainly profit the most from a reduction of the ILS sensitive area. Above that, it is questionable whether the difference between shapes in CAT I is large enough to be of any operational meaning to the controller. Thus, BZO-B and BZO-C are again the applicable phases.

3.10.3 Analysis
Analysis of this measure mainly focussed on controller feedback regarding the operational consequences of reducing the ILS sensitive area at certain exits. Except for having to address changes in the markings and/or the antennas the controller would need to be able to clearly identify when the aircraft has actually vacated the ILS sensitive area. This means that by looking on the radar or traffic situation display, the runway controller should be able to quickly verify that the ILS sensitive area is completely vacated and free for the next landing aircraft. During interviews, however, controllers argued that it would be difficult to judge from either surface movement radar or MLAT positions whether the aircraft completely left the ILS sensitive area when still on the exit. This means that controllers usually

only accept that the ILS sensitive area is free once an aircraft has entered the taxiway. This operational difficulty would thus mean that any improvement regarding the shape of the ILS sensitive area would have to be larger than a rather small shift on the runway exit.

The costs of new antennas were not addressed in the mentioned investigations, but LVNL performed a study on ILS improvements in 2008 that indicated that the cost for installation alone would amount to €300,000-400,000 (depending on the configuration). It is therefore assumed that equipment costs might amount to about half a million Euros per ILS installation including training and certification aspects.
Further, study [Landing Capacity] looked at the differences between the currently used rectangular shape and a fishtail shape of 150m and 120m respectively. In BZO-C this led to a theoretical improvement of 2 (150m) and 3 (120m) aircraft movements per hour.

Tabel6: Resultaten van gereduceerde ILS SA grootte (gebaseerd op alle banen):

Totale Tijd ILS CatIII Operatie (tijd / **capaciteit**)	ILS CatIII tijd	Baancapaciteit
Huidige operatie	3m15sec	**18.4/hr**
Rechthoekige SA (zonder pieken)	3m06sec	**19.3/hr**
Fishtail (150m brede SA)	2m57sec	**20.3/hr**
Fishtail (120m brede SA = OFZ)	2m46sec	**21.6/hr**

This improvement could only be achieved when controllers were able to exactly determine whether the aircraft has left the fishtail areas of which the dimension varies per runway exit. Therefore, it is expected that the operational result will be less relevant.

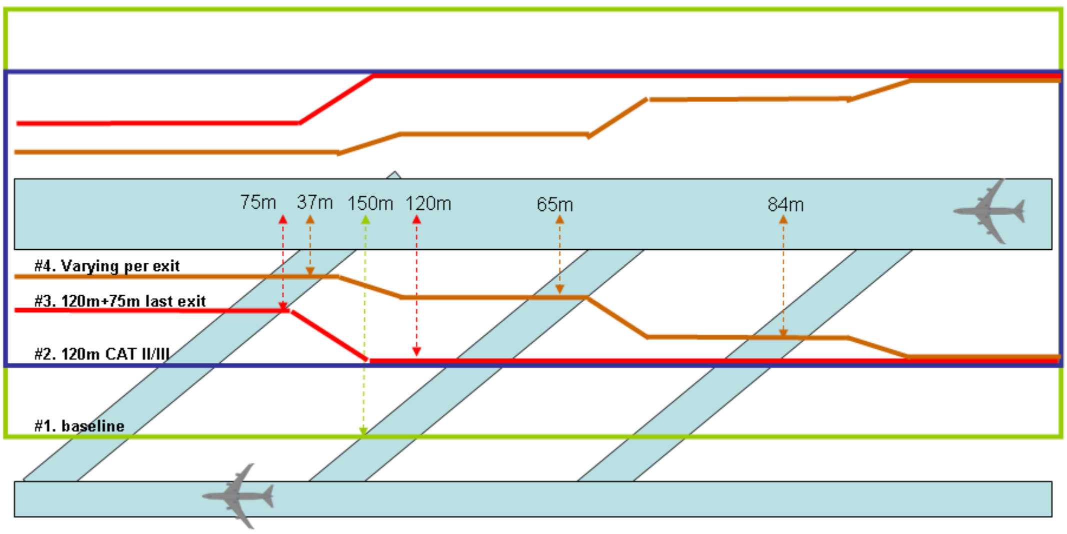
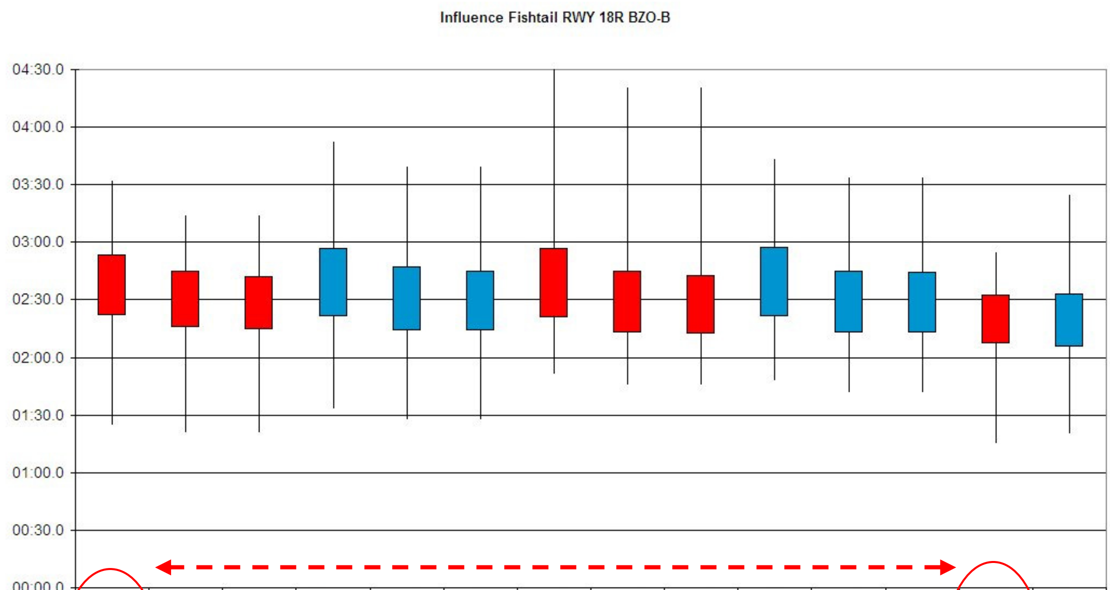


Figure 3-16: Analysis of Different ILS Shapes with ROT Analysis Data

Using the ROT analysis, three alternative shapes of the ILS SA were projected on the actual ROT data for runway 18R/18C to ascertain the potential reduction in the time needed to vacate the ILS SA.

1. No Fishtail, Cat II/III op 150m (baseline situation)
2. Cat II/III op 120m
3. Cat II/III op 120m and Cat II/III for runway 18R-V3 en 18C-W8 at 75m
4. Tapered ILS SA using a Watts antenna: for RWY18R: Cat II/III SA V1(84m), V2 (65m) and V3 (37m)

Figure 3-17compares the three alternative shapes with the current dimension of the ILS SA.



	RWY18R BZO-B No Fishtail	RWY18R BZO-B Cat III 120m	RWY18R BZO-B Cat III 120m + FT	RWY18R BZO-C No Fishtail	RWY18R BZO-C Cat III 120m	RWY18R BZO-C Cat III 120m + FT	RWY18C BZO-B No Fishtail	RWY18C BZO-B Cat III 120m	RWY18C BZO-B Cat III 120m + FT	RWY18C BZO-C No Fishtail	RWY18C BZO-C Cat III 120m	RWY18C BZO-C Cat III 120m + FT	RWY18R BZO-B FT Watt	RWY18R BZO-C FT Watt
Average	02:21.9	02:15.4	02:14.5	02:21.3	02:14.1	02:13.6	02:20.5	02:12.9	02:12.2	02:21.1	02:12.9	02:12.5	02:07.3	02:05.4
Min	01:25.0	01:20.5	01:20.5	01:33.0	01:27.8	01:27.8	01:51.0	01:45.9	01:45.9	01:47.9	01:41.9	01:41.9	01:15.2	01:20.4
Max	03:32.0	03:14.0	03:14.0	03:52.0	03:39.3	03:39.3	04:35.9	04:20.2	04:20.2	03:43.0	03:33.2	03:33.2	02:54.3	03:24.6
Ave+2SD	02:53.2	02:44.8	02:42.4	02:56.9	02:47.0	02:45.0	02:56.6	02:44.8	02:42.9	02:57.3	02:45.2	02:44.4	02:32.7	02:33.1

#1 #2 #3 #4

Figure 3-17: Results of Analysis of Different ILS Shapes at RWYs 18C/R

The maximum benefit would be achieved with a Watts antenna (#4) that uses a tapered ILS SA. This would shorten the overall time needed to vacate the runway for runway 18R with approximately 20 and 24 seconds during BZO-B and BZO-C respectively. A drawback is that the RC has to assess for each of the three possible exits whether an aircraft has passed the ILS SA which varies for each exit.

3.10.4 Pros and Cons

On the positive side, a smaller ILS sensitive area would contribute to a reduced time to vacate the runway. However, such a measure would have to overcome operational difficulties regarding the detection of the aircraft vacating the area and infrastructural changes regarding the changes in runway holding point markings (possibly including stop bars) and/or new antennas. Using a different antenna has many implications. Apart from the antenna model chosen, it needs to be decided what kind of transmitter can be used. Maintenance training and costs is another issue.

Additionally, for the operation the installation of a new antenna would mean that the runway could not be used as CAT III again right away. A successful completion of a demonstration phase is required and may take up to one year to demonstrate compliance with standards regarding to reliability, accuracy, integrity and continuity. Finally, the costs of the antenna units would amount to roughly €400,000 each.

3.10.5 Conclusion

Considering all abovementioned difficulties it seems that the measure has a low priority as opposed to more easily implementable measures such as Measure 3 and Measure 8 that are trying to address the same operational problem (leaving the ILS sensitive area as quickly as possible).

3.10.6 Recommendation

Given the relatively high costs of changing or implementing and evaluating infrastructure elements and the operational difficulties to exactly determine whether an aircraft has vacated a differently shaped ILS sensitive area, it is recommended to give a lower priority to this measure. Although a theoretical maximum benefit of 3 aircraft movements in BZO-C could be shown, it is questionable whether such a benefit could be obtained in real operations.

In order to exactly determine the consequences, operational exercises would have to be carried out presenting controllers with differently shaped ILS sensitive areas and determining the actual maximum number of movements per hour that could be achieved given the problems in detection under BZO-B and BZO-C conditions.

3.11 M11: Reduce Spacing on Final for BZO-B and BZO-C

3.11.1 Aim of Measure

The current spacing on final is 6 NM during BZO-B and 8 NM during BZO-C. The spacing is needed to cater for the increased ROT and time needed to vacate the runway. This is mainly caused by more intensive working procedures for the pilot and ATC and includes SMR handovers by ATC, additional and/or longer R/T, less visual cues for pilot, higher probability that an exit could not be anticipated by a pilot, reduced taxi speeds and confusion when a runway exit has two directions.

In order to reduce the spacing, all previously described measures need to be considered. This is done in the analysis section.

3.11.2 Applicable Phases

The measure initially applies to BZO-B (6NM spacing on final).
However, the analysis is also performed for BZO-C as data for this phase was also available and results can be used to reassess the current spacing on final during BZO-C.

3.11.3 Analysis

The time during BZO-B and BZO-C that aircraft need to cover the distance from 2 NM before the runway threshold to entering the taxiway (2NM_TWY) is shown below. The bars represent the average value but statistically one should consider the lines above the bars. These lines correspond to 97.7% of all data (considering a normal distribution around the average value). It can be seen that the 2NM_TWY times for BZO-B and BZO-C do not differ significantly.

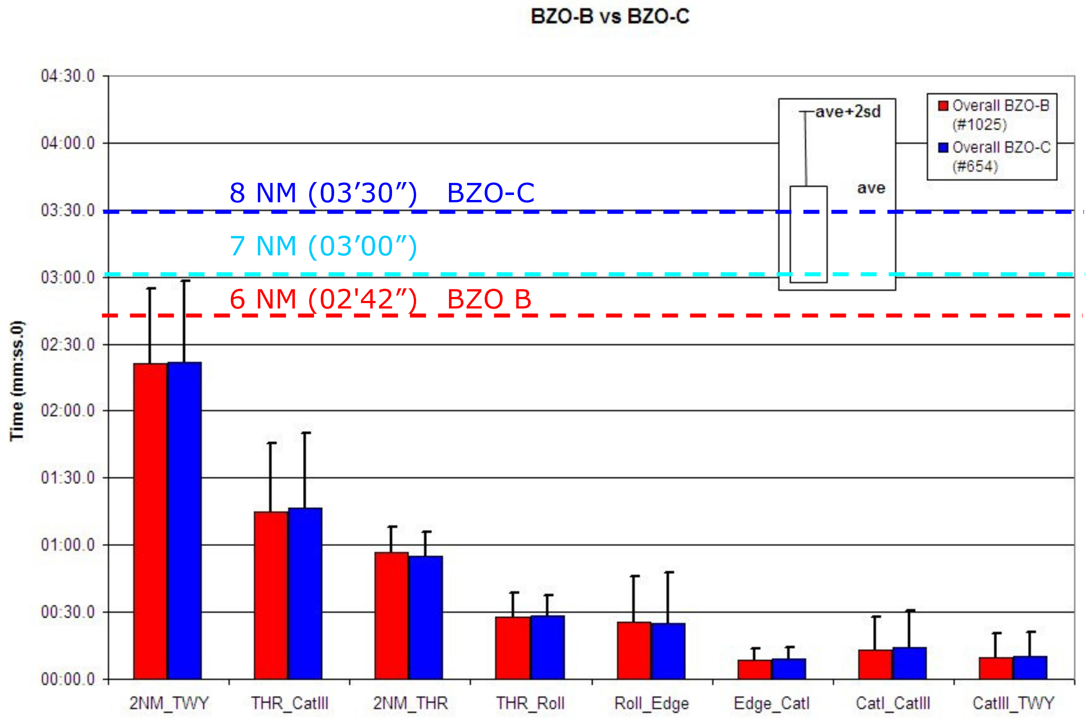


Figure 3-18: ROT Analysis Results for BZO-B and BZO-C

One may argue that the applied spacing during BZO-C (8 NM) appears to be too strict. This is also confirmed when reviewing the applied separation minima at e.g. Paris Charles-de-Gaulle and London Heathrow.

Table 3-4: Applied Spacing during LVC at Other European Airports (in NM)

Airport (2004)	ILS-CAT I	ILS-CAT II	ILS-CAT IIIa	ILS-CAT IIIb
Paris Charles de Gaulle	2,5-3	6	6	6
Frankfurt	2.5-3	6	8	8
London Heathrow	2.5-3	6	6	6
Amsterdam	3	6	8	9
Madrid Barajas	3	6	6	n/a
Munich	3	6	6	6
Rome Fiumicino	3-5	Not specified	Not available	Not available
Barcelona	4	16	16	16
Zurich	3	6	6	6
Vienna	2.5	5	5-7	5-7
Milan Malpensa	3	8	10	15

N.B.: CAT I corresponds with BZO-A, CAT II with BZO-B, and CAT IIIa with BZO-C.

A more detailed insight into the characteristics of cases that do not occur often, i.e. the remaining 3.6%, can be obtained by constructing a cumulative distribution.

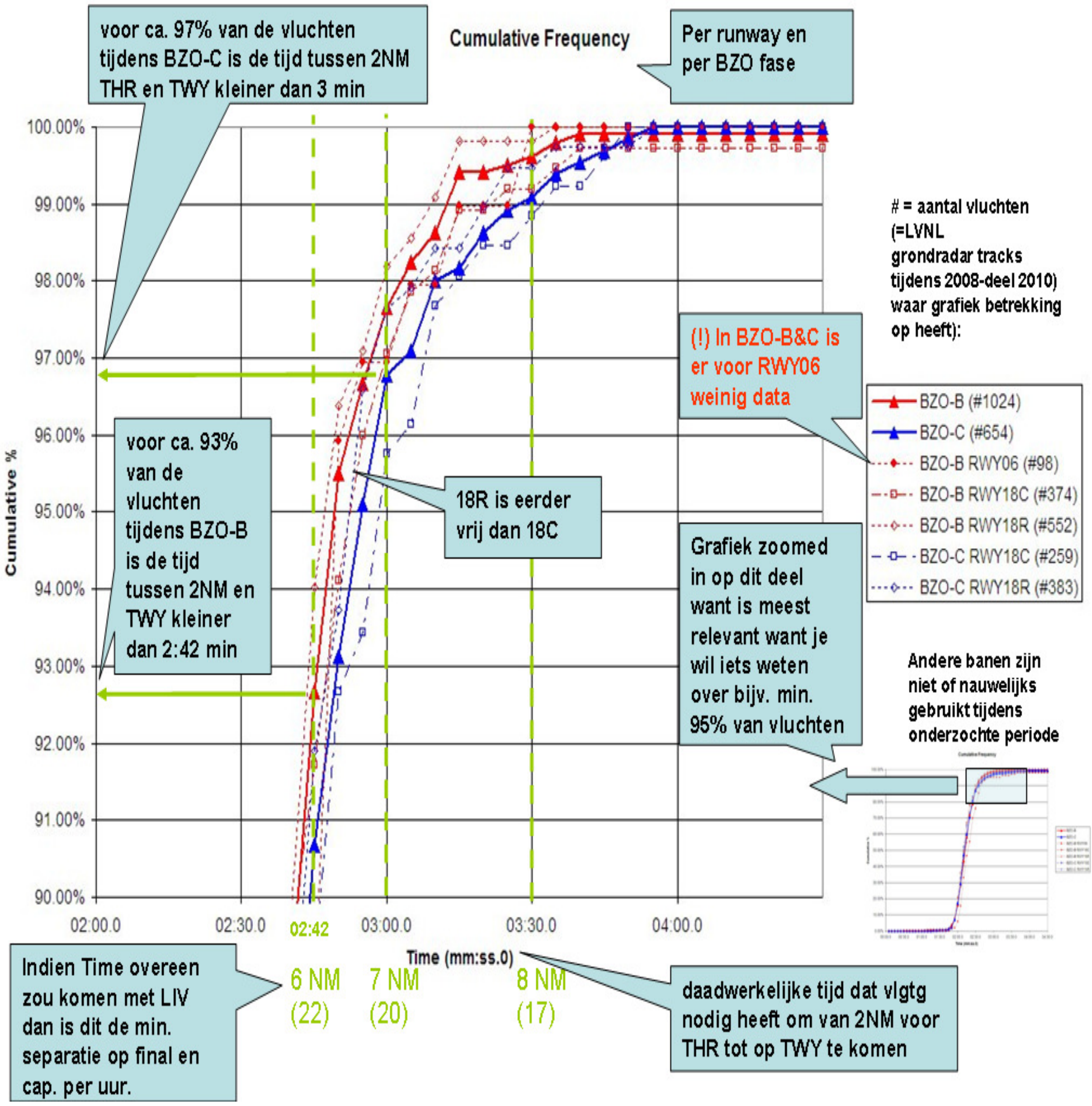


Figure 3-19: Cumulative Distribution of ROT Results per RWY and BZO

In the following graphs the total BZO-B and BZO-C times are calculated according to wake turbulence category and home and non-home carrier.

Wake turbulence category

Figure 3-20 shows the ROT for medium and heavy aircraft. Even the majority of heavy aircraft (min. 93%) need less than 3 minutes during BZO-C to traverse from 2NM threshold to the TWY.

The number of movements that need more than 3 minutes to vacate the runway (e.g. 3%, 7%, or any other number) which is acceptable to ATC needs to be evaluated internally at LVNL. In the current situation approx. 7% of flights need more than 6 NM spacing during BZO-B.

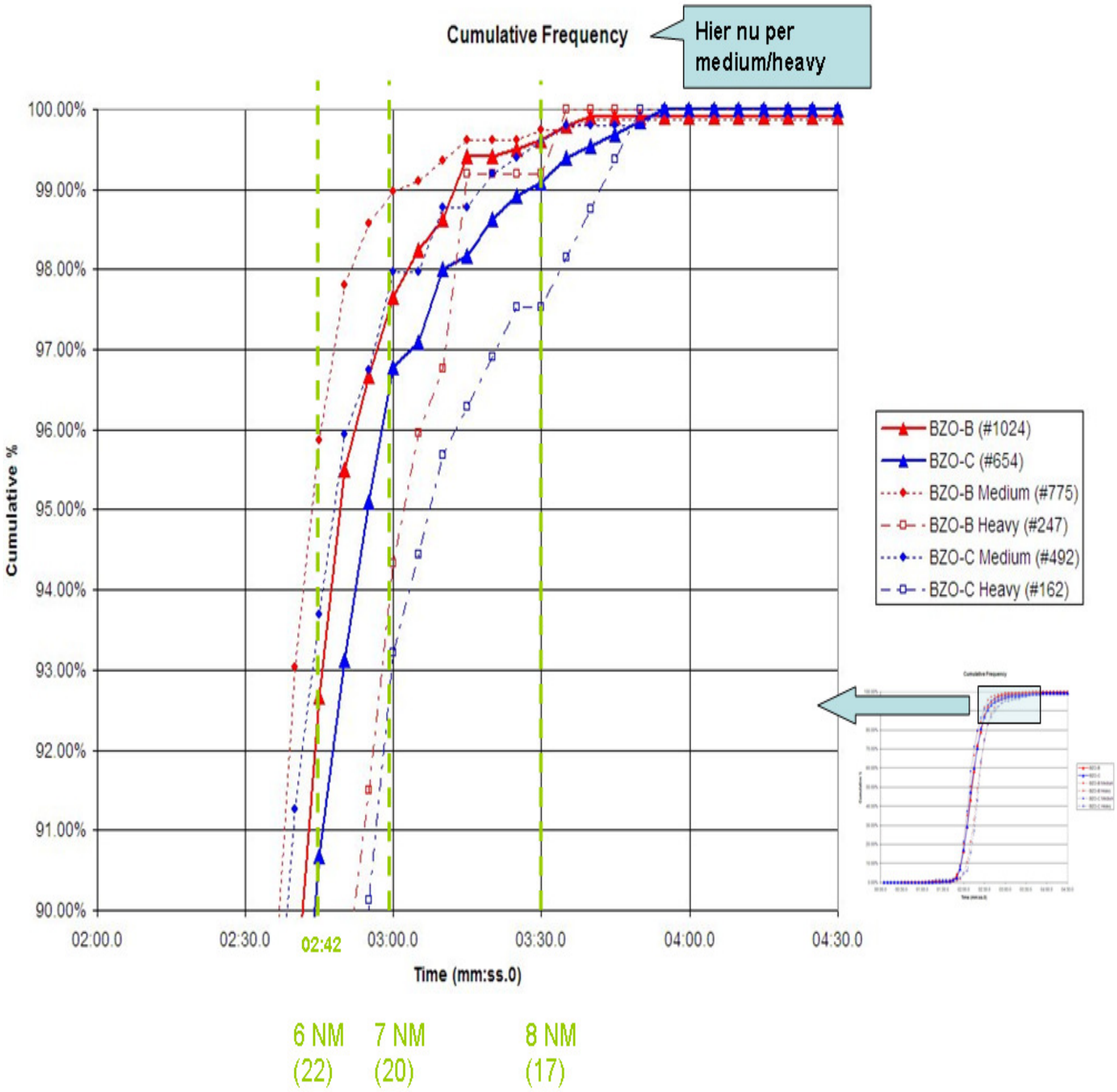
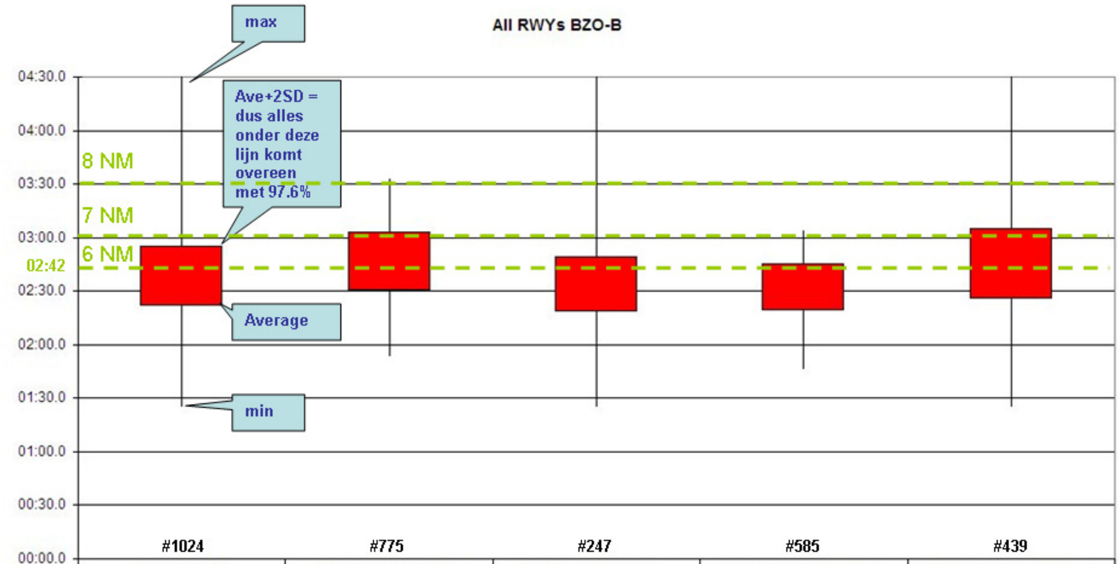


Figure 3-20: Cumulative Distribution of ROT Results per A/C Category

Home vs. non-home carrier

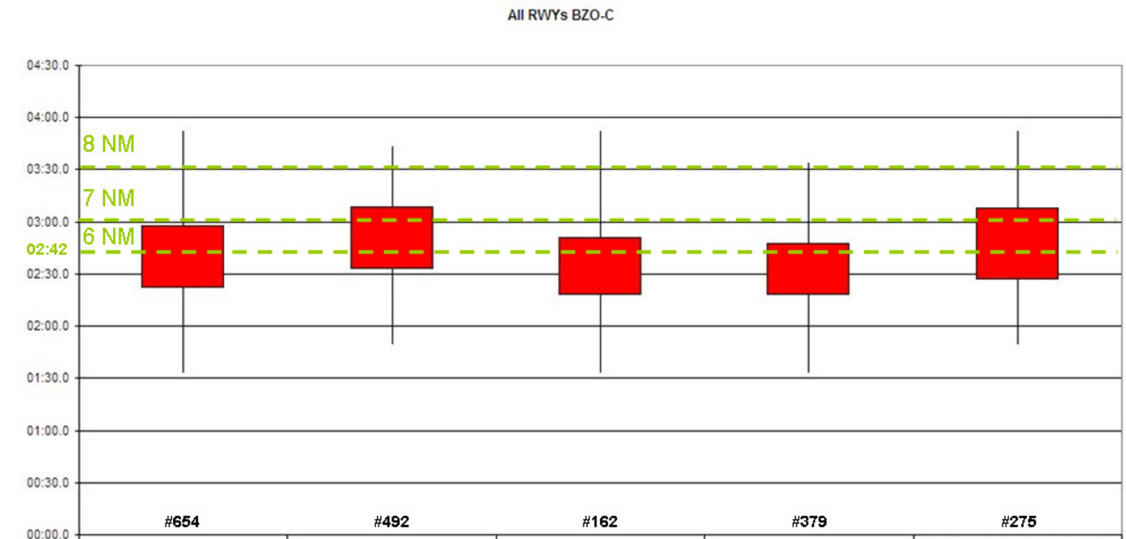
As already observed earlier, it is clear that non-home carriers (non-KLM) require more time (approx. 20 sec.) to vacate the runway during BZO-B and BZO-C than the home carrier[14] (KLM).

[14] Non-home carrier also includes TRA/MPH aircraft but removing them from the dataset does not have a significant effect on the non-home carrier results.



	All RWYs BZO-B	All RWYs BZO-B Heavies	All RWYs BZO-B Mediums	All RWYs BZO-B Home Carrier	All RWYs BZO-B Non-home carrier
Average	02:21.8	02:30.1	02:18.6	02:18.9	02:25.5
Min	01:25.0	01:53.0	01:25.0	01:46.0	01:25.0
Max	04:35.9	03:32.9	04:35.9	03:03.9	04:35.9
Ave+2SD	02:55.1	03:03.4	02:49.2	02:45.1	03:04.8

Figure 3-21: ROT Analysis Results for Different Categories in BZO-B



	All RWYs BZO-C	All RWYs BZO-C Heavies	All RWYs BZO-C Mediums	All RWYs BZO-C Home Carrier	All RWYs BZO-C Non-Home Carriers
Average	02:21.5	02:32.6	02:17.6	02:17.7	02:26.6
Min	01:33.0	01:49.0	01:33.0	01:33.0	01:49.0
Max	03:52.0	03:43.0	03:52.0	03:34.0	03:52.0
Ave+2SD	02:57.8	03:08.4	02:50.7	02:47.3	03:08.1

Vergelijking BZO-C met BZO-B (vorige slide) laat zien dat er nauwelijks verschil is.

Figure 3-22: ROT Analysis Results for Different Categories in BZO-C

The potential for reducing the ROT and reducing the time needed to vacate the ILS SA is determined by individual measures listed in the table below. The expected gain is also listed and these figures are based on comparing the various ROT graphs. No distinction is made between BZO-B and BZO-C in this table because ROT graphs exhibit similar characteristics.

Table 3-5: Potential Gain per Measure

ID	Measure	Consider for Implementation	Gain (sec.)
M3	ILS SA awareness campaign	☺	10-20
M6	Standard routes and no auto QSY[15]	☹	-
M7+ M8	Reduce complexity of exits within ILS SA & Extend yellow-green centreline	☺	10-20
M9	Apply RETILs	☺	15-30
M10	Reduce impact of ILS SA	☹	-

It is likely that one or more of the above measures are able to structurally reduce the ROT and/or time to vacate the ILS SA with at least 10-35 seconds.
The current maximum RWY capacity during BZO-B is 22 aircraft per hour which corresponds with a landing interval (LIV) of 2’42”. If the LIV could be reduced to e.g. 2’22” and a separation of 5 NM instead of 6 NM is possible, then the landing capacity increases from 22 to 25 aircraft per hour.

Table 3-6: Separation Table (from ATC Service Regulations - LVNL VDV)

Separation (NM)	Landing interval, LIV (Minutes)	Capacity (A/C per Hour)
3	1.8	33
4	2.0	30
5	2.5	24
6	2.7	22
7	3.0	20
8	3.5	17
9	3.7	16
10	4.0	15
12	5.0	12
14	6.0	10

[15] It should be considered, though, that an LVNL Training Bulletin will address the issue of additional runway controller instructions instead of “no Auto-QSY”.

From the ROT graphs it appears that for BZO-C, and without implementation of any ROT reducing measure, the separation on final could be reduced from 8 NM to 7 NM. It is, however, advised to implement one or more of the previous measures shown above to reduce the probability that non-home carriers require more time to vacate the runway and thereby increase the landing interval.

3.11.4 Pros and Cons

Benefits:

1. BZO-B: In case 20 seconds can be structurally reduced from the ROT and the time to vacate the ILS SA by means of one or two of the presented measures, a reduction of the separation from 6 to 5 NM can be considered.
2. BZO-C: The ROT data supports a reduced spacing from 8 to 7 NM which would increase the landing capacity from 17 to 20 per runway. This would bring the total inbound capacity (2+1 runway-use) to 40 aircraft (instead of 34) per hour.

Drawbacks:

1. Evaluation of the percentage of aircraft acceptable to ATC that may need a longer landing interval.
2. Revision of ATC working procedures (VDV) and training.

3.11.5 Conclusion

Implementation of the measures (ILS SA awareness campaign, reduce complexity exits and extend yellow-green centreline) is expected to reduce the ROT and vacating the ILS SA with at least 10-35 seconds. This means that spacing could be reduced, if the landing interval during BZO-B can be reduced by about 20 seconds.

More benefit, however, is expected from reducing the spacing in BZO-C to e.g. 7 NM.

3.11.6 Recommendation

It is recommended to focus on improving sustainability during BZO-C since benefits are larger and are likely to be accomplished more easily than for BZO-B.
Within LVNL the process of considering a reduced separation during BZO-C is already ongoing. Data presented in this study should be used to explore possibilities as there is strong evidence that a reduction is feasible. Feasibility also depends on the number of movements that need more than 3 minutes between 2NM from THR to vacating the runway (3%, 7%, or any other number) which is acceptable to ATC. This figure needs to be evaluated internally at LVNL.
ROT data suggest that additional measures are not a prerequisite for reducing the spacing during BZO-C. It is, however, recommended to implement the most promising ones (i.e. ILS SA awareness campaign, reduce complexity exits and extend yellow-green centreline) in order to reduce the probability that aircraft need extra attention from RC/GC.

To be able to reduce spacing during BZO-B, one or more of the presented measures are a prerequisite. Depending on the outcome of the LVNL internal evaluation on how to proceed during BZO-C, a decision can be made regarding BZO-B as it is expected that changes for phases BZO-B and BZO-C will be implemented simultaneously for reasons of safety and training.

4 Conclusions and Recommendations

From a ground control perspective, measures to improve efficiency that could be accomplished before 2012 could only consider a change in operation in the control tower with the current set of controller tools. The scope of new tools that are expected to increase efficiency is beyond 2012 and concerns planning tools such as Departure and Surface Managers, Electronic Flight Strips and related safety nets or virtual block control, the latter also being considered unsuited for Schiphol Airport. All other existing measures are not only technically out of the scope of this study but are also beyond the scope of 2012 and concern changes to cockpit systems and, inevitably, changes in the way of delegating responsibility between ATC and the cockpit crew.
For ground control, or rather taxiway guidance, this leaves us with one measure that is easily implementable, namely modifications in signage in critical areas, such as the transition from taxiway Q to junction A27. Still, additional research should investigate whether there are more areas that are apt for improvement and analyse the best solutions.
Three other measures are considered easily implementable which are all related to runway occupancy and therefore landing capacity. These are an extension of the yellow-green alternate centre line lighting indicating the ILS Sensitive Area until the aircraft has clearly left the area (meaning until it has reached the centre of a parallel taxiway), a campaign for ILS Sensitive Area awareness including awareness regarding the yellow-green centre line lighting, and finally a training bulletin addressing additional runway controller instructions that eliminate the need for not using Auto-QSY in BZO-B and worse conditions.

Generally, the time needed to travel towards a runway exit and the time needed to vacate the ILS SA show a relatively large range of values. Measures that can reduce these times are expected to result in lower ROT values and lower ILS SA vacating times, thereby leading to a higher runway throughput and possibly lower separation standards and higher runway capacity. Apart from abovementioned easily implementable measures regarding awareness campaigns and ILS SA lighting, there are several additional measures which are more challenging and more difficult to implement. They concern a revision of difficult exits (such as W7 and N4 which offer two possibilities for entering taxiway B) and a consequential change in operations, the implementation of RET indicator lights helping the pilot identify high-speed exits in time to safely vacate the runway, and changes in ILS technology. Needless to say that all mentioned measures may result in large infrastructure reconstruction efforts.
Another more challenging measure that considers ground control would be the deployment of a third ground controller in BZO-A and BZO-C, the two phases that show ground capacity limitations. Apart from logistical aspects, operational issues would have to be sorted out before such a measure could be implemented. Therefore, research in the form of real-time simulations and a cost-benefit analysis is recommended.

The earlier mentioned training bulletin for runway controllers would eliminate the need to abolish Auto-QSY from BZO-B on, so this measure was discarded. The same goes for the use of standard taxi routing. Apart from the fact that it is questionable whether the measure will have a large effect as most routing is already standard, there is also no clear idea yet on how to apply this operationally without reducing flexibility for the controller. One possibility would be to prioritise

inbound traffic on standard routes. The impact of such an operational change could be assessed in fast-time and real-time simulations.
As to the use of 2+1 runway combinations in off-peak no clear indication of the deeper causes of a capacity shortfall in marginal conditions with 1+1 runway usage could be found. Essentially, the data available was not sufficient to draw any conclusions as to the gravity of the effect, nor were there any comments from controllers supporting that assumption. Finally, a change in marginal visibility criteria was also discarded as it was deemed that the effect was too small to outweigh any related operational or safety issues.

Recently a new proposal for the noise enforcement system for Schiphol was published. One of the measures proposed to reduce noise hindrance is to apply *idle reverse thrust* during wheel braking. This way of decelerating results in larger landing distances which in turn leads to longer ROTs. It is therefore recommended to refrain from using this braking method during BZO-B and BZO-C (and wet runways) as it increases the ROT.

Feasibility/Costs/Benefits
The following table gives an overview over feasibility of the measures and their expected costs and benefits:

ID	Measure	VC	Feasibility	Costs	Benefits	Result
M1	Modify Cloud Base and Visibility Criteria for Marginal Visibility	M	Safety issues	Not assessed	Unverifiable	Dismissed (no benefits expected)
M2	2+1 Runway Usage during Off-peak	M	Inconclusive data	Not assessed	Unverifiable	Dismissed (off-peak problem unclear)
M3	Awareness Campaign for ILS Sensitive Area	A (B, C)	Available before 2012 and easy to implement	Very low (several hundred Euros)	10-20 seconds of ROT	Implemented
M4	Simplification of Ground and Runway Signage	A (B, C)	Available before 2012 and easy to implement	Thousands to ten-thousands of Euros	Not assessed	Start initiative for re-evaluation of signage
M5	Introduce Third Ground Controller	A (B, C)	Probably available before 2012 but requires changes in operation and systems	Not assessed but requires changes in i/s and systems as well as training	Not assessed but expectation to increase overall GND capacity and safety	Perform RTS and CBA
M6	Apply Standard Taxi Routes and	B (C)	Available before 2012 and easy to	Not assessed but training	Unverifiable	Solutions to problems are already

	No Auto-QSY		implement but potential safety issues	costs are expected		implemented; procedures for standard routing could be improved (additional research)
M7	Reduce Complexity of Exits within SA	B (C)	Available before 2012 and easy to implement	Per exit: between 1500 and 200,000 Euros (paint/ remove/ lighting)	15-20 seconds of ROT	Decommission W7 left-hand turn and re-evaluate N2, N3, N4 before using RWY27 in BZO-B or worse
M8	Extended Yellow-Green Centreline	B (C)	Available before 2012 and easy to implement	Not assessed but expected to be in the order of thousands of Euros for exchanging filters for one runway	15-20 seconds of ROT	Implemented
M9	Apply Rapid Exit Taxiway Indicator Lights (RETIL)	B (C)	Available before 2012	Not assessed but expected to be high because of changes to i/s	15-30 seconds of ROT	Experience at Gatwick supports use but i/s costs high; perform CBA for RWY 18R
M10	Reduce Impact of ILS SA	B (C)	Probably available before 2012 but requires changes in i/s and disturbs operation	About 500,000 Euros per antenna	Unverifiable because of operational implications	Dismissed
M11	Reduce Spacing on Final for BZO-B and BZO-C	B, C	Sum of different improvement steps feasible before 2012	Sum of all measures	Tentatively reduction from 6 to 5 NM in BZO-B and from 8 to 7 NM in BZO-C	Implement M3, M7, M8 and changes to BZO-C without measures

All these mentioned considerations lead to the following categorisation and prioritisation of measures:

Prioritisation

- Easily implementable (should be implemented right away in 2011):
  - M3: ROT and ILS SA Awareness campaign
  - M8: Extend Yellow-green alternate lighting on taxiways
  - M4: Runway and taxiway signage
  - M6: Training bulletin addressing additional runway controller instructions that need to be given to reduce the impact of premature Auto-QSY handovers (or the need for standard taxi routes) on ROT

- More challenging (decisions on further R&D and implementation still need to be taken because of larger investments):
  - M7: Reduce complexity of exits within ILS SA
  - M9: Install RETIL
  - M5: Apply 3rd Ground Controller

- Difficult to implement (investment considered too large):
  - M10: Optimise ILS shape and size changes

- Discarded (not advised due to reasons stated above):
  - M6: Standard taxi routing and no auto QSY
  - M2: 2+1 runway use off-peak
  - M1: Change marginal visibility criteria

Recommended Research

- M2: More data from the delay analysis to investigate the impact of marginal conditions and off-peak (KLM)

- M4: Airport signage improvement study (AAS)

- M5: 3rd Ground Controller Real Time Simulation (RTS) and Cost Benefit Analysis (CBA) (NLR/LVNL)

- If RWY 27 is used again during BZO-B/C conditions:
  Study to look into flow issues (e.g. fast-time study) around F apron (NLR/LVNL)

Several of the abovementioned measures to reduce ROT will consequently lead to reducing final approach spacing and improving sustainability. During BZO-C benefits are expected to be larger and likely to be accomplished more easily than for BZO-B.

Within LVNL the process of considering a reduced separation during BZO-C is already ongoing. Data presented in this study should be used to explore possibilities as there is strong evidence that a reduction is feasible.
Current ROT data suggest that additional measures are not a prerequisite for reducing the spacing during BZO-C. It is, however, recommended to implement the most promising ones mentioned above in order to reduce the probability that aircraft need extra attention from runway and ground controllers.

To be able to reduce the spacing during BZO-B, one or more of the presented measures for reducing ROT are a prerequisite.

5 References

[Landing Capacity]	Rozeboom et al.: *"Verhoging landingscapaciteit, tijdens marginaal en slecht zicht condities"*, KDC/2008/032 versie 1.00, KDC 17-11-2008
[Ground Control Capacity]	Dubbeldam et al.: "*Verhoging van de grondafhandelingscapaciteit op basis van het huidige banenstelsel: Ontwikkeling van een strategie voor verhoging VEM van het grondsectorsysteem in 2015 – 2020*", D3/D4: Oplossingen en Strategie, KDC/2007/0121, Version 1.0, KDC 19-09-2008
[Runway Capacity]	Gibbs, van Dronkelaar: "*Capaciteits Verhoging Start- en Landingsbanen*", NLR-CR-2008-115
[QRH SPL TWR]	QRH Schiphol Tower, Standard Procedures and Data Low Visibility Operations, Version 3.03, Issue 017
[AIP Netherlands]	Aeronautical Information Package The Netherlands
[QRC]	QRC LVNL, Issue 049, effective from 03-12-2009
[SANDOR]	Smit, Slootbeek: SANDOR - Safe Airport Navigation Demonstrator, KDC/2010/0065, Version 1.0, KDC 20-10-2010
[Improved Forecasts]	ten Hove et al.: "*Improved Low visibility and Ceiling* *Forecasts at Schiphol Airport*", KDC/2008/0089, Version 1.0, KDC 08-07-2008
[VDV]	Voorschriften Dienst Verkeersleiding, VDV 2 – Schiphol TWR/APP
[ICEPOD]	LVNL, POD De-icing seizoen 2009-2010, Doc. Nr. R-488, 28-08-2009]
[ICAO Annex 14]	International Civil Aviation Organization (ICAO): "*Annex 14: Aerodrome Design and Operations, Volume I*", Fourth Edition - 2004, ICAO Publication, Montreal, 2004
[AIP-UK]	Aeronautical Information Package for the U.K.
[TUD 2009.TEL.7390]	TU Delft, Thesis Liselot Hofkamp, Analyse and improve the reliability of hourly capacity for Schiphol's runway system in extreme weather conditions
[NNHS]	Brief Hans Alders aan Min V&W, Min. VROM, 19 augustus 2010, Uitwerking van het nieuwe normen en handhavingsstelsel voor Schiphol.
[Optimisation ILS SA]	Verpoorte, Heijstek: "*Improvement of the Landing Capacity by Optimisation of the Size and Shape of the ILS Sensitive Area*", NLR-CR-2008-255-VOL-1

Annex I Solutions Identified in Recent Projects

Measures identified in [Landing Capacity]:

Mens:
- ROT & ILS SA Awareness campagne
- Bepaling van de protection area grens
- Nauwkeuriger handhaven van de separatie

Machine:
- Landingsbaan exit locatie
- ILS+ (inclusief NLR resultaten [Optimisation ILS SA])
- Niet landen op baan 27 tijdens BZO
- Verbeterde Visuele Guidance (tijdens BZO)
- MLS
- GBAS

Procedure:
- Optimalisatie vrijmaken ILS SA
- Verkleining 2 NM afstand vrij aanvliegen
- Gebruik maken van de volledige landingscapaciteit tijdens 2+1 baangebruik

Measures identified in [Ground Control Capacity]:

Tabel 3.1 Shortlist high-potentials

#	Omschrijving	Opmerking
S2	Kop RWY 24: Bypass langs rijbaan Bravo ("Chicago variant")	Voor deze oplossing zijn in een latere fase subvarianten ontwikkeld, zie hoofdstuk 4.
S3	Kop RWY 24: Aanleg rijbaan Tango naar Kop 24 en aanleg Sierra 6½ en 4½	Voor deze oplossing zijn in een latere fase subvarianten ontwikkeld, zie hoofdstuk 4.
S5	Kop RWY 18L: Rijbaan rondom kop 18L	
S6	Kop RWY 18L: Extra startintersectie vanaf E6	
S7	Kop RWY 09: Nieuwe rijbaan van Charlie naar noordzijde kop 09	
S8	Kop RWY 09: Extra startintersecties zuidkant RWY 09	
S9	Vliegtuig "klaar bij de baan"	
S12	Onafhankelijke sleeproute noord van RWY 09/27	
S17	Introductie derde Ground Controller	
S18	Verdubbeling rijbaan Quebec	Voor deze oplossingen zijn in een latere fase subvarianten ontwikkeld, zie hoofdstuk 4.
S19	Aanleg bufferplaatsen in het Noordwest areaal	Is als randvoorwaardelijk gesteld bij de nadere toetsing
S23	Rijbaan tussen Juliet en Yankee platform	
S26	Enhanced / Synthetic vision voor cockpit en controller	
S31	Verplaatsen VOP's van de C- en F-pier	
S32	Verplaatsen G-buffer	
S36	Volledige gebiedsverantwoordelijkheid bij LVNL	
S38	Introductie vaste taxisnelheid	
S43	Aanleg draaipunten (rijbaan Victor)	
S44	Aanleg bypass in rijbaan Victor	
S46	Aanpassen verlichting	In relatie tot opstoppingen bij de baankoppen bij BZO
S47	Gebruik maken van tegenover elkaar liggende intersecties	In relatie tot opstoppingen bij de baankoppen bij BZO
S48	Toestaan van intersectiestarts tijdens BZO-A	

Measures identified in [TUD 2009.TEL.7390]:

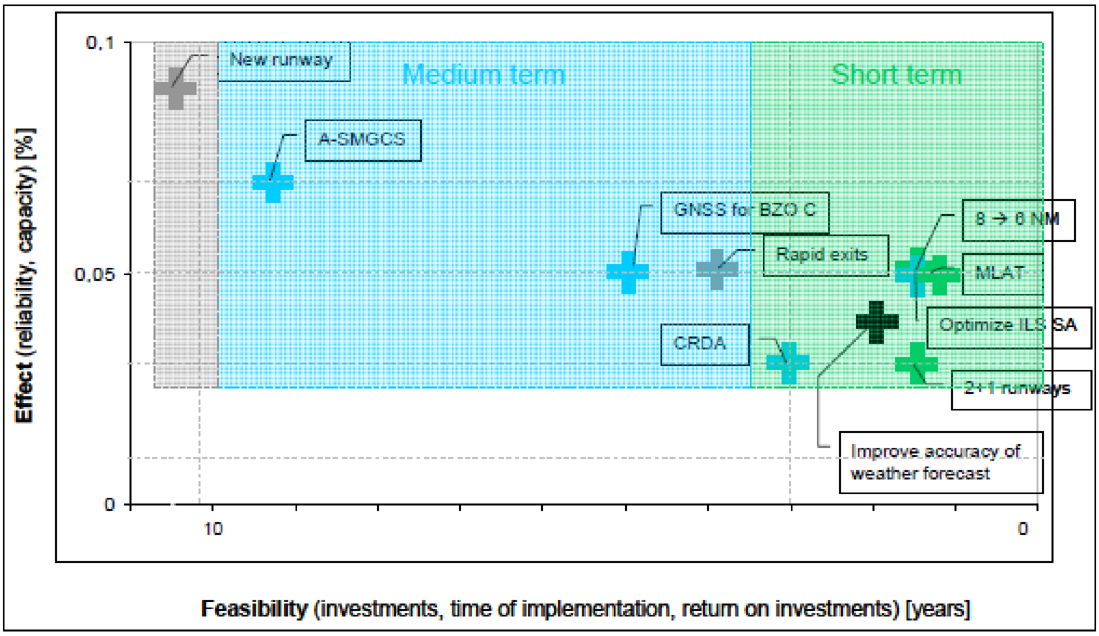


Figure 5-25: Effect vs. feasibility subdivided into short term, medium term and long term investments

Operationele verbetermaatregelen

Verhogen van de maximaal aanvaardbare dwarswind en rugwind	In gebruik nemen van de autoland functie tijdens harde wind omstandigheden. De autoland functie kan dwarswinden handelen van 25 knopen.
Verlagen van de zicht restricties en afhankelijkheid van convergerende banen	Verlagen van het minimale separatie niveau (van 8 NM naar 6 NM). Door de minimale separatie afstand te verlagen zal er, bij een bepaalde grondsnelheid, een stijging zijn in uurcapaciteit.
Introduceren van meer 2+1 baancombinaties tijdens BZO	Door meer 2+1 baancombinaties aan te bieden tijdens BZO zal de uurcapaciteit langer op niveau blijven.
Accepteren van een hoger percentage missed approaches	Bij het verhogen van het risico op missed approaches zal er een verlaging zijn in minimale separatie afstand wat een op missed approaches zal er een verlaging zijn in minimale separatie afstand wat een stijging geeft in uurcapaciteit. Hier zal een optimaal punt bereikt moeten worden. Onduidelijk is of dit punt reeds bereikt is.
In gebruik nemen van multi-lateration en ground-labelling	Multi-lateration en groundlabelling wordt al gebruikt, maar de capaciteit kan wellicht nog verhoogd worden.
Introduceren van een derde Ground Controller als stand-by tijdens BZO	Als tijdens BZO C een derde Ground Controller stand-by kan staan, zal de uurcapaciteit met een factor 1,5 toenemen.

Verbeteren van de situational awareness van de vlieger	Tijdens BZO C en D zijn vliegers volledig afhankelijk van de communicatie met de Ground Controller omdat de vliegers geen idee hebben waar ze zich bevinden, waar ze naartoe moeten en wie of wat er om zich heen bevindt. Door deze situational awareness te verbeteren kan de verantwoordelijkheid tijdens het taxiën teruggebracht worden naar de vlieger.

Technische verbetermaatregelen

Optimaliseren van de ILS Sensitive Area	Het optimaliseren van de ILS SA zal het gebied verkleinen zodat de vliegtuigen dit gebied sneller kunnen vrijmaken voor het opvolgende vliegtuig.
Onafhankelijk maken van de ILS Sensitive Area	Introduceren van Microwave Landing System (MLS). MLS is begin jaren ’90 geïnstalleerd op Schiphol. Doordat de klanten van Schiphol, de luchtvaartmaatschappijen, geen MLS hebben aangeschaft, wordt het systeem nu van Schiphol weggehaald. Introduceren van Global Navigation Satellite System (GNSS). De ontwikkelingen omtrent GPS naderingen en landingen zijn nog niet ver genoeg voor Category III landingen tijdens BZO C en D. Wanneer deze ontwikkelingen gedaan zijn, kan de nadering onafhankelijk gesteld worden van de ILS SA. Integreren van verschillende sensoren. Door de sensoren van de ILS, de GPS en de altimeter te integreren en via een filter de grootste errors eruit te filteren, kan het laatste stuk van de nadering onafhankelijk gemaakt worden van de ILS SA.
In gebruik nemen van Converging Runway Display Aid (CRDA).	De Runway Controller kan CRDA gebruiken als hulpmiddel om op convergerende banen te opereren. Dit zal het aantal te gebruiken 2+1 baancombinaties tijdens BZO verhogen.
Implementeren van A-SMGCS (SANDOR workshop)	Rule based Moving Map. Met de Airport Moving Map kan de vlieger nauwkeurig zien waar hij zich in het veld bevindt. Ground traffic display. Met Ground traffic display kunnen de omringende voertuigen en vliegtuigen geprojecteerd worden in de cockpit. Datalink. Via Datalink en CPDLC kan de vlieger zijn (klarings)route digitaal. ontvangen van de landingsbaan tot aan de gate en kan deze geprojecteerd worden in de cockpit. Auto-taxi. Auto-taxi zal het taxiproces versnellen omdat iedereen in dezelfde flow zich voortbeweegt. Brake to vacate. Met brake-to-vacate wordt het remvermogen en de van tevoren bepaalde baanafrit ingesteld en wordt de snelheidsbepaling automatisch geregeld. Zo kan de runway occupancy time effectief benut worden.

Infrastructurele verbetermaatregelen

Aanleggen van meer (snelle) baan op- en afritten	Door meer rapid exit taxiways aan te leggen zal de runway occupancy time dalen.

Aanleggen van nieuwe landing- en startbanen	Met een nieuwe baan kan de capaciteit van het gehele banenstelsel verhoogd worden.
Verlengen van bestaande landing- en startbanen	Met het verlengen van de Oostbaan kan deze baan opgenomen worden in het reguliere banenstelsel. De bruikbaarheid van de Oostbaan zal verhoogd worden.

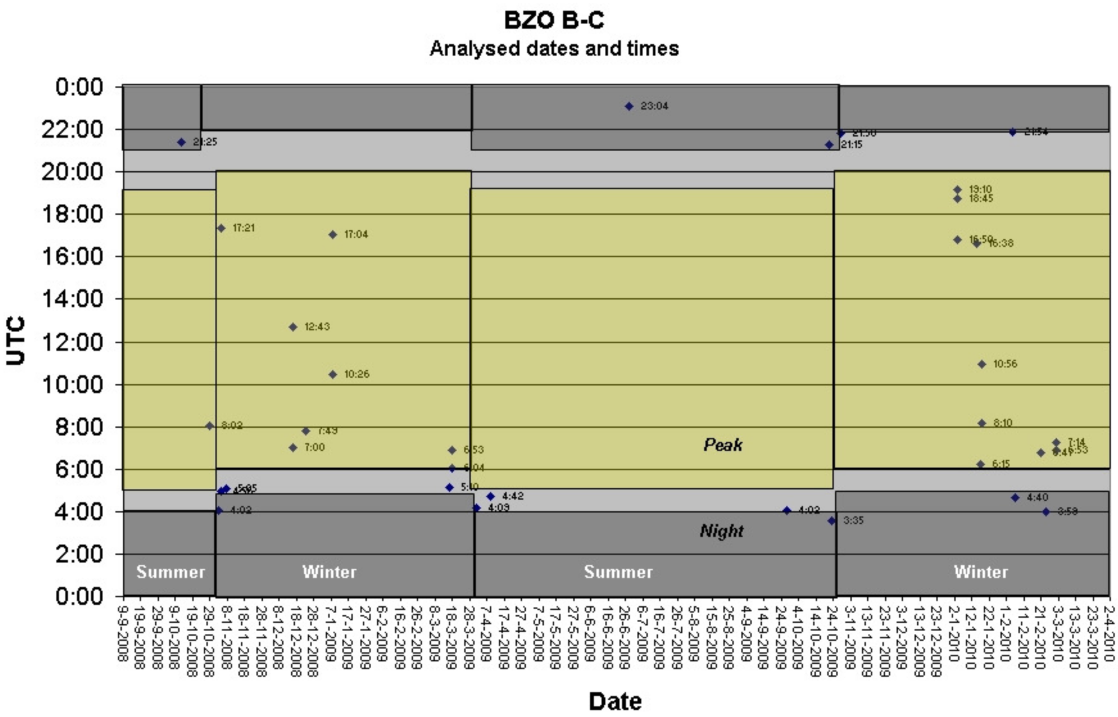
Overige verbetermaatregelen

Verbeteren van de nauwkeurigheid van de weersverwachtingen om nauwkeurigere flowmaatregelen uit te roepen	Met het verbeteren van de nauwkeurigheid van de weersverwachtingen kunnen de uitgegeven flowmaatregelen beter geregeld worden. Juist ook wanneer de extreme weerssituatie verwacht wordt weer voorbij te zijn, kan de capaciteit direct verhoogd worden waarbij de binnenkomende vliegtuigen al in de buurt van Schiphol moeten zijn.
Aanpassen van het vluchtschema	Verplaatsen van het vertrekschema naar een later tijdstip. Als het gehele vertrekschema verplaatst wordt naar een later tijdstip zal de transferpassagier een ruimere overstaptijd hebben.

Annex II ROT Analysis

For a detailed description of approach methodology and results please refer to NLR-CR-2010-249.

Analysed Data



Description of Steps

The following definitions have been used in determining the specific steps in the landing phase of an aircraft as has been used in the script of the Surveillance Analyse Tool.

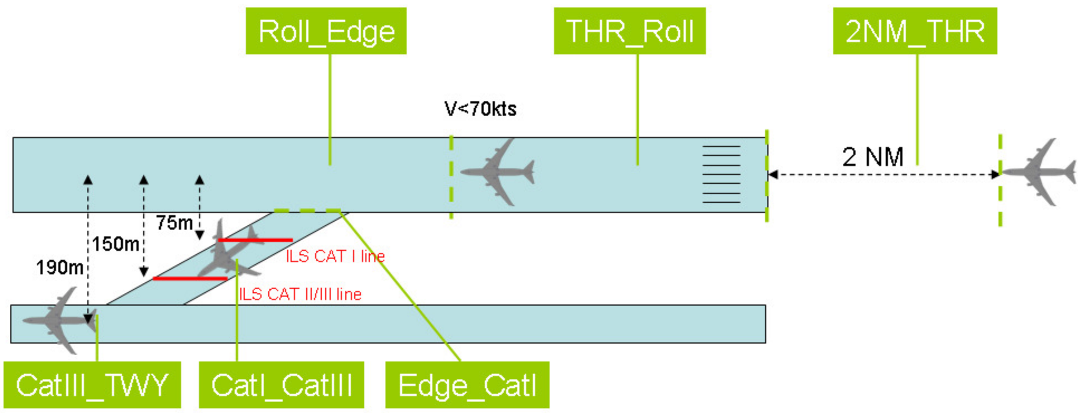
- The moment at which the aircraft passes a point 2NM from the runway threshold (:2NM).
  - Definition: the timestamp of the last track-plot before the track-plot is closer then 2NM to the runway threshold.
- The moment the aircraft has passed the runway threshold (:THR)
  - Definition: the timestamp of the last track-plot before the track-plot is passed the runway threshold.
- The moment the aircraft has slowed to the rolling speed (:Roll)
  - Definition: the timestamp on which the track-plot has for the first time a ground speed of 70kts or less according to the surveillance tracker.
- The moment the aircraft starts exiting the runway (:Edge)

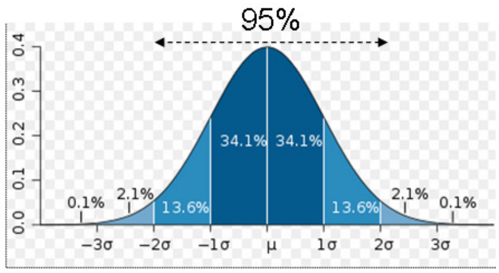
- Definition: the timestamp on which the track-plot is for the first time more then 22m from the centerline of the runway.

- The moment the aircraft bases the ILS CAT I line (:CATI)
  - Definition: the timestamp on which the track-plot is for the first time more then 75m from the centerline of the runway.

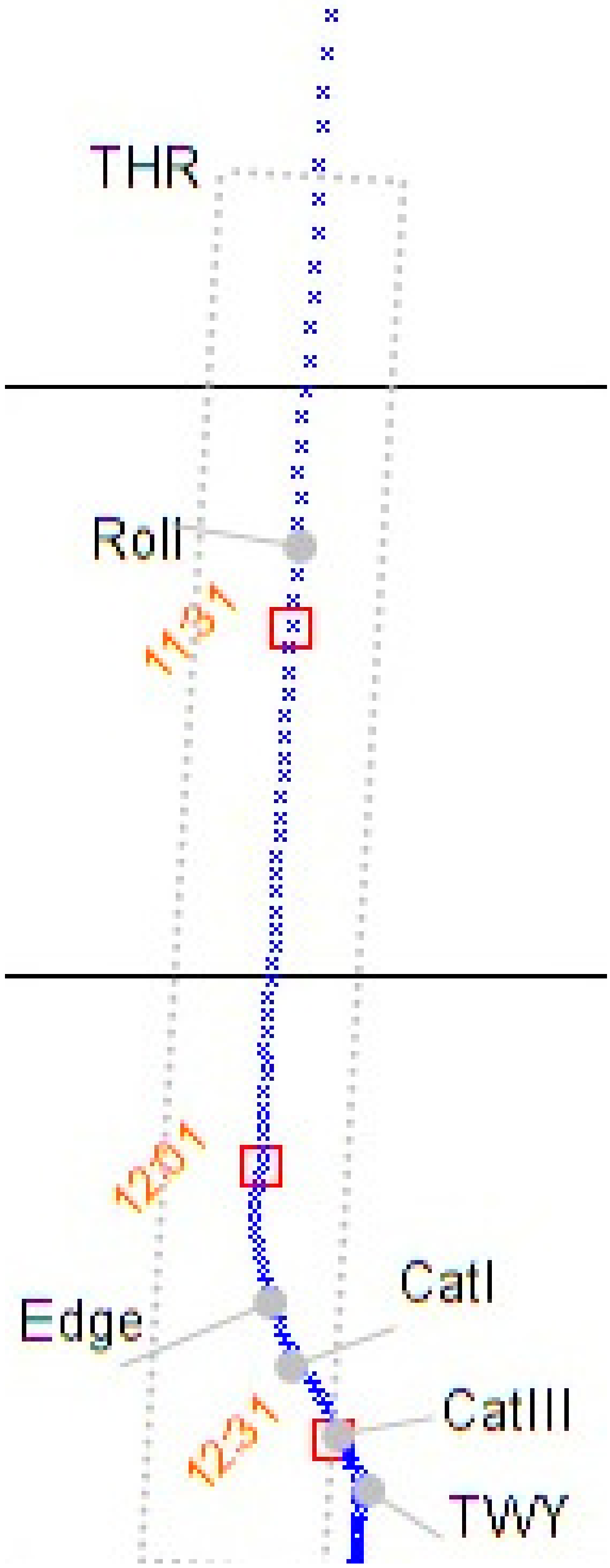
- The moment the aircraft bases the ILS CAT II/III line (:CATIII)
  - Definition: the timestamp on which the track-plot is for the first time more then 150m from the centerline of the runway.

- The moment the aircraft is with the tail outside the ILS CAT II/III SA (:TWY)
  - Definition: the timestamp on which the track-plot is for the first time more then 190m from the centerline of the runway. This is estimated based on 150m + 7m + sin30° x 66m (This takes the angle of the RET in to consideration, the length of B747, the location of the transponder at a front position, and a MLAT inaccuracy of 7m).

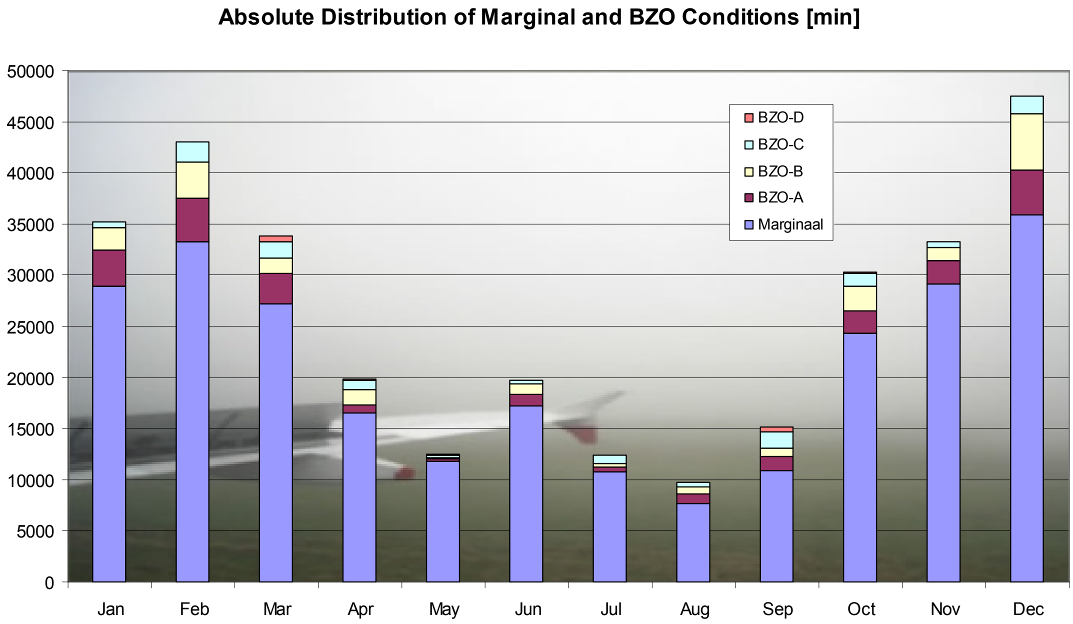




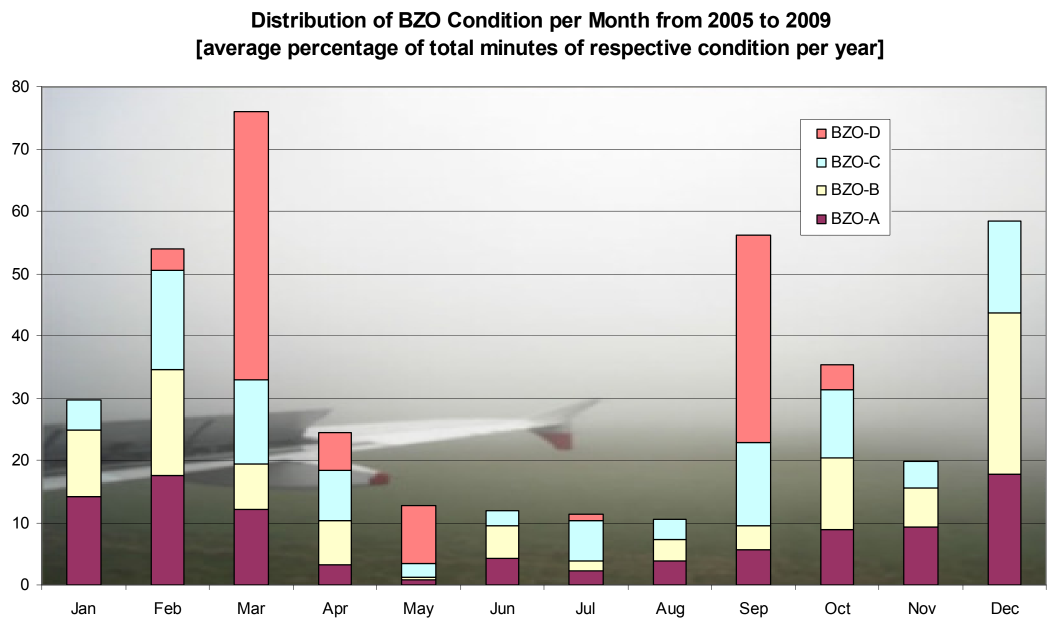
Example of Track



Annex III Distribution of BZO Conditions

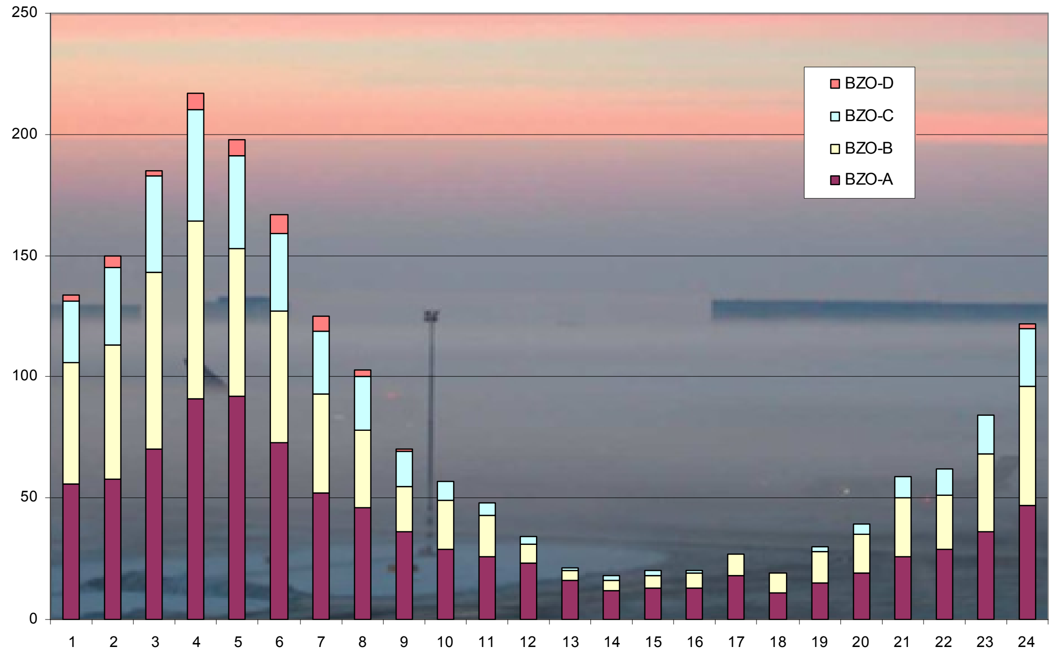


N.B.: this is the same figure as Figure 2-1 including marginal visibility and therefore has less detail regarding the other visibility conditions.



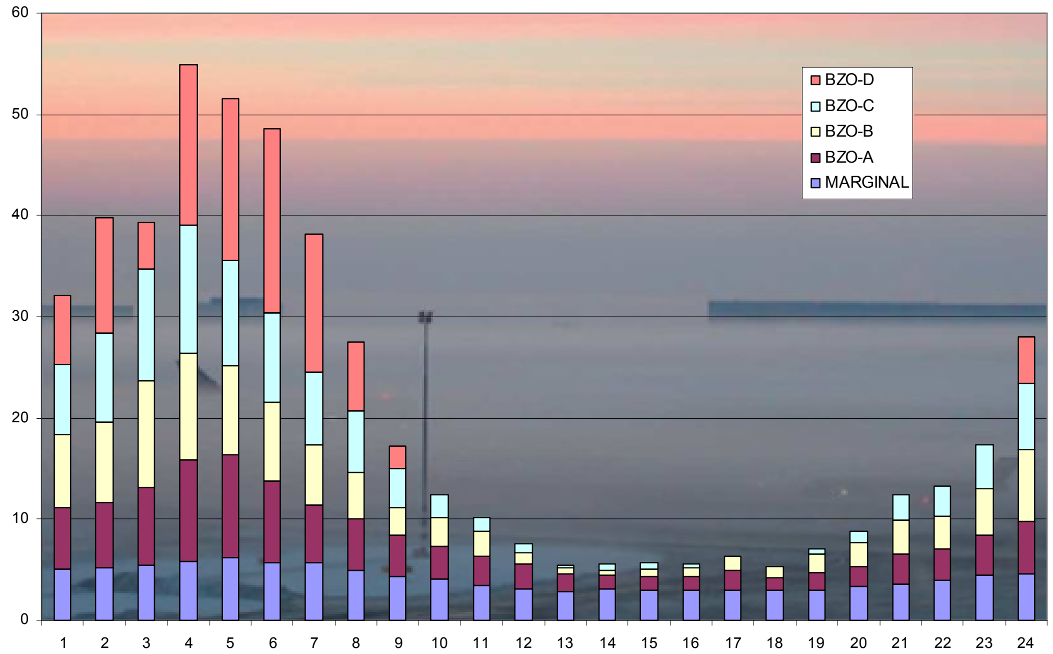
N.B.: the figure is not comparing BZO conditions, as the percentages represent the relative occurrence (in minutes) of a condition per month (each BZO condition adds up to 100% when summing up the months).

Distribution of Occurrence of BZO Condition per Time of Day from 2005 to 2009



N.B.: the same figure as Figure 2-2 without marginal conditions, offering more detail.

Relative Distribution per BZO Condition of Occurrence of Condition at Time of Day from 2005 to 2009



N.B.: the same figure as Figure 2-2 with a relative distribution per BZO condition (each BZO condition adds up to 100% when summing up the hours).