



SOURDINE II

D4.2-2b

Safety assessment of approach procedure II-A on Schiphol airport (Argumentation-based analysis)

Project acronym: SOURDINE II
Project full title: "Study of Optimisation procedURes
for Decreasing the Impact of NoisE II"
Project number: GRD2-2000-30105
Contract number: G4RD-CT-2000-00394
Start date: 12 November 2001
Duration: 45 months

Sourdine II Consortium:

NLR	<i>Stichting Nationaal Lucht- en Ruimtevaartlaboratorium</i>	NL
AENA	<i>Aeropuertos Españoles y Navegación Aérea</i>	ESP
AIRBUS F	<i>AIRBUS FRANCE SAS</i>	F
EUROCONTROL	<i>European Organisation for the safety of Air Navigation</i>	INT
ISDEFE	<i>Ingenieria de Sistemas para la Defensa de España S.A.</i>	ESP
INECO	<i>Ingenieria y Economia del Transporte</i>	ESP
SICTA	<i>Sistemi Innovativi per il Controllo del Traffico Aereo</i>	IT

Document Change Log

Release	Author	Affected Sections / Comments	Date
0.1	NLR	All, creation.	06/11/03
0.2	NLR	All, analyses of all conflict scenarios included.	18/03/04
0.3	NLR	All, version for internal review.	02/04/04
0.4	NLR	All, internal review comments processed, version for external review.	19/08/04
0.9	NLR	All, version for review by INECO.	31/12/04
0.91	NLR	All, comments processed and finalised.	24/05/05
1.0	NLR	Finalised.	03/06/05
1.1	NLR	Update after comments to D4.2-1	14/06/05
2.0	NLR	Inclusion of EC approval	01/08/05

Document Distribution

Partner	Distribution list
AENA	Pablo Escalonilla Sanchez Alfredo Gomez de Segura
Airbus France	Michel van Boven
EUROCONTROL Experimental Centre	Peter Hullah Laurent Cavadini
Ineco	Peter Lubrani
Isdefe	Marcos Esteban Medina
NLR	Ruud Den Boer Collin Beers
SICTA	Mariacarmela Supino

Review and Approval of the Document

Organisation Responsible for Review	Reference of comment documents	Date
INECO	Version 0.9	29/03/05
Organisation Responsible for Approval	Name of person approving the document	Date
Project Manager	Ruud den Boer	03/06/05
Work Package Leader	Jelmer Scholte	03/06/05
EC Official	Morten Jensen	28/07/05

Document Information	
Document title	Safety assessment of approach procedure II-A on Schiphol airport (Argumentation-based analysis)
Version	2.0
Date	01/08/05
Classification	Public
Workpackage	WP 4.2
Document identification	S II D4.2-2b v2.0.doc

Contributing Partners	Authors
NLR	J.J. Scholte, scholte@nlr.nl , +31 (0) 20 511 36 45 M.H.C. Everdij, everdij@nlr.nl , +31 (0) 20 511 35 22

Contact Information
National Aerospace Laboratory, NLR Attn. Mr. J.J. Scholte Anthony Fokkerweg 2 1059 CM Amsterdam The Netherlands Tel.: +31-20-5113645 Fax: +31-20-5113210 e-mail: scholte@nlr.nl

Summary

Within the Sourdine II project, various noise-efficient aircraft operation procedures have been developed. In the Sourdine II report [S II D6.6 v0.2], a concept of operations has been developed for one of these procedures, approach procedure II-A. This Continuous Descent Approach (CDA) procedure features a fixed three-dimensional flight path, which is flown using P-RNAV (Precision Area Navigation). Characteristic for this procedure is that from 7000ft a fixed descent angle of 2° is used until the glide path intercept. The procedure thus does not include a horizontal segment before glide path intercept, but it is not a classical CDA with idle thrust; some speed constraints are in force, and thrust has to be applied when required. This way it is aimed to reduce noise hindrance, while maintaining capacity.

Obviously, a newly proposed concept of operation cannot be implemented if it is not sufficiently safe. Therefore, the risks associated with this specific operation applied to Schiphol airport have been assessed using the safety assessment methodology TOPAZ [TOPAZ]. This methodology combines an argumentation-based approach with a simulation-based approach. This safety assessment is documented in four parts:

Safety assessment of approach procedure II-A on Schiphol airport

D4.2-2a	Main document
D4.2-2b	Argumentation-based analysis
D4.2-2c	Simulation-based analysis
D4.2-2d	Collection of expert interviews

The current document is D4.2-2b. Document D4.2-2a is the main document of the safety assessment for this operation, and contains the description of the study, the main results, the conclusions, and an executive summary of the safety assessment.

Table of Contents

Summary	4
1. Introduction	6
1.1. Background.....	6
1.2. Objective	6
1.3. Relations with other documents	7
1.4. Structure of this document.....	8
1.5. Glossary.....	8
1.6. References	9
2. Risk assessment per conflict scenario	11
2.1. Introduction	11
2.2. Conflict scenario 1: Conflict between aircraft merging	17
2.2.1. Introduction	17
2.2.2. Structure of conflict scenario 1	17
2.2.3. Severity assessment for conflict scenario 1.....	21
2.2.4. Frequency assessment for conflict scenario 1	21
2.2.5. Risk assessment results for conflict scenario 1	27
2.2.6. Safety bottleneck identification for conflict scenario 1	28
2.3. Conflict scenario 2: Conflict between two aircraft on the same route	29
2.3.1. Introduction	29
2.3.2. Structure of conflict scenario 2	29
2.3.3. Severity assessment for conflict scenario 2.....	30
2.3.4. Frequency assessment for conflict scenario 2	31
2.3.5. Risk assessment results for conflict scenario 2.....	33
2.3.6. Safety bottleneck identification for conflict scenario 2	33
2.4. Conflict scenario 3: Conflict between two aircraft established on their respective localizers	35
2.4.1. Introduction	35
2.4.2. Structure of conflict scenario 3	35
2.4.3. Severity assessment for conflict scenario 3.....	36
2.4.4. Frequency assessment for conflict scenario 3	36
2.4.5. Risk assessment results for conflict scenario 3.....	37
2.4.6. Safety bottleneck identification for conflict scenario 3.....	38
2.5. Conflict scenario 5: Wake vortex encounter	39
2.5.1. Introduction	39
2.5.2. Structure of conflict scenario 5	39
2.5.3. Severity assessment for conflict scenario 5.....	40
2.5.4. Frequency assessment for conflict scenario 5	40
2.5.5. Risk assessment results for conflict scenario 5.....	42
2.5.6. Safety bottleneck identification for conflict scenario 5.....	42
3. Summary of results	44

1. Introduction

1.1. Background

With the continuing growth of air traffic as well as the ever increasing level of urbanisation around most airports in Western Europe, the impact of aircraft noise and emissions on the quality of life for the surrounding communities has become a serious issue to be dealt with. Many European airports already face the conflicting problems of increasing their airport capacity to meet the amount of traffic, and the increasing pressure from the general public to reduce environmental impact, particularly noise and emissions, of the increased traffic volume. This has already resulted in specific local constraints to the operation of aircraft, not only around major airports such as Schiphol, Gatwick or Frankfurt, but also more regional airports are already experiencing the pressure to impose constraints to aircraft movements. Therefore, reduced nuisance to the community is a serious issue for the airline transport industry if the projected sustained growth is to be pursued.

A possible solution to noise reduction around an airport is the definition of new approach and departures procedures. By modifying or optimising the operations and traffic flow of aircraft around the airport, it should be possible to achieve noise reduction. In workpackage 3 of the Sourdine II project, many new noise abatement procedures were defined [S II D3.1-1]. All these procedures were assessed with respect to their noise impact, by executing very accurate single event simulations for the A320 and the A340 aircraft [S II D5.3]. Based on these simulations, apart of a baseline approach procedure and a baseline departure procedure, 4 approach procedures and 2 departure procedures were selected for further evaluation [S II D3.1-2].

The four approach procedures are Continuous Descent Approach (CDA) procedures. Each of these features either a fixed three-dimensional flight path, or a vertical flight path that is flown with a constant speed. Furthermore the configuration in which the procedure is flown varies; also one of the procedures includes a steeper final approach path. The departure procedures considered are optimised versions of the noise abatement procedures NADP1 and NADP2 of ICAO. One of these aims to decrease the noise level close to the runway ('optimised close-in'), the other further away from the runway ('optimised distant'). All six procedures are flown with P-RNAV (Precision Area Navigation).

1.2. Objective

This document supports a safety assessment of a particular Sourdine II operation, developed for approach procedure II-A on Schiphol airport in [S II D6.6 v0.2] and based on the corresponding procedure developed in [S II D3.1-2]. The operation considered is a Continuous Descent Approach (CDA) procedure on Schiphol airport. It features a fixed three-dimensional flight path, which is flown using P-RNAV (Precision Area Navigation). Characteristic for this procedure is that from 7000ft a fixed descent angle of 2° is used until the glide path intercept. It is not a classical CDA with idle thrust; some speed constraints are in force, and thrust has to be applied when required. This way it is aimed to reduce noise hindrance, while maintaining capacity. The term CDA is however stuck to, as the procedure does not feature a horizontal segment before glide path intercept.

Main objective of the safety assessment is to provide an overview of the risks associated with this operation. Using the safety assessment methodology TOPAZ (Traffic Organization and Perturbation AnalyZer), the assessment aims to show which parts of the operation are most safety critical, and to give feedback to the operational concept designers. An argumentation-based approach and a simulation-based approach are combined; using the argumentation-based approach conclusions are drawn using argumentations built from input retrieved mainly from operational experts, whereas the simulation-based approach features Monte Carlo simulations of a stochastic model.

The operation of which the safety is assessed is the one described in Section 4 of [S II D4.2-2a]. This description of the operation is based on the description of approach procedure II-A for Schiphol airport in [S II D6.6 v0.2].

1.3. Relations with other documents

The Sourdine II safety assessment of approach procedure II-A on Schiphol airport is documented in four parts:

Safety assessment of approach procedure II-A on Schiphol airport

D4.2-2a	Main document
D4.2-2b	Argumentation-based analysis
D4.2-2c	Simulation-based analysis
D4.2-2d	Collection of expert interviews

The current document is D4.2-2b. Document D4.2-2a [S II D4.2-2a] is the main document of the safety assessment of approach procedure II-A on Schiphol airport. It contains the description of the study, the main results, and the conclusions. In this document so-called conflict scenarios are constructed, for which the detailed analysis takes place in the current D4.2-2b and in D4.2-2c [S II D4.2-2c]. In the current D4.2-2b this analysis is done for the conflict scenarios that are analysed using an argumentation-based approach, and in D4.2-2c for the conflict scenario that is analysed using a simulation-based approach. In D4.2-2d [S II D4.2-2d] the minutes of all operational expert interviews held for this safety assessment are collected.

The above set of four documents is part of the Sourdine II safety assessments. The main deliverable structure of the safety assessments is:

D4.2-1	Safety assessment of Sourdine II procedures (Top-level document).
D4.2-2	Safety assessment of approach procedure II-A on Schiphol airport.
D4.2-3	Safety assessment of approach procedure V and departure procedure 2 on Barajas airport.

D4.2-1 [S II D4.2-1] is the top-level document of the safety assessment of 4 approach procedures and 2 departure procedures selected for further evaluation in [S II D3.1-2]. D4.2-1 contains the overall approach, the main results and the conclusions. The safety assessment of approach procedure II-A on Schiphol airport is described in the documents constituting D4.2-2, among which the current document. The safety assessments for approach procedure V and departure procedure 2 on Barajas airport are described in [S II D4.2-3].

The relations between all these documents is illustrated by the following figure:

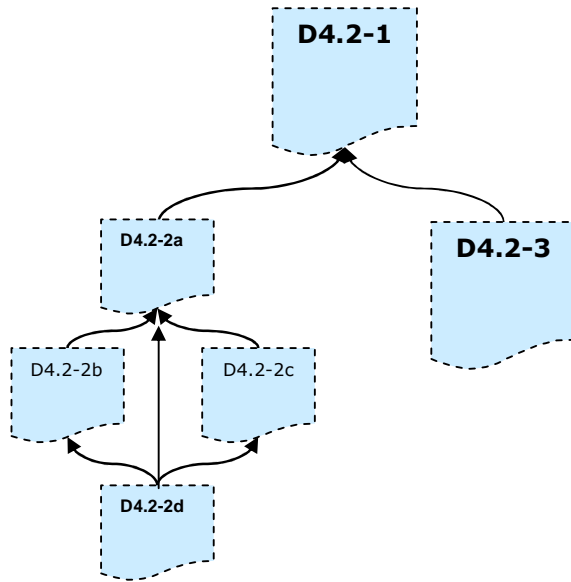


Figure 1: Overview of the Sourdine II D4.2 deliverables and their relations

Apart from these Sourdine II deliverables, two NLR company confidential documents have been produced of which the results are used as input in D4.2-2c. These are:

- An NLR memorandum [DCPN] on the construction of a Dynamically Coloured Petri Net (DCPN) used for the implementation of the mathematical model described in D4.2-2c; and
- An NLR memorandum [B&U assessment] on the details of the bias and uncertainty assessment used in D4.2-2c.

1.4. Structure of this document

The structure of this document, D4.2-2b, is as follows:

- Section 1 introduces the current document.
- In Section 2 the actual risk assessment takes place per conflict scenario.
- In Section 3 the results are summarised.

As this document contains the analyses part of the safety assessment described in [S II D4.2-2a], no conclusions are drawn here. For conclusions one is referred to [S II D4.2-2a].

1.5. Glossary

ACC	Area Control Centre
AIP	Aeronautical Information Publication
APP	Approach Control
ATC	Air Traffic Control

ATCo	Air Traffic Controller
ATIS	Automatic Terminal Information Service
CDA	Continuous Descent Approach
DME	Distance Measuring Equipment
EAT	Expected Approach Time
FL	FlightLevel
FMC	Flight Management Computer
FMS	Flight Management System
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
HMI	Human Machine Interface
IAF	Initial Approach Fix
ILS	Instrument Landing System
L	Left
NAVAID	NAVigation AID (ground radio station for navigation)
NM	Nautical Mile
P-RNAV	Precision Area Navigation (RNP-1 compliant)
QNH	Q-code for Natural Height (altimeter setting)
R	Right
RNAV	aRea NAVigation
RNP	Required Navigation Performance
R/T	Radio-Telephony
TCAS	Traffic alert and Collision Avoidance System
TMA	Terminal Manoeuvring Area
TOPAZ	Traffic Organization and Perturbation AnalyZer
TWR	ToWeR
VFR	Visual Flight Rules
VOR	Very high frequency Omnidirectional Range

1.6. References

Short Reference	Author / Organisation, Title, Edition, Date and Reference
[B&U assessment]	Park, M.N.J. van der, Everdij, M.H.C., <i>Bias and Uncertainty assessment for simulation-based safety assessment within Sourdine II</i> , National Aerospace Laboratory NLR, Memorandum ATSF-2005-056, NLR Company Confidential, June 2005.

[DCPN]	Park, M.N.J. van der, <i>Dynamically Coloured Petri Net specification for simulation-based safety assessment within Sourdine II</i> , National Aerospace Laboratory NLR, Memorandum ATSF-2005-055, NLR Company Confidential, June 2005.
[Hallock et al., 2003]	Hallock, J.N., S.P. Osgood, and J. Konopka, Wake vortex effects on parallel runway operations, In: <i>American Institute of Aeronautics and Astronautics</i> , 2003.
[QSA Approve]	Gibbs, A.P.R., <i>Safety assessment of Schiphol RNAV transition routes</i> , APPROVE W41NLR-Safety-V0.5, Final Draft Version 0.5, 23 July 2003.
[QSA ATC-Wake]	Scholte, J.J., G.B. van Baren and S.H. Stroeve, <i>Qualitative safety assessment of the ATC-Wake operation</i> , NLR-CR-2003-463, Version 1.0, September 2003.
[S II D3.1-1]	Sourdine II, <i>Definition of new noise abatement procedures</i> , version 1.0, 10-03 2003, INECO.
[S II D3.1-2]	Sourdine II, <i>Definition of new noise abatement procedures</i> , version 2.5, 02-04 2004, update report INECO
[S II D4.2-1]	Sourdine II D4.2-1, Scholte, J.J., Antón Cruz, M.F., and Vinagre, L., <i>Safety assessment of Sourdine II procedures (Top-level document)</i> , version 2.0, August 2005.
[S II D4.2-2a]	Sourdine II D4.2-2a, Scholte, J.J., Everdij, M.H.C., Van der Park, M.N.J. and Smeltink, J.W., <i>Safety assessment of approach procedure II-A on Schiphol airport (Main document)</i> , version 2.0, August 2005.
[S II D4.2-2c]	Sourdine II D4.2-2c, Park, M.N.J. van der, and Everdij, M.H.C., <i>Safety assessment of approach procedure II-A on Schiphol airport (Simulation-based analysis)</i> , version 2.0, August 2005.
[S II D4.2-2d]	Sourdine II D4.2-2d, Everdij, M.H.C. (Editor), <i>Safety assessment of approach procedure II-A on Schiphol airport (Collection of expert interviews)</i> , version 2.0, August 2005.
[S II D4.2-3]	Sourdine II, D4.2-3, Antón Cruz, M.F., and Vinagre, L., <i>Safety assessment of approach procedure V and departure procedure 2 on Barajas airport</i> , version 2.0, August 2005.
[S II D5.3]	Sourdine II, D5.3, <i>Single Event Noise Calculations</i> , Airbus
[S II D6.3 v0.2]	Sourdine II, D6.3, H. Huisman, M.I. Roerdink, C.S. Beers, and E.S. Hartlieb, <i>Real time simulations results</i> , Version 0.2, 3 March 2005, NLR.
[S II D6.6 v0.2]	Sourdine II, D6.6, C.S. Beers, <i>Concept of Operation for the Schiphol airport simulations</i> , Version 0.2, 30 October 2003, NLR.
[SARA]	Jong, C.J.M. de., J.W. Smeltink, A.P.R. Gibbs, and E.A.C. Kruijssen, <i>Safety argument for RNAV approaches</i> , NLR-CR-2003-578, November 2003.
[TOPAZ]	TOPAZ accident risk assessment methodology in: <i>FAA/Eurocontrol Safety Action Plan 15, ATM safety techniques and toolbox</i> , 2005, available at: http://www.eurocontrol.int/eec/public/standard_page/safety_doc_techniques_and_toolbox.html .

2. Risk assessment per conflict scenario

This section gives the details of the risk assessment of conflict scenarios 1, 2, 3, and 5. For those conflict scenarios, steps 4, 5, 6, and 7 of the safety assessment methodology TOPAZ presented in Section 2 of [S II D4.2-2a] are covered. In Section 2.1 the conflict scenarios identified in [S II D4.2-2a] are repeated, and some further detailed information on the application of the approach in the current study is gathered. Also, in that section some terminology is introduced. Starting in Section 2.2, each conflict scenario is treated in a separate (sub-) section 2.x. For each conflict scenario a separate (subsub-) section 2.x.y is given for:

- The introduction to the conflict scenario, including possible sub scenarios;
- A more detailed description of the structure of the conflict scenario in terms of hazard clusters playing a role;
- The assessment of the severity of the conflict scenario (step 4);
- The assessment of the frequency of the conflict scenario for each applicable severity class (step 5);
- The assessment of the risk tolerability (step 6); and
- The identification of the safety bottlenecks (step 7).

2.1. Introduction

In this subsection some detailed information on the application of the methodology in the current assessment is given. The conflict scenarios, introduced in [S II D4.2-2a], are repeated, and the general structure of these conflict scenarios is explained. The severity assessment approach is explained, as is the frequency assessment approach. Also, the usage of expert opinion will be explained, and some terminology is introduced.

Conflict scenarios

The list of all conflict scenarios and hazard clusters playing a role in it is copied from [S II D4.2-2a] in Table 1, as is a map indicating the locations of the conflict scenarios, in Figure 2.

Table 1: Conflict scenarios and sub scenarios, and the relations with the hazard clusters.

Conflict scenario				Clusters that play a role in the occurrence of the conflict scenario	Clusters that play a role in the resolution of the conflict scenario
1	Conflict between aircraft merging	1a	Conflict between two aircraft merging onto one route at MICOL	B, C, D, F	K, L, M
		1b	Conflict between two aircraft merging onto one route at NARSI (after a direct-to from SUGOL)	B, D, F	K, L, M
		1c	Conflict between two aircraft merging onto one route at EH708 (after an extended downwind)	B, D, F	K, L, M
2	Conflict on same route before CDA	2a	Conflict between two aircraft on the same route before the CDA (from ARTIP, SUGOL or RIVER)	D, F	K, L, M
		2b	Conflict between two aircraft on the same route on the same CDA (from ARTIP or the one from RIVER/SUGOL)	D, F	K, L, M
		2c	Conflict between two aircraft on the same route, on the extended downwind	D, (B), F	K, L, M
		2d	Conflict between two aircraft on the same route, on the same ILS	D, F	K, L, M
3	Conflict between aircraft on parallel ILSs	3	Conflict between two aircraft established on their respective localizers (one for 18R and one for 18C)	B, J	K, L, M
4	Conflict between aircraft turning in	4	Conflict between two aircraft (one for 18R and one for 18C) of which at least one is turning in to intercept its localizer, the other aircraft may also be turning in or already be established on its own localizer.	E, C, F	K, L, M
5	Wake vortex encounter	5a	An aircraft flies into the wake vortex of an aircraft of the traffic flow that it is to be merged with	G	K, L, M
		5b	An aircraft flies into the wake vortex of the preceding aircraft in the same approach flow	G	K, L, M
		5c	On the parallel approach an aircraft flies into the wake vortex of the aircraft flying on the parallel lane	G	K, L, M
		5d	While turning in for parallel approaches an aircraft flies into the wake vortex of the aircraft turning in on the parallel lane	G	K, L, M

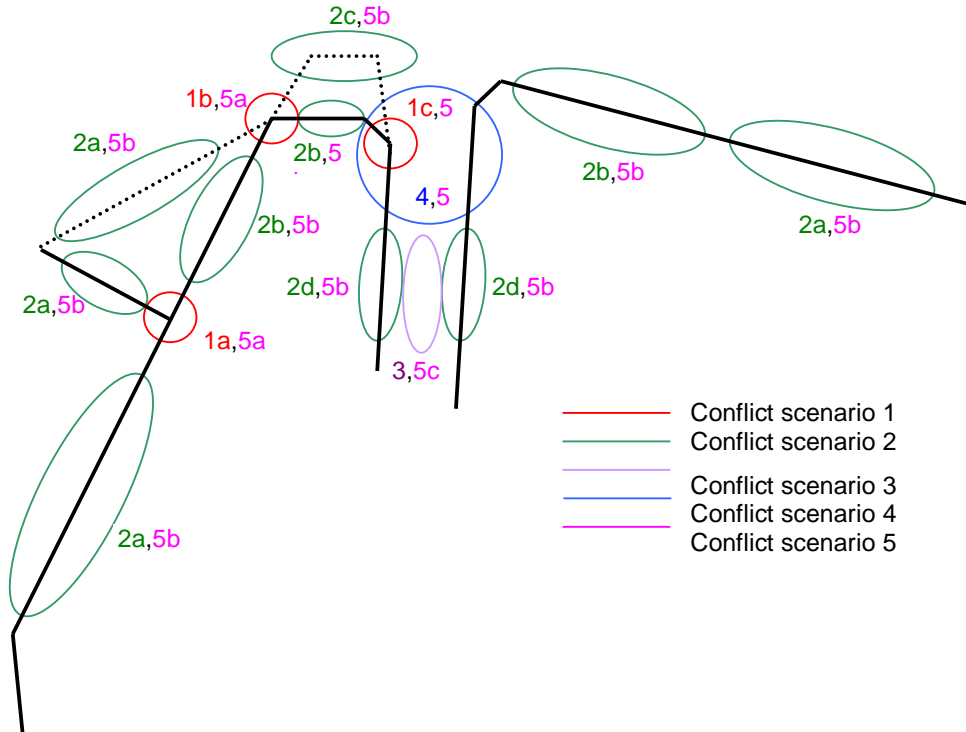


Figure 2: Overview of the considered routes and the locations of the conflict scenarios and sub-scenarios on the map of the Schiphol TMA and surroundings. For readability of the figure, the distance between the ARTIP approach and the RIVER / SUGOL approach has been enlarged.

The general structure of a conflict scenario is shown in Figure 3. The root of the conflict describes the causes of the conflict. For each conflict scenario it will be made clear how the root hazards can lead to the conflict; this is done using 'and' and 'or' relations and using the hazard clusters. The consequences of the conflict depend on the resolution part, in which the same three hazard clusters generally play a role. Generally, the consequences can be classified into the four severity classes and the additional 'no effect' class. This will be done in the severity analysis.

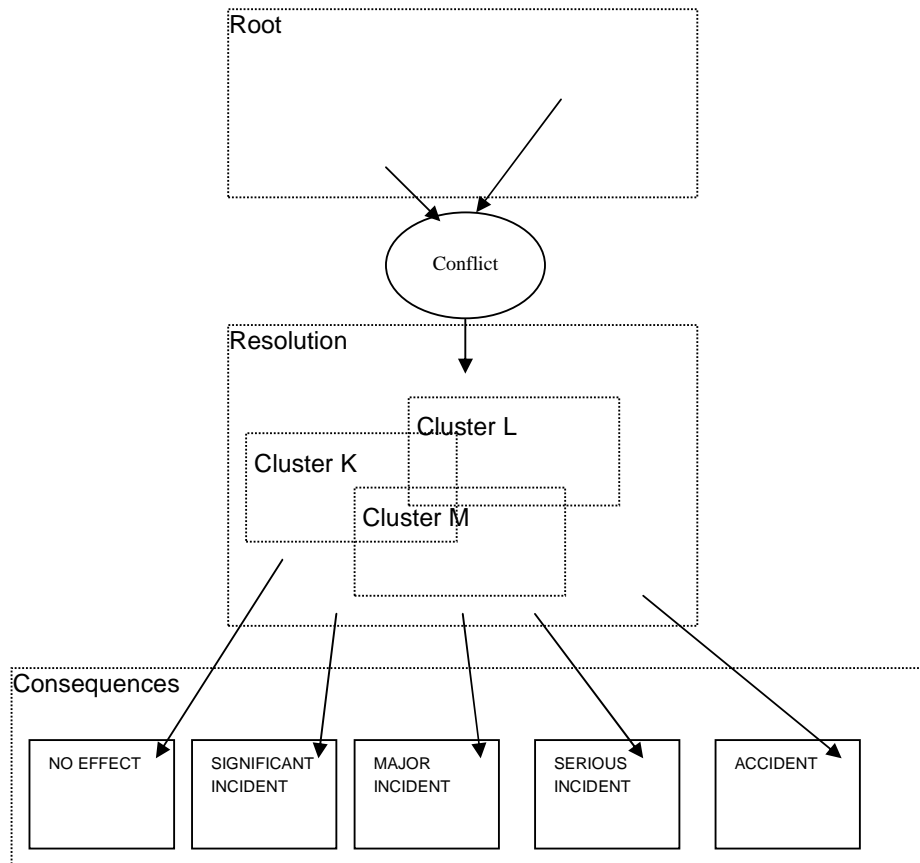


Figure 3: General structure of the conflict scenarios

Severity assessment approach

For each of the identified conflict scenarios it is determined which of the severity classes, as introduced in Section 3.2 of [S II D4.2-2a], are applicable. The severity classification distinguishes between SIGNIFICANT INCIDENT, MAJOR INCIDENT, SERIOUS INCIDENT, and ACCIDENT severity.

If a conflict occurs, then the consequences and the severity of its consequences depend strongly on many factors, such as the conditions under which the conflict occurs, the geometry of the conflict, and on whether (timely) resolution of the conflict takes place. Therefore, often a range of severity classes apply to a conflict scenario. In this assessment the spectrum of all possible conflict scenario outcomes are divided into 'bands' of reasonably determined severity that moreover have a clear operational interpretation.

Frequency assessment approach:

For each possible severity outcome of each conflict scenario the frequency of occurrence is assessed. This is done using the frequency classes introduced in Section 3.2.3 of [S II D4.2-2a]: PROBABLE, REMOTE, EXTREMELY REMOTE, and EXTREMELY IMPROBABLE.

As main input for the frequency assessment, interviews are organised with operational experts. Additionally, statistical databases can be used. The data gathered serve as input to the frequency assessment; in the end the frequency is assessed by the safety analysts, using argumentations

based on the data and opinions retrieved. Also, information from the real-time experiments [S II D6.3 v0.2] is used.

In some cases argumentations on the risk tolerability are taken into account to give a final classification of the frequency and of the risk. Assumption 1 of [S II D4.2-2a] can then be of importance; it is repeated here:

Assumption 1. In the current operation conflict scenarios have TOLERABLE risk at most, unless it appears from operational expert interviews or other sources that this is not the case.

Complicating factors in assessing the frequency of a conflict ending in a given severity at once can be that there is often little or no experience with the new operation, and that the situation may involve several variables. This holds especially for the more severe outcomes of the conflict, since these situations occur rarely, and accordingly less information is at hand about the behaviour of air traffic controllers and pilots in such situations. As a result, there will be uncertainty in the frequency estimates. This uncertainty should be dealt with carefully. The approach chosen here is that intervals are chosen to account for part of the uncertainty. This means that often more than one frequency class is selected for an assessed frequency.

Usage of expert opinion

The expert opinion used for the argumentation-based analysis of conflict scenarios has been retrieved via expert interviews, see [S II D4.2-2d]. To guarantee anonymity of the interviewees, they are referred to by a code. Two recently retired TWR/APP controllers, ATC_07 and ATC_10, were interviewed. The latter of these was actively involved in the development of night CDAs to be used at Schiphol airport. The interview with ATC_10 took place after this expert had got acquainted with the concept of operation during an experimental run at the ATC simulation facility NARSIM. Some observations made during this session are also contained in [S II D4.2-2d]. Furthermore, a B737 first-officer, PLT_03, and a B747 captain, PLT_04, were interviewed, and parts of interviews with another B737 captain, PLT_05, and with a test and former commercial pilot, PLT_08, were used for the argumentation-based assessment. All these pilots are active commercial pilots.

The interviews were semi-structured, meaning that a question list was used, but that depending on the answers retrieved, some improvisation took place in order to go deeper into the more interesting subjects. Generally, the following steps were taken in the interviews for the conflict scenarios or sub scenarios:

- The identified causes (e.g. root hazards) for the conflict were considered, and it was judged whether the causes have a significant share in the total frequency of the conflict or not;
- Having considered the various causes and their relevance for the conflict scenario, questions were asked to obtain an estimate for the total frequency of each root cluster and of the root of the conflict scenario;
- It was investigated what the behaviour of the interviewed expert would be in case of the conflict. Accordingly, would the expert detect the situation rapidly, and which actions would the expert take?
- Having discussed the behaviour in the conflict situations, the expert was asked how probable it is that the conflict evolves to each next severity class, or how probable it is that the expert would prevent the conflict from getting to a worse severity class.

For some conflict scenarios these steps were taken in great detail. For other conflict scenarios or sub scenarios the answers to these questions were derived more by comparison to a conflict scenario or sub scenario that had already been discussed, or by comparison to an existing situation. In the latter case, also the safety of the particular existing situation was checked for a judgement on its safety. This way, the interviews were efficient, preventing considering similar situations in detail twice, focusing on the scenarios that feature more new aspects when compared to the current situation, and focusing on those conflict scenarios of which it is most unclear whether the risk is tolerable or not.

Furthermore, during these interviews, the context of situations was always of importance. For instance, if an expert gave examples from his or her experience, the context revealed whether the specific situation could also occur in the operation now under consideration or if this is not possible.

The interview results serve an input to the frequency assessment, but as stated before, the frequency is assessed by the safety analysts, using argumentations based on the data and opinions retrieved.

Usage of terminology

In the severity and frequency assessment, frequently the terms '*deviation*' and '*separation*' are used. It is important that these are introduced properly, as this will avoid confusion.

In the current document the term '*deviation*' refers to a deviation of the aircraft from an '*ideal, four-dimensional conflict-free flight path*' that the aircraft could fly. The '*ideal flight paths*' of different aircraft are not in conflict with each other, and are such that air traffic controllers require a minimal number of instructions to control these aircraft.

Three types of deviations are distinguished: longitudinal (i.e. along the flight path), lateral (i.e. in the horizontal direction perpendicular to the flight path), and vertical deviations (i.e. into another altitude). Combinations of these deviation types are also possible.

It is noted that a deviation can thus be caused by an error or misunderstanding of a pilot or ATCo, but also by a non-optimal planning that causes an aircraft already having a deviation when it entering the TMA.

Next, an important issue is the separation between aircraft. Usually the controller can opt for two types of separation, either vertical separation or horizontal separation. In the TMA the vertical separation minimum is 1000ft, and the horizontal separation minimum is generally 3 NM, excluding stricter wake vortex separation minima. Since the horizontal separation minimum can be applied to aircraft both flying next to each other and behind each other, we call this separation horizontal separation in the current document. Only in some instances, if this makes the explanation clearer, the term '*longitudinal separation*' is used referring to head-tail horizontal separation between aircraft on the same route.

2.2. Conflict scenario 1: Conflict between aircraft merging

2.2.1. Introduction

This section considers the risk for conflict scenario 1: Conflict between two aircraft merging onto one route. The conflict scenario consists of three sub-conflict scenarios:

- 1a Conflict between two aircraft merging onto one route at MICOL
- 1b Conflict between two aircraft merging onto one route at NARSI (after a direct-to from SUGOL)
- 1c Conflict between two aircraft merging onto one route at EH708 (after an extended downwind)

2.2.2. Structure of conflict scenario 1

For an overview of the structure of this conflict scenario, one is referred to the general structure in Figure 3. In the current section, first the structure of the causes of the conflict scenarios is specified further, including a summary of the hazards playing a role in each cluster. It is noted that this structure is not identical for each sub scenario. Next, the resolution part of the conflict scenario is explained.

Root structure

The deviation of either one of the merging aircraft can cause the conflict scenario. The causes for conflict scenario 1 come from four hazard clusters:

B	Lateral deviation from optimal route (except for overshoots)
C	Vertical deviation from optimal route
D	Longitudinal deviation from optimal route (including deviations in timing and speed)
F	Deviations due to more general major hazards affecting several aircraft

The structuring of these clusters into the conflict scenario varies over the sub scenarios:

Structure of causes for sub scenario 1a

Necessary conditions for a conflict in sub scenario 1a are both a deviation in the vertical plane *and* a deviation in the horizontal plane. Reason is when aircraft coming from SUGOL and aircraft coming from RIVER merge at MICOL they should fly on different altitudes (see [S II D4.2-2a]), and they should have separation in the horizontal plane. Thus, both types of deviations are necessary conditions. A deviation in the horizontal plane can be caused by both a longitudinal and a lateral deviation; accordingly either a hazard in cluster C or a hazard in cluster D can be the cause. Deviations in the vertical plane are caused by hazards in cluster B.

Taking the viewpoint of the deviating aircraft, necessary conditions for a conflict are thus:

- A hazard in cluster C or a hazard in cluster D; *and*
- A hazard in cluster B; *and*
- The presence of another aircraft.

Hazards in cluster F can also cause the conflict; this is treated separately in the analysis of the sub scenario, as in this case the resolution of the conflict will be quite different.

Structure of causes for sub scenarios 1b and 1c

When merging at NARSI or EH708, vertical separation is not prescribed; however it is possible that the controllers do aim for this vertical separation. Therefore the occurrence of a hazard in cluster B is not a necessary condition for a conflict, and thus cluster B plays more a side role in the conflict. Necessary conditions for a conflict are here:

- A hazard in cluster C or a hazard in cluster D; *and*
- The presence of another aircraft.

Hazards in cluster F can also cause the conflict; which will again be treated separately in the analysis for the sub scenarios.

Summary of root hazards in the clusters

During the expert interviews the operational experts judge whether each group of hazards can play a significant role or not. This makes the operational expert aware of the hazards playing a role in a cluster, such that this expert can next judge better on the frequency of a whole cluster. Objective of the grouping below is merely to support the interviews and the frequency assessment by giving an overview which subjects play a role.

Cluster B: Lateral deviation

- *Navigation inaccuracy*: Because of the FMC software, loss of RNP caused by GPS signal loss or other NAVAID failure or errors, autopilot problems.
- *Database inaccuracy*: Examples are wrong or missing waypoints, and an outdated database.
- *Different behaviour in curves*: Cutting corners, differences between databases or aircraft.
- *FMS problems*: FMS interprets database differently, FMS does not accept a direct-to, FMS in the wrong mode.
- *Pilot error in route*: wrong waypoint entering, poor crew (situational) awareness, possibly because of TCAS.
- *ATCo error, including R/T confusion*: Wrong, late, or no clearance.
- *Weather influences*: Strong fluctuating crosswind, windshear.

If an aircraft deviates laterally from the intended flight path, merging the aircraft will become more difficult. It is noted that in sub scenario 1a however the aircraft will nominally still have vertical separation; in the other sub scenarios this is not necessarily the case.

Cluster C: Vertical deviation

- *Performance difference between aircraft*: For example different vertical speeds.
- *TCAS alerts*: TCAS can issue a vertical resolution alert.
- *QNH variation*: QNH may deviate or may be set wrongly, possibly because of forgetting a temperature correction.
- *Confusion about the altitude* following incorrect ATC clearance or a pilot error.

If an aircraft deviates vertically from the intended flight path, in sub scenario 1a this may mean that it has to be merged with the other traffic flow while the vertical separation is already lost. In sub scenarios 1b and 1c vertical deviation is not necessarily a conflict cause.

Cluster D: Longitudinal deviation

- Non-optimal *EAT timing accuracy* (that is, the timing at which ACC delivers the aircraft at the IAF).
- *Position errors*: Possible causes are computation errors and magnetic variations.
- *Performance differences* between different aircraft: different speeds, problems to loose both speed and height in time.
- *Incorrect speed instructions*: ATCos will have to rely more on speed instructions.
- *Weather influences*: Wind, turbulence.

If an aircraft deviates longitudinally from the intended flight path, merging the aircraft will generally become more difficult. In sub scenario 1a however the aircraft will nominally still have vertical separation; in the other sub scenarios this does not need to be the case.

Clusters B, C, and D: Combination of these deviations; hazards that cause a combination of the previous types of deviations.

- General *weather influences*. Wind, windshear, the procedure may become unflyable.
- *Wrong or inaccurate information*: ATIS, AIP, ATC route or flightplan errors, resolution of TCAS screen, publication error in procedure, procedure wrong, wrongly coded, wrongly loaded, incorrect title.
- General *pilot errors or confusion*: Workload and situational awareness may play a role. Also pilot wondering what to do when ATCo does not give clearance, is included. The pilot may fly the procedure manually.
- General *ATCo errors or confusion*: Workload and situational awareness may play a role; the controller might interfere too much.
- General *R/T errors or confusion*: Call sign confusion, failure in frequency changes, non-standardised phraseology.
- *Aircraft technical problems*: FMC takes too long to compute, or FMS failure.
- Culture differences, lacking training, unfamiliarity of pilots, confusing route design or nomenclature.
- Flightplan erroneous or missing from FMS.
- Pilot selects wrong route or runway, or flightplan erroneous or missing at ATC.
- Aircraft not capable or equipped for procedures, or total navigation system failure on single aircraft, or approach not properly armed.

Since these hazards can cause a combination of the deviation types, in each of the three sub scenarios it is possible that such a hazard immediately leads to a conflict, since they can cause loss of both vertical separation and horizontal separation.

Cluster F: Deviations due to more general major hazards

- Loss of radar.
- Loss of communication.

These are general types of hazards. It will be necessary to investigate the effect of these hazards in the operation under consideration separately from the other deviation causes, because these hazards can also affect the resolution of the conflict in a significant way.

Resolution structure

The resolution hazards that have been identified have been divided into hazards related to the pilots (cluster K), hazards related to the controllers (cluster L), and hazards related to communication (cluster M).

K	Resolution compromised, pilot related
L	Resolution compromised, controller related
M	Resolution compromised, communication related

Generally, for a conflict to be resolved it needs to be detected and next solved. If a controller detects the conflict, then hazards from all three clusters can prevent the resolution initiated after this detection, as the controller uses R/T to have a pilot make an action and solve the conflict. If a pilot detects the conflict, then hazards in cluster K are mostly important, though also then the hazards in cluster L and M can play a role in failure of the resolution, as the pilot may have contact with the controller first before taking action.

Resolution hazards can prevent conflicts from being solved, or can delay resolution. The longer resolution is postponed, the more severe the conflict will be. However, also geometry of the conflict plays a role in the severity. Therefore, in the frequency assessment the possible occurrence of these resolution hazards is taken into account when assessing the probability that a conflict end in an outcome of a certain severity.

In the following, it is summarised which hazards play a role in the resolution clusters:

Cluster K: Resolution compromised, pilot related

- A high crew *workload*, for instance because of the HMI, or after a speed instruction during the RNAV transition.
- A lacking *situational awareness* of the crew, for instance because of a poor cockpit layout, failure to see the other aircraft on the display, unclear nomenclature, failure to monitor alerts, because of TCAS.
- Crew *distraction* or restlessness (also headdown time).
- *TCAS alerts*, after a speed instruction, or when merging with different vertical speeds.
- *Culture differences*, for example in following procedures.
- Inadequate *contingency arrangements*.

Cluster L: Resolution compromised, controller related

- A high ATC *workload*, after GNSS failure, also because of HMI, and failure to monitor alerts.
- A lacking *situational awareness* of ATC, whether an aircraft is flying on a heading or RNAV, about RNAV equipment status, infrastructure availability, separation standards.
- Little *airspace available* for manoeuvring; conflicts have to be solved more by speed differences which requires a different strategy and may be impossible, VFR traffic may be interfering.
- *ATCo role* changes from controlling to monitoring (low workload, vigilance problems?).
- *Hand-over* of an aircraft that is not conflict free.
- Inadequate *contingency arrangements* and inadequate safeguarding.

- *Radar loss.*

Cluster M: Resolution compromised, communication related

- *R/T congestion*, also after simultaneous RNAV failure; if
- *A communication failure*, especially after NARSI.
- The lack of *party-line effect* when pilots are in different sectors.
- *R/T confusion*, because no clear identification difference between conventional and RNAV transition name or R/T too long to identify RNAV transition, or because of (non-standardised RNAV) phraseology, call-sign confusion
- A failure in *frequency change*.

2.2.3. Severity assessment for conflict scenario 1

Irrespective of the root hazards that cause the conflict and irrespective of the sub scenarios, the general severity definitions of Section 3.2 of [S II D4.2-2a] can be translated to the current conflict scenario; this is done as follows:

SIGNIFICANT INCIDENT: All non-nominal situations that are detected and resolved while separation (3NM or 1000ft) still exists, costing an increased workload, and situations in which the separation is violated somewhat while ATC or pilots are fully able to recover, such that the separation stays above a minimum of 1.5NM or 500ft.

MAJOR INCIDENT: The separation is not maintained, and no early detection and resolution of the situation by controllers or pilots takes place. The separation stays above 1.5NM or 500ft while the situation is not yet under control, or the separation gets below 1.5NM and 500ft while the situation is already under control.

SERIOUS INCIDENT: While the separation is already below 1.5NM and below 500ft the situation is still not under control, and thus an abrupt manoeuvre is required to avoid a collision (for instance after a late ATCo call, or a see-and-avoid action by one of the pilots), or the conflict is not detected and it is a matter of luck that a collision does not take place.

ACCIDENT: Here the conflict is not successfully resolved, and the geometry is such that the aircraft collide.

2.2.4. Frequency assessment for conflict scenario 1

The frequency assessment will take place per sub conflict scenario.

1a Conflict between two aircraft merging onto one route at MICOL

Root of the conflict

First the frequency is assessed for each type of deviation.

Longitudinal deviation: The EAT timing plays an important role in the concept considered. According to PLT_04 it would be much better if ATC would tell the pilots were to be at which moment (e.g., at the IAF, or at the merging point MICOL), than to use (many) speed instructions. Reason is that it is hard for ATC to know all the details about the behaviour of every single aircraft type. All interviewed experts agree that the difficulty of reaching an accurate EAT timing is a relevant cause for longitudinal deviation at the merging point. Also in the TMA the performance differences in combination with

speed instructions are important factors, and are causes for longitudinal deviations. Positioning errors are not expected to contribute significantly; weather influences such as wind can contribute.

According to ATC_07, every pair of aircraft will need speed instructions near MICOL (ATC_07). ATC_07 assesses that it is very probable that the separation around MICOL is not sufficient to maintain separation during the CDA; however separation is generally not yet the problem at the merging point. Furthermore, ATC_07 expects that about once per month the separation gets below 1.5 NM, while vertical separation of 1000ft is still maintained; this roughly corresponds to once every 17,000 flights.

ATC_10 expects that at the IAF speed deviations will occur more often than longitudinal, lateral or vertical deviations; this can cause longitudinal deviations before reaching MICOL.

PLT_03 expects longitudinal deviation around MICOL about once every 5 flights.

PLT_04 opines that longitudinal deviation is much more relevant than lateral deviation. However, PLT_04 expects that ATC will generally be able to guarantee separation. If using speed instructions then this will be at the cost of for instance a high workload. If ATC would however use fly-over times, thus telling the pilot at which moment to arrive at which point, then separation can be guaranteed much more easily.

It is concluded that because of longitudinal deviation horizontal separation will be infringed often (independent of the vertical separation), but not very often in a serious way.

Lateral deviation: Of the seven classes of causes mentioned (see Section 2.2.2, Cluster B), the interviewed experts agree that navigation inaccuracy does not play a significant role since it is based primarily on GPS instead of VOR/DME, and that database inaccuracy and FMS problems are not expected to play a significant role either. Weather influences may only contribute significantly in case of thunderstorms, but then the procedure will be terminated. The different behaviour of aircraft in curves is expected to be limited and relatively predictable. Accordingly, pilot errors and ATCo errors (or inaccuracy) are the most likely causes for significant lateral deviations.

ATC_07 expects that a significant lateral deviation will occur about once every 800 flights, but stresses that the frequency of pilot errors in this estimate must be confirmed by pilots. ATC_10 states that the aircraft will pass fairly well over the IAF; only in quiet periods aircraft may be given a short-cut.

In [QSA Approve], it was assessed for a similar conflict scenario that a 'large lateral deviation' occurs once every 2500 flights.

PLT_04 opines that lateral deviations are very infrequent, and that longitudinal deviations are much more relevant. PLT_03 expects lateral deviations to occur about once every 30 or 40 flights, but thinks these deviations are only small; note that this pilot also expects longitudinal deviation to occur significantly more often than lateral deviations.

It is concluded, that significant lateral deviations will occur significantly less frequently than longitudinal deviations.

Vertical deviation: The interviewed experts agree that the probability of significant vertical deviations near the merging point MICOL depends to a large extent on the way traffic is transferred by ACC at the IAF to APP. Though according to the description of the operation in [S II D4.2-2a] the aircraft are transferred by ACC while they fly level, it is questionable whether this will also be the case in reality. In current practice it also appears that aircraft are often still descending to their cleared flight level while passing over the IAF.

From the expert interviews the following conclusions are drawn on the five identified 'classes of causes' for vertical deviation (see Section 2.2.2, Cluster C): Performance differences between aircraft will only play a role in case the aircraft are still descending when approaching MICOL; they do not

appear very relevant otherwise. TCAS alerts may occur near the merging point; however the vertical deviation caused by such an alert is generally a conflict avoiding deviation, not a causing one. The variation of the QNH may play a role, depending on where the transition altitude between flight levels and heights will be. It is assumed (see [S II D4.2-2a], Section 4.3) that this transition altitude will be located higher than currently, in order to prevent a transition during the CDA. Accordingly, this could play a role before starting the CDA. Temperature correction, or forgetting to correct, is not expected to lead to deviations of hundreds of feet. Finally, general confusion about the altitude can always occur, but not very frequently.

ATC_07 assesses that a significant vertical deviation would occur about once a week on Schiphol airport given current traffic numbers. Using an estimated 200,000 approaches per year, this corresponds to about once every 4000 flights.

ATC_10 states that it does happen that aircraft do not pass the IAF at the correct altitude. In such case, ACC will clear the aircraft to the required altitudes. However, the approach controller can still deviate from this by having the aircraft fly at a different altitude, still respecting the required 1000ft separation.

PLT_03 expects a vertical deviation frequency of about once every 20 flights if the aircraft descend into the TMA; if they fly level, which they should, then this value is around once every 100 flights.

PLT_04 expects a vertical deviation of about 1000ft about once a year on Schiphol airport (this corresponds more or less to once every 200,000 flights); smaller deviations can occur more often.

It is concluded that small vertical deviations are expected to occur regularly.

Combination of these deviations: Some causes were identified that can potentially cause a combination of the previous kinds of deviations. However, ATC_07 states that most likely hazards will cause only one type of deviation. PLT_04 adds that if such a cause leads to a combination of deviations, this is more likely to be detected rapidly. PLT_03 remarks that this issue depends on the way traffic is handed over by ACC: if ACC hands over an aircraft that still flies 'fast and high', then longitudinal and vertical deviations could occur simultaneously. ATC_10 agrees on this.

General causes like radar failure and communication failure: The interviewed controller ATC_07 opines that a failure of the radar or the working position is an issue for which sufficient back-up possibilities exist, considering the low frequency of occurrence. Also, there is more than one radar. All interviewed experts agree that it is certainly not a bigger problem in the operation under consideration than in the current operation; perhaps the situation is even more safe, because the traffic flows are more predictable than the radar vectoring practices used today.

Total failure of communication with one or more aircraft for a significant period of time do not occur often (ATC_07, PLT_03); global ones are even very rare (PLT_04). Additionally, losses of communication are much less of a problem in the operation under consideration than in current Schiphol operations. This is the case because of the frequent vectoring in the latter, and everybody being sent to SPL FL70 in the latter. In the operation under consideration traffic flows are much more predictable (PLT_03, ATC_07). ATC_07 mentions however that the higher traffic rates in the TMA can increase the risk. In the current study only conflicts between approaching aircraft are considered, and the maximum number of approaching aircraft stays the same as in current operations. Therefore the effect of this is expected not be significant within this conflict scenario.

From these arguments it is concluded that these general causes do not contribute significantly to the accident and incident frequencies in this conflict scenario.

Resolution of the conflict

Generally, ATC_07 expects that conflicts may be solved somewhat less easily than in current operations, because there is less space available, especially at the traffic rates of 34 aircraft per runway per hour. PLT_03 expects the flight crew to have a higher workload, but also a better situational awareness in the operation considered than in current operations; the R/T load may also increase slightly. PLT_04 opines that in these kinds of conflicts the crew's part in conflict solving is limited.

For each of the deviation types, the resolution is considered:

Only longitudinal deviation: It was estimated by ATC_07 that once per month the horizontal separation due to longitudinal deviation gets below 1.5 NM, while vertical separation is still 1000ft. In such a case the controller must take serious action, mainly for keeping an efficient traffic stream and to maintain separation in the total traffic picture, thus also with the departing traffic.

PLT_03 states that this will generally not lead to a loss of separation, since vertical separation will generally be maintained. ATC_10 expects to work with a lot of shortcuts and direct-to instructions, as is also seen in the simulator session of ATC_10.

Only lateral deviation: Since it is unlikely and not particularly more critical that both aircraft deviate, there are four situations thinkable; the aircraft from SUGOL flying too much to the left or right, and the aircraft from RIVER flying too much to the left or right.

ATC_07 judges these four situations as not being such a problem. At the route from RIVER there is more time to correct deviations. Only lateral deviations of over 1 NM will give problems.

PLT_03 thinks these situations are generally not a problem; however if the aircraft from SUGOL deviates to the left then it must be taken care that the aircraft from RIVER does not start to descend on its intended CDA yet, as then separation is lost very fast.

It is noted that if the aircraft from RIVER deviates to the left, then it could be a problem if it starts its descent as it should.

Only vertical deviation: Following the same type of reasoning as for lateral deviations, here the situations to be considered are; the aircraft from SUGOL can fly either too low or too high, and the aircraft from RIVER can fly either too high or too low.

Again ATC_07 judges each one of these four situations as not being a problem, and adds that the deviations to lower altitudes are unlikely.

PLT_03 judges the situation of the aircraft from SUGOL flying too high as most relevant; generally, one will notice this and contact ATC, take action, or follow a TCAS alert.

Frequency assessment per severity class

SIGNIFICANT INCIDENT:

In a SIGNIFICANT INCIDENT separation is lost or at stake. This means that both laterally and vertically the separation is not assured. Considering the horizontal separation, it was judged that lateral deviations will occur much less frequently than longitudinal deviations. Longitudinal deviation will however occur very frequently. This is only considered as a SIGNIFICANT INCIDENT, if vertical separation is also infringed or at stake. Small vertical deviations are also expected to occur regularly, and it is thus clear that the frequency of this conflict scenario occurring and ending in a SIGNIFICANT INCIDENT is in the highest frequency class; thus, a SIGNIFICANT INCIDENT is expected to be PROBABLE.

MAJOR INCIDENT:

The severity can only become a MAJOR INCIDENT or worse if lateral or longitudinal deviation occurs *and* the vertical separation is lost, and if this happens in such a way that it is not assured that the spacing stays above half of the minimum separation.

Generally, near the merging point it is tried to have the aircraft separated both laterally and vertically. Accordingly, both horizontal separation and vertical separation must be lost significantly:

- From the expert statements on the vertical deviation above, it is expected that a vertical deviation that is so large that vertical separation can drop below half the separation minimum occurs about once every 1000 to 10,000 flights, based on the numerical estimates made when discussing the root of the conflict in the current section.
- Considering lateral and longitudinal deviations, it is clear from the above that laterally the separation will in many cases not be maintained. Here, mainly longitudinal deviations play a role. The common opinion of the experts appears to be that longitudinal separation may be infringed often, but not very often in a serious way. A loss of horizontal separation that is so large that the spacing may decrease below the half of the minimum, is expected to occur at most once every 10,000 flights, based on the numeric estimates made when discussing the root of the conflict in the current section.
- The frequency of loss of both lateral and vertical separation in such a way that separation can get below the half of the minimum is expected to be somewhat larger than the product of the individual probabilities, since there may be common causes that cause both types of deviation simultaneously. However, the effect of this was expected to be limited. Taking also in account that the conflicts were generally judged as 'not so critical' (ATC_07) and thus can be often solved before they become a MAJOR INCIDENT, it can be deduced that the MAJOR INCIDENT frequency should be REMOTE or even EXTREMELY REMOTE.
- As a special case the lateral deviation to the left by the SUGOL aircraft is considered, since in combination with an aircraft from RIVER that starts its CDA this can cause a conflict without the occurrence of vertical deviation. However, lateral deviations are expected to have a small frequency, and only in some cases this will be a significant deviation to the left, and only in some cases the RIVER aircraft will indeed be nearby and actually start the CDA, and in only some cases the situation can be such that the separation can drop below half the minimum. Accordingly, this is not expected to bring the frequency to another frequency class.

It is concluded that the MAJOR INCIDENT frequency will be REMOTE or even EXTREMELY REMOTE.

SERIOUS INCIDENT:

The SERIOUS INCIDENT frequency will be smaller still than the MAJOR INCIDENT frequency. In this case, the situation is still not under control while the spacing between the aircraft decreases below the half of the separation minima. This would require that both crews and the Air Traffic Controller would allow the conflict to develop this far. As all the interviewed experts are positive that the outcome of the current conflict scenario can be held in hand, it is expected that the serious incident frequency is in the EXTREMELY REMOTE class at worst.

ACCIDENT:

Last-grasp pilot and ATC actions may still prevent a situation that qualifies as a serious incident from becoming an accident. Also, the air is big and therefore a significant part of the 'serious incident' situations do not become an accident. Accordingly, because of these last-grasp actions and geometrical 'luck' the accident frequency is still significantly smaller than the serious incident frequency; it could be either EXTREMELY REMOTE or EXTREMELY IMPROBABLE.

1b Conflict between two aircraft merging onto one route at NARSI (after a direct-to from SUGOL)

Root of the conflict

Obviously, a precondition for a merging conflict near NARSI is that ATC sends an aircraft from the route from SUGOL direct to NARSI. ATC_07 and PLT_03 are confident that this will only occur outside peak hours, when there is sufficient space, and when a merging conflict near NARSI is very improbable. Also PLT_04 states that ATC will only give a direct NARSI if this will not cause any problems near NARSI. However, from the simulator session of ATC_10 it appears that ATC_10 frequently applies direct NARSIs. Also once the aircraft on the RIVER-MICOL-NARSI route gets a heading for a while in order to maintain sufficient separation with an aircraft from SUGOL to NARSI. Still, direct NARSIs are expected to be less frequent than aircraft from SUGOL flying via MICOL, though it is unclear if this will be slightly less (as for ATC_10) or much less (as stated by ATC_07, PLT_03, and PLT_04).

Though vertical separation is not prescribed for merging at NARSI, it is expected that generally 1000ft separation is maintained until horizontal separation is ensured (ATC_07, PLT_03). However, the conditional probability of a loss of vertical separation is still larger around NARSI than around MICOL, because 1000ft separation is not prescribed around NARSI while it is around MICOL. During the experimental run of ATC_10 vertical separation was not always maintained as ATC_10 was sure to control the situation laterally.

When comparing the NARSI situation to the MICOL situation, the effect of the lower frequency of merging situations is expected to at least as important as the effect of the larger conditional probability of loss of vertical separation. Therefore the conflict probability at NARSI is at most as large as around MICOL.

Resolution of the conflict

Considering the resolution of conflicts, ATC_07 states that merging is easier around NARSI than around MICOL because of the smaller angle between the traffic streams; but also that the possibility of controlling using speed instructions may be smaller because the speeds are already lower. PLT_03 expects that resolution is easier because speeds and speed differences are lower and thus there is more time to act in case of a conflict. PLT_04 on the other hand opines that the later in the approach the more difficult it is to solve a conflict. Therefore, it is not sure whether resolution is more or less difficult around NARSI than around MICOL; the differences however are expected to be limited.

Conclusion

Conflicts around NARSI are expected to have at most the same frequency as around MICOL, mainly because direct NARSI will only be applied when traffic permits. The differences in the resolution possibilities are limited. Therefore, the frequency of each severity class is expected to be of the same class as the frequency of conflict 1a at most.

1c Conflict between two aircraft merging onto one route at EH708 (after an extended downwind)

Root of the conflict

Extended downwinds can be used in case the traffic flow is still not optimal around NARSI. However, ATC_07 is very strong in the opinion that extended downwinds will never solve the problem of an aircraft that does not fit in, and that they will therefore not be applied. More precisely: once one aircraft gets an extended downwind, the next aircraft would also have to fly an extended downwind, and traffic handling thus gets poorer and poorer. Therefore, ATC_07 would rather send an aircraft back to the stack than give it an extended downwind. PLT_04 expects that the extended downwind will not be applied often, but only when necessary, and PLT_03 expects that it will be applied for say once every 10 aircraft. ATC_10 states that an extended downwind leg creates a strange turn, and that it creates a more complex vectoring situation, and that it will be preferred to prevent this in an earlier stage.

It is thus expected that extended downwinds will only be applied for a very small part of the approaching aircraft, and only when it is not very probable THAT they can cause a merging problem near EH708. It is recognised that it is questionable whether vertical separation will be applied when the aircraft do have to merge at EH708, but still conflicts will occur much less frequent near EH708 than near MICOL.

Resolution of the conflict

Similarly as for conflict scenario 1b, it is not sure whether resolution is more or less difficult around EH708 than around MICOL; the differences however are expected to be limited.

Conclusion

Compared to sub scenario 1a, the conflict probability is expected to be much smaller, and the resolution is not very different in sub scenario 1c. Therefore, the frequency of each severity class is expected to be at most of the same class as the frequency of conflict 1a, and possibly a class lower.

1 Total frequency estimates for conflict scenario 1

As an incident will occur in conflict scenario 1 if and only if an incident occurs in either one of the three sub scenarios, and as we consider the probabilities per flight, the frequency estimates for the three sub scenarios can be summed to retrieve the estimates for the total conflict scenario. The frequency estimates for conflict scenario 1c however show that these do not contribute significantly to the risk already associated with sub scenario 1a. Furthermore, the frequency estimates of conflict scenario 1b are at most as large as those for conflict scenario 1a.

However, one additional argument is to be included: the operational experts all agree that no unacceptable risks are expected in this part of the operation. ATC_10 believes that the operation will not give problems in practise, excluding conflict scenario 4. ATC_07 expects the only problems to occur in the end of the approach, e.g. after having passed NARSI for the approach to runway 18R. PLT_03 regards the concept of operation safer than the current operation, also excluding conflict scenario 4. PLT_04 does not see any essential differences with the safety of the current operations; a point of attention is that co-operation between pilots and ATC could be improved, by having ATC give the pilots more freedom to do what is necessary to obtain a specified goal.

For this reason it is concluded that the UNACCEPTABLE class does not apply to the current conflict scenario.

2.2.5. Risk assessment results for conflict scenario 1

The frequency assessment per severity class are combined in the following risk tolerability diagram:

Table 2: Risk tolerability matrix for conflict scenario 1

Severity Frequency	ACCIDENT	SERIOUS INCIDENT	MAJOR INCIDENT	SIGNIFICANT INCIDENT
PROBABLE	UNACCEPTABLE	UNACCEPTABLE	UNACCEPTABLE	TOLERABLE
REMOTE	UNACCEPTABLE	UNACCEPTABLE	TOLERABLE	NEGLIGIBLE
EXTREMELY REMOTE	UNACCEPTABLE	TOLERABLE	NEGLIGIBLE	NEGLIGIBLE
EXTREMELY IMPROBABLE	TOLERABLE	NEGLIGIBLE	NEGLIGIBLE	NEGLIGIBLE

It is concluded that the risk associated with this conflict scenario is assessed to be TOLERABLE.

2.2.6. Safety bottleneck identification for conflict scenario 1

As the risk associated with conflict scenario 1 is assessed to be TOLERABLE, no safety bottleneck identification takes place. However, the following issues are considered of importance:

- Though at the merging points no conflicts with UNACCEPTABLE risk occur, it is possible that the aircraft are not spaced in a 'perfect' way, and that problems will occur later on the route. If so, then this will appear in the other conflict scenarios.
- When applying short-cuts to NARSI, vertical separation is usually not provided. If this short-cut will be used more regularly than assessed, then this could have a negative impact on the safety level. Attention should be paid to this issue.

2.3. Conflict scenario 2: Conflict between two aircraft on the same route

2.3.1. Introduction

This section considers the risk for conflict scenario 2: Conflict between two aircraft on the same route. The conflict scenario consists of four sub-conflict scenarios:

- 2a Conflict between two aircraft on the same route before the CDA
- 2b Conflict between two aircraft on the same CDA
- 2c Conflict between two aircraft on the same extended downwind
- 2d Conflict between two aircraft on the same ILS

Figure 2 on page 13 shows where each of these conflict scenarios can occur.

2.3.2. Structure of conflict scenario 2

The general structure of a conflict scenario, given in Figure 3, is also valid here. The structure of the causes of the conflict scenarios is further specified, per sub scenario, in the current section. Also the resolution part of the conflict scenario is explained.

Root structure

The deviation of either one of the aircraft on the same route can cause the conflict scenario. The causes for conflict scenario 2 are in the following clusters:

B	Lateral deviation from optimal route (except for overshoots)
D	Longitudinal deviation from optimal route (including deviations in timing and speed)
F	Deviations due to more general major hazards affecting several aircraft

The structure of these clusters depends on the sub scenario:

Structure of causes in sub scenarios 2a, 2b, and 2d:

In sub scenarios 2a, 2b, and 2d the aircraft are following each other on the same route. If these get a conflict, this will mean that longitudinally something went wrong. Therefore, necessary conditions for a conflict are:

- A hazard in cluster D; *and*
- The presence of another aircraft.

Like for conflict scenario 1 the hazards in cluster F are treated separately as causes for the conflict scenario.

Structure of causes in sub scenario 2c:

In sub scenario 2c the aircraft are flying the extended downwind. Since this features a large curve, here a lateral deviation can also cause a conflict. The necessary conditions for a conflict are thus:

- A hazard in cluster B or a hazard in cluster D; *and*

- The presence of another aircraft.

Again, cluster F is also a cause and this is treated separately.

Summary of root hazards in the clusters

The hazard clusters B, D, and F were already explained and summarised for conflict scenario 1. Some hazards were however identified that apply specifically to conflict scenario 2. These are given in the following:

Cluster D: Longitudinal deviation

- Speed differences after the Outer Marker and between the Outer Marker and the threshold.
- Different systems fly the capture differently.

Cluster B: Lateral deviation

- Incompatibility between FMS logic and final approach leg length
- Uncertain a/c behaviour after downwind leg
- Low-end equipment does not allow leg type

Clusters B, and D: Combination of these deviations

- Pilot wonders what to do when ATCo does not give (APP) clearance

Cluster F: Deviations due to more general major hazards

For this cluster there are no additional hazards to the ones already listed for conflict scenario 1.

Resolution structure

Resolution of the conflict can be hampered by the hazards in clusters K, L, and M, as explained before for conflict scenario 1:

K	Resolution compromised, pilot related
L	Resolution compromised, controller related
M	Resolution compromised, communication related

For a summary of the hazards in these clusters one is referred to the description for conflict scenario 1 in Section 2.2.2; no additional hazards apply.

2.3.3. Severity assessment for conflict scenario 2

In the context of conflict scenario 2, the general severity definition of Section 3.2 of [S II D4.2-2a] is used similarly as in conflict scenario 1. However, here it is noticed that mainly the horizontal separation minimum is of importance, as in-trail flying aircraft are considered, and vertical separation is thus generally not maintained. The severity classes are thus:

SIGNIFICANT INCIDENT: All non-nominal situations that are detected and resolved while separation (1000ft or 3NM or larger in case of wake vortex separation) still exists, costing an increased workload, and situations in which the separation is violated somewhat while ATC or pilots are fully able to

recover, such that the separation stays above a minimum of half the longitudinal separation minimum or 500ft.

MAJOR INCIDENT: The separation is not maintained, and no early detection and resolution of the situation by controllers or pilots takes place. The separation stays above half the longitudinal minimum or 500ft while the situation is not yet under control, or the separation gets below half the longitudinal minimum and 500ft while the situation is already under control.

SERIOUS INCIDENT: While the separation is already below half the longitudinal minimum and below 500ft the situation is still not under control, and thus an abrupt manoeuvre is required to avoid a collision (for instance after a late ATCo call, or a see-and-avoid action by one of the pilots), or the conflict is not detected and it is a matter of luck that a collision does not take place.

ACCIDENT: Here the conflict is not successfully resolved, and the geometry is such that the aircraft collide.

2.3.4. Frequency assessment for conflict scenario 2

First, some general considerations are done, based on input from the real time simulations [S II D6.3 v0.2]. Next, the assessment of the frequencies for the sub scenarios is done, also using information on the occurrence of hazards in clusters B, C, D, and F as considered for conflict scenario 1..

General considerations

For assessing the frequencies for the longitudinal kind of problems which occur in this conflict scenario, the findings of the Sourdine II real time simulation results [S II D6.3 v0.2] are specifically of interest. Two separate sets of real time simulations were conducted, one set for cockpit simulations, and one set for ATC simulations. All these simulations focussed on the approach procedure for runway 18R, and those especially the longitudinal behaviour was taken into account in those simulations. Of course one should be careful to draw conclusions based on these simulations alone, as the number of runs is too low for statistical significance of frequencies of non-nominal events. However, interesting objective and subjective data was retrieved, and can be taken into account here.

In the cockpit simulations the approach on runway 18R was considered. The pilots were positive on the approach procedure considered here: the perceived safety was not significantly different from the baseline vectoring procedure. The same holds for their situational awareness, for their workload, and also for the acceptance of this procedure. Finally, the use of speed brakes did not differ significantly from that in the baseline procedure, which also indicates that safety was not at stake.

In the ATC simulations the traffic approaching runway 18R was under control by the ATCos and run by pseudo-pilots; the traffic to the parallel runway 18C was scripted. The general opinion of the participating controllers was that operation is perceived to be quite safe, as the use of fixed lateral paths seems safer than vectoring. Also, the situational awareness and their workload was considered to be good. However, in some cases the traffic load was too high, and some controllers had doubts whether the procedure is workable, because the controller becomes much more reactive than proactive, and hence the controller is less sure how things will develop.

2a Conflict between two aircraft on the same route before the CDA

This conflict will occur very infrequently, as the initial separation between aircraft entering the TMA is at least 5 NM (nominally), while the minimum separation in the TMA is 3 NM. It does not really matter whether peak hours or off-peak hours are considered, as in off-peak hours aircraft often enter the TMA in bunches. All this is confirmed by the results of the interview with ATC_07. Also, PLT_04 agrees most problems are expected further down the routes as separation decreases, and ATC_10 expects that when merging at MICOL the situation becomes more complex. PLT_03 is the only interviewed expert that expects more problems to occur in sub scenario 2a than in 2b, 2c, and 2d, as this expert expects the traffic flow there to be still not sufficiently orderly; and especially near ARTIP,

as there is more traffic than near the other IAFs. However, also here PLT_03 expects the risk to be comparable to or smaller than the current operations.

However, as PLT_03 stands quite alone here, and as it may be expected that these kinds of global traffic pictures are better judged by ATCos, it is concluded that because of decreasing separation along the route and because of the merging of two traffic streams at MICOL, the risk associated with conflict scenario 2a is insignificant when compared to the risk of sub scenario 2b, in which longitudinal conflicts of aircraft on the same CDA is considered. This holds for the frequency of all severity classes. Also, the interviewed experts expect the problems in the areas of sub scenario 2a to be small enough to justify concluding that the risk is TOLERABLE at most. Accordingly, the frequency of each severity class in this sub scenario is not further specified.

2b Conflict between two aircraft on the same CDA

The opinions of each of the experts on the frequencies and risk tolerability for this sub scenario are summarised as follows:

ATC_07 judged the situation as follows: *“The initial separation at the IAF may be insufficient to maintain separation until the runway in case of 34 aircraft per hour [...] If the capacity is increased above this, then this will lead to losses of separation (< 3 NM) after NARSI or EH708. In peak hours such a loss of separation can hardly be solved, because there is no space on the RNAV route to solve this well. If there would have been a solution then this would have been applied already before. Accordingly, in many cases an aircraft will have to get out of the sequence and return to the stack, where it has to be fitted in again. This is like an emergency solution that is not really workable: this is too labour-intensive, it costs too much attention, there may be problems concerning separation with departure routes, co-ordination, and other tasks. Safety is then at stake, and in a serious way.”* Furthermore, ATC_07 states there will be more problems with longitudinal separation on the CDA from RIVER/SUGOL than on the CDA from ARTIP.

ATC_10 however states that as long as ACC sticks to the agreements and delivers the traffic on the correct time, speed, height and position to APP, and if the wind is correct in the computer, then the controller only needs to monitor the flight. This expert does admit that FMSes are not very well in working with two parameters (that is, to fly a desired height *and* speed profile). Conclusion of ATC_10 is that here the operation will not give any problems in practise; much depends however on the details in the implementation, such as the exact R/T procedures, the way the ideas of the procedure designers are transferred by means of maps and databases, and so on.

PLT_03 expected the risk of this conflict scenario to be comparable to current operations, or slightly better, because of the improved brackets around the EAT with which ACC delivers the traffic to Approach. PLT_04 suggested to interview controllers on this type of conflicts; PLT_04 did expect however that closer to the runway, the margins are smaller.

Hence, one of the interviewed controllers expects the risk to become too high if the traffic rates are indeed as in the concept currently under consideration; the other expects that this scenario will not give any problems, provided that the details in the final implementation are really well handled. Also the general considerations described above resulting from the real-time simulations should be taken into account here.

Finally, it is concluded that it is uncertain whether the risk associated with this conflict scenario is TOLERABLE or not. Thus, though detailed frequency analysis appeared not to be possible, a final judgement on the risk is made: the risk is TOLERABLE at best, and possibly UNACCEPTABLE.

2c Conflict between two aircraft on the same extended downwind

Interviewed controller ATC_07 notes that there will not be two consecutive aircraft on the extended downwind, since the extended downwind will be avoided as much as possible, both in peak hours and in off-peak hours. ATC_07 would rather send an aircraft back to the stack than use the extended

downwind. The other interviewed controller, ATC_10, agrees that the extended downwind will not be used regularly, as it features a strange turn, and after an extended downwind the situation gets more complicated than if a heading would already have been applied before, e.g. between MICOL and NARSI. PLT_03 agrees that in sub scenario 2c conflicts are very unlikely. Therefore, the frequency of a conflict between two consecutive aircraft on the same downwind is negligible when compared to the other sub scenarios.

2d Conflict between two aircraft on the same ILS

The analysis for sub scenario 2b largely holds here as well, though ATC_10 claims that once ILS-established there will be no more problems. ATC_07 however claims that for the aircraft flying to runway 18R the problems are expected after passing NARSI or EH708, and PLT_04 stated that the further down the route, the smaller the margins, and thus problems get more and more probable. It is noted that in this sub scenario one can always initiate a missed approach.

The same conclusions as for sub scenario 2b apply here: the risk is TOLERABLE at best, and possibly UNACCEPTABLE.

2 Total frequency estimates for conflict scenario 2

As an incident or accident will occur in conflict scenario 2 if and only if an incident or accident occurs in either one of the four sub scenarios, the frequency estimates for the sub scenarios can thus be summed to retrieve the estimates for the total conflict scenario. The frequency estimates for conflict scenarios 2a and 2c show that these do not contribute significantly to the risk already associated with sub scenario 2b and 2d.

As such, the frequencies are determined by the sum of the frequencies for sub scenario 2b and 2d. Detailed frequency analysis was not possible, but a good final judgement on the risk could be made: the risk is TOLERABLE at best, and possibly UNACCEPTABLE.

2.3.5. Risk assessment results for conflict scenario 2

The conclusions drawn in Section 2.3.4 lead to the following risk tolerability diagram:

Table 3: Risk tolerability matrix for conflict scenario 2

Severity Frequency	ACCIDENT	SERIOUS INCIDENT	MAJOR INCIDENT	SIGNIFICANT INCIDENT
PROBABLE	UNACCEPTABLE	UNACCEPTABLE	UNACCEPTABLE	TOLERABLE
REMOTE	UNACCEPTABLE	UNACCEPTABLE	TOLERABLE	NEGLIGIBLE
EXTREMELY REMOTE	UNACCEPTABLE	TOLERABLE	NEGLIGIBLE	NEGLIGIBLE
EXTREMELY IMPROBABLE	TOLERABLE	NEGLIGIBLE	NEGLIGIBLE	NEGLIGIBLE

Accordingly, the risk is expected to be is TOLERABLE at best, and possibly UNACCEPTABLE.

2.3.6. Safety bottleneck identification for conflict scenario 2

From the frequency analysis it appears that sub scenarios 2b and 2d are the main contributors to the risk. Also, it appears that sub scenarios 2a and 2c do not contribute significantly to the risk, and that judging only these two sub scenarios, the risk would have been classified as TOLERABLE at worst.

Accordingly, safety bottlenecks are to be searched for in sub scenarios 2b and 2d: conflicts between aircraft flying on the same route, flying the CDA or already on the ILS.

Considering these sub scenarios 2b and 2d, it appears that though the risk on the routes from SUGOL and RIVER to runway 18R is larger than the risk on the route from ARTIP to 18C, all of these routes contribute to the possibly UNACCEPTABLE risk classification.

The reason for the risk being possibly UNACCEPTABLE is that longitudinal separation problems can occur caused by an insufficient initial separation at the IAF and by a reduced ability to provide separation in case of 34 aircraft per hour; this could ultimately lead to danger of collision. Though near the IAFs and also near the merging point MICOL still no problems are expected, this causes that later on losses of separation may occur. For the route to runway 18R this is expected to be possible after NARSI or EH708; for the route to runway 18C the similar part, at the end of the approach.

One cause for this reduced ability to maintain a good spacing can immediately be identified as a safety bottleneck: The declared capacity of 34 aircraft per hour per runway. When assuming a much lower traffic rate, then the risk can decrease to a level below (possibly) UNACCEPTABLE, as then the spacing between the aircraft is generally larger, and the controllers have more time and airspace available. This mainly follows from the interview with ATC_07, the controller who was confident in the risk being UNACCEPTABLE for the situation with 34 aircraft per hour.

Further causes why there is a reduced ability to maintain a good spacing are:

- The aircraft have trouble flying both a vertical profile and speed, also because changing circumstances (e.g., wind predictions change differ from actual wind) are not taken into account;
- The controllers become more reactive, and should not vector anymore while speed instructions have only limited efficacy, also because controllers do not know the exact performance and reaction of the aircraft; and
- The non-optimal timing of the traffic entering the TMA.

All these causes can also be regarded as safety bottlenecks, though it is unclear whether they all have to be solved in order to get the risk out of the UNACCEPTABLE region.

Furthermore, it is stressed by one of the experts interviewed that the details of the final implementation are of uttermost importance for the safety of the operation. This includes for instance the exact R/T procedures, the way the ideas of the procedure designers are transferred by means of maps and databases, and so on.

2.4. Conflict scenario 3: Conflict between two aircraft established on their respective localizers

2.4.1. Introduction

This section considers the risk for conflict scenario 3: Conflict between two aircraft established on their respective localizers. Accordingly, in this conflict scenario an aircraft deviates from its ILS course after it had already been ILS-established, and this causes a conflict with an aircraft that is approaching the parallel runway. Figure 2 on page 13 illustrates where this conflict scenario can occur.

2.4.2. Structure of conflict scenario 3

For the general structure of the conflict scenario one is again referred to Figure 3. The structure of the root and the resolution part of the conflict scenario is further explained next.

Root structure

The following clusters play a role in the root of the conflict:

B	Lateral deviation from optimal route (except for overshoots)
J	Unstable approach while ILS-established
C	Vertical deviation from optimal route

Structure of causes for conflict scenario 3

When both aircraft are already established on parallel ILSs a conflict can occur because of an unstable approach. Also, general lateral deviation hazards can cause the conflict. Accordingly, necessary conditions for a conflict are here:

- A hazard in cluster B or a hazard in cluster J; *and*
- The presence of another aircraft.

It is noted that the hazards in cluster C (vertical deviation) can also play a role in the conflict, as due to the staggering of the parallel runways the parallel approaching aircraft would normally not have the same height when conflicting laterally.

Summary of root hazards in the clusters

Hazard clusters B, and C have already been introduced in more detail in Section 2.2.2 on conflict scenario 1; most hazards mentioned play a role here as well, and no hazards are identified that play a role here but not in conflict scenario 1. Therefore, here only cluster J is described in more detail:

Cluster J: Unstable approach while ILS-established

- *ILS reliability* in parallel approaches; also: interruption and disturbance of the signal, and failure of the ILS receiver in the aircraft.
- The approach is not properly armed, or the approach is not executed in approach mode.
- *Unawareness* of the crew of the need to navigate accurately.
- *Auto-pilot* problems, or pilots may program the equipment while flying manually.
- *Weather* influences: turbulence, fluctuating strong crosswind, wind shear.

- The *wake vortex* of another aircraft.
- Limited *flyability* of the procedure, because of for instance automation confusion when a/c intercepts final "*from above*", or while descending.
- *Runway misidentification*: it may be possible that the parallel runway is detected visually.

Resolution structure

Resolution of the conflict can be hampered by the hazards in clusters K, L, and M, as explained before for conflict scenario 1.

K	Resolution compromised, pilot related
L	Resolution compromised, controller related
M	Resolution compromised, communication related

Additional resolution hazards in this conflict scenario are:

- Unclearness of the breakout procedure (unfamiliarity, language problems, inconsistency with other procedures, insufficient training).
- Obstruction of the breakout path by traffic or buildings.
- Sharp turns close to the ground.

Furthermore the hazards summarized for these clusters in Section 2.2.2 also play a role.

2.4.3. Severity assessment for conflict scenario 3

In the context of conflict scenario 3, the general severity definitions of Section 3.2 of [S II D4.2-2a] can not simply be used the way it was done in the previous conflict scenarios, since the aircraft on parallel ILSs are allowed to have a horizontal separation less than 3NM. Instead, the aircraft must keep on their own side of the NTZ. Therefore, the following severity classification is used:

SIGNIFICANT INCIDENT: All non-nominal situations that are detected and resolved while the aircraft have still not entered the NTZ, costing an increased workload, and situations in which an aircraft does enter the NTZ somewhat while ATC or pilots are fully able to recover, such that the aircraft does not get closer to the parallel lane than its own lane.

MAJOR INCIDENT: An aircraft does enter the NTZ, and no early detection and resolution of the situation by controllers or pilots takes place. The deviating aircraft does not get closer to the parallel lane than its own lane while the situation is not yet under control, or the aircraft does get closer while the situation is already under control.

SERIOUS INCIDENT: While the deviating aircraft is already closer to the parallel lane than its own lane and the separation is below 1.5NM and 500ft, the situation is still not under control, and thus an abrupt manoeuvre is required to avoid a collision (for instance after a late ATCo call, or a see-and-avoid action by one of the pilots), or the conflict is not detected and it is a matter of luck that a collision does not take place.

ACCIDENT: Here the conflict is not successfully resolved, and the geometry is such that the aircraft collide.

2.4.4. Frequency assessment for conflict scenario 3

In the frequency assessment of this conflict scenario use will be made of Assumption 1 in [S II D4.2-2a], Section 3.4. Accordingly, the risk of the conflict scenario will be compared to the similar conflict

scenario in current operations. Here it is assumed that a comparable situation in the current operation has TOLERABLE risk at most, unless the operational expert interviews indicate that this is not the case.

Root of the conflict

A conflict between two aircraft that were or are already established on their respective ILSs for runway 18C and 18R is very unlikely. This is stated by ATC_07 and PLT_03. The distances between these runways are namely quite large (2100 metres). Furthermore, PLT_03, PLT_04 and both ATCos interviewed agree that the situation is fully comparable to the situation in the current operations.

PLT_04 goes into the causes in some more detail: The most likely cause for the conflict considered is an ILS failure. However, the ILS ground station is monitored, and if it fails, the aircrew may still land based on the GPS. Furthermore, aircraft are usually equipped with three ILS receivers, and if these fail all three, the aircrew are likely to opt for a go-around. PLT_05 mentions extreme weather conditions and system failures as possible causes, but also states this conflict scenario is the least critical of all conflict scenarios considered.

Resolution of the conflict

All experts interviewed agree that the situation is fully comparable to the current situation. PLT_04 was questioned in some more detail about the specific resolution hazards for this conflict scenario. It appears that the break-out procedure is simple enough to be clear. There are no obstructing obstacles or buildings in the vicinity. Other traffic (e.g., a helicopter, coast guard) will not be allowed in the vicinity during these types of procedures, and thus cannot obstruct the break-out procedures. Sharp turns close to the ground are not expected, and thus will not form a problem. PLT_03 adds to these arguments of PLT_04 that in this situation an ATCo instruction will not be questioned but will immediately be followed.

Conclusion

It has appeared that in current operations the conflict is not seen as a critical situation. Furthermore, the experts are very confident that the conflict scenario is completely comparable to the current situation. Therefore, Assumption 1 in [S II D4.2-2a], Section 3.4 is used, to conclude that for this scenario the operation considered has TOLERABLE risk at most. It is therefore not judged necessary to detail the frequencies further. However, it is roughly assessed that the applicable frequencies are at most one class better than the TOLERABLE class, as NTZ intrusions are still possible because of weather influences or system failures, and not every intrusion will immediately be corrected.

2.4.5. Risk assessment results for conflict scenario 3

The conclusions drawn in Section 2.4.4 lead to the following risk tolerability diagram:

Table 4: Risk tolerability matrix for conflict scenario 3

Severity Frequency	ACCIDENT	SERIOUS INCIDENT	MAJOR INCIDENT	SIGNIFICANT INCIDENT
PROBABLE	UNACCEPTABLE	UNACCEPTABLE	UNACCEPTABLE	TOLERABLE
REMOTE	UNACCEPTABLE	UNACCEPTABLE	TOLERABLE	NEGLIGIBLE
EXTREMELY REMOTE	UNACCEPTABLE	TOLERABLE	NEGLIGIBLE	NEGLIGIBLE
EXTREMELY IMPROBABLE	TOLERABLE	NEGLIGIBLE	NEGLIGIBLE	NEGLIGIBLE

Accordingly, the risk associated with conflict scenario 3 is TOLERABLE.

2.4.6. Safety bottleneck identification for conflict scenario 3

As the risk associated with conflict scenario 3 is assessed to be TOLERABLE, no safety bottleneck identification takes place.

2.5. Conflict scenario 5: Wake vortex encounter

2.5.1. Introduction

In this section the risk is considered for conflict scenario 5: Wake vortex encounter. As is illustrated in Figure 2 on page 13, this conflict scenario consists of four sub scenarios:

- 5a An aircraft flies into the wake vortex of an aircraft of the traffic flow that it is to be merged with
- 5b An aircraft flies into the wake vortex of the preceding aircraft in the same approach flow
- 5c On the parallel approach an aircraft flies into the wake vortex of the aircraft flying on the parallel lane
- 5d While turning in for parallel approaches an aircraft flies into the wake vortex of the aircraft turning in on the parallel lane

The sub division of this conflict scenario into the sub scenarios 5a, 5b, 5c, and 5d is similar to the division of the collision risk into conflict scenarios 1, 2, 3, and 4, as can be seen in the following table:

Table 5: Relations between the collision risk related conflict scenarios and the wake vortex related sub scenarios 5a to 5d.

Situation	Risk related to danger of collision	Risk related to danger of wake vortex
Merging aircraft	Conflict scenario 1	Sub scenario 5a
Aircraft on same route before CDA	Conflict scenario 2	Sub scenario 5b
Aircraft on parallel ILSs	Conflict scenario 3	Sub scenario 5c
Aircraft turning in	Conflict scenario 4	Sub scenario 5d

2.5.2. Structure of conflict scenario 5

For the general structure of the conflict scenario one is again referred to Figure 3. The structure of the root and the resolution part of the conflict scenario is further explained next.

Root structure

The causes of this conflict are part of cluster G, which considers wake vortex encounters.

G	Wake vortex encounter
---	-----------------------

Hazards that cause a deviation, such as those in clusters B, C, and D, may also play a role, but as this is more indirectly, these will not be considered in detail again here.

Structure of causes for conflict scenario 5

Often the wake vortex encounters follow from aircraft being too close to each other; therefore the hazards causing a deviation also play a role. For sub scenario 5a the structure of deviations leading to aircraft being too close together is similar as for conflict scenario 1; for sub scenario 5b similar to conflict scenario 2, and for sub scenario 5c similar to conflict scenario 3. The causes for the deviation for sub scenario 5d are similar as for conflict scenario 4; see [S II D4.2-2c].

Summary of root hazards in the clusters

The hazards in cluster G are typically related to the possible kinds of wake vortex encounter that can occur, which already appears in the sub scenario definition. Furthermore wind may be an important

factor, for instance blowing the vortex from one lane to another. Also, wake vortices travel downwards in time.

Resolution structure

The resolution hazards are again those in clusters K, L, and M:

K	Resolution compromised, pilot related
L	Resolution compromised, controller related
M	Resolution compromised, communication related

These clusters have already been discussed in detail.

2.5.3. Severity assessment for conflict scenario 5

A wake vortex can either cause controllability problems of the aircraft that flies into it, or structural damage to that aircraft. For both kinds of problems, the general severity classes introduced in Section 3.2 of [S II D4.2-2a], can be used again. From [QSA ATC-Wake] some more information is retrieved:

The interception angle of the aircraft with the wake vortex is of importance. This interception angle is defined such, that if an aircraft flies into the wake vortex of an aircraft that was flying in front of it in exactly the same direction, this angle is zero. Small interception angles will generally result in controllability problems. Higher interception angles will generally result in structural damage.

According to the experts interviewed for [QSA ATC-Wake], the main severity indicators for controllability problems are the roll angle due to the vortex encounter, the altitude at which the encounter occurs, and the pilot reaction. In particular, vortex encounters with large roll angles, at low altitudes and with unfavourable pilot reaction are more severe. With respect to structural damage, the main severity indicator is whether or not the damage leads to a situation that is within the aircrew's capabilities.

In sub scenario 5b the aircraft fly in-trail and therefore the interception angles will be small. Here controllability problems are expected. For the other three sub scenarios both small and large interception angles are possible; therefore both structural and controllability problems can occur.

2.5.4. Frequency assessment for conflict scenario 5

Root and resolution of this conflict scenario are considered at once. The four 'sub scenarios' introduced before will be considered separately.

5a An aircraft flies into the wake vortex of an aircraft of the traffic flow that it is to be merged with

PLT_03 expects that wake vortex issues are not really a problem around the merging points. Around the main merging points, especially MICOL, 1000ft separation will tried to be maintained, and it is improbable that the wakes go down that much. ATC_10 never heard of a wake vortex encounter in a merging situation. Furthermore, the opinion of the experts generally is that the encounters are more probable when aircraft fly in-trail; therefore sub scenario 5b will contribute more to the risk than sub scenario 5a.

5b An aircraft flies into the wake vortex of the preceding aircraft in the same approach flow

It appears from the interviews that this sub scenario is the most interesting from a safety point-of-view. The general opinion of the interviewed experts is that the closer to the runway, the more critical it gets, because the ground becomes closer and because separation decreases.

Comparison is made to the current operation, in which also the same traffic numbers apply. Further away from the runway the aircraft do fly more in-trail than in the current vectoring operation, and thus the risk may be somewhat higher than in current operations. However the bulk of the risk is currently near the runway, as longitudinal separation decreases during the approach. As seen in conflict scenario 2, it is possible that it occurs that this decrease in separation is significant. This is mainly built on the opinion of ATC_07; see Section 2.3.4 for more on this issue. It is unclear whether this will cause only losses of separation (as in conflict scenario 2), or also wake vortex problems. Therefore, it cannot be ruled out that this will cause the risk to get into the UNACCEPTABLE class; the risk is assessed to be TOLERABLE at best.

5c On the parallel approach an aircraft flies into the wake vortex of the aircraft flying on the parallel lane; and

5d While turning in for parallel approaches an aircraft flies into the wake vortex of the aircraft turning in on the parallel lane

These sub scenarios each consider two aircraft on parallel lanes for final approach; in sub scenario 5d at least one of these two aircraft is turning in, while in sub scenario 5c both aircraft are already ILS established. In certain crosswind conditions, the wake may travel from one parallel lane to another. The interviewed experts agree however that wake vortex encounters are more relevant for the aircraft that fly in-trail (which are considered in sub scenario 5b). But, they also mentioned that when compared to current operations, the turning-in may become somewhat more prone to wake vortex encounters, as the 1000ft vertical separation rule between parallel approaches is not in force in the concept of operation considered.

Some small calculations can be made 'on-the-back-of-an-envelope' to get more feeling for the probability of these wake vortex encounters. The assumed crosswind component limits for landing runway selection are 20 knots (including gusts), and the distance between the runways is 2100 metres (see Section 4.1 in [S II D4.2-2a] for these data). Conservatively, a crosswind component of 20 knots is here assumed, and it is not taken into account in the following that such strong crosswinds could have a negative impact on the lifetime of wake vortices. Then it would take about 210 seconds for the centre of a wake to travel from one runway to another. As the wake vortex expands in time, the edge of the wake vortex will reach the other runway somewhat before; for this edge it takes in the order of 190 seconds to reach the other runway. From [Hallock et al., 2003] it can be read that the most severe wake vortices, those of aircraft of the Heavy weight category, have a lifetime that is more or less Gaussian distributed with a mean of 100 seconds. At least 90% of those wakes last shorter than 180 seconds. Accordingly, it is quite improbable that a wake vortex travels from one runway to the other while it still has not decayed sufficiently not to cause a wake vortex encounter.

Due to the staggering of the runways and because wake vortices descend in time, aircraft approaching runway 18C can only be hindered by aircraft approaching runway 18R in a combination of crosswind and tailwind. Without the tailwind, the wake vortex would namely be blown under the path of the aircraft approaching runway 18R. As the tailwind criteria are strict, and the staggering of the runways is substantial, this scenario is very improbable.

Aircraft approaching runway 18R can be hindered by the vortex of an aircraft approaching runway 18C in strong Eastern wind. However, this wind is relatively rare on Schiphol airport, and it already appeared that given the crosswind limits it is quite improbable that a wake vortex is blown from one runway to another while it still has not decayed.

It is concluded that these sub scenarios will not play a significant role in the total frequency assessment for this conflict scenario.

5 Total frequency estimates for conflict scenario 5

The risk of this conflict scenario is determined by sub scenario 5b; consequently the risk is in the UNACCEPTABLE class or TOLERABLE at best. More detailed frequency analysis did not take place.

2.5.5. Risk assessment results for conflict scenario 5

The conclusions from Section 2.5.4 lead to the following risk tolerability diagram:

Table 6: Risk tolerability matrix for conflict scenario 5

Severity Frequency	ACCIDENT	SERIOUS INCIDENT	MAJOR INCIDENT	SIGNIFICANT INCIDENT
PROBABLE	UNACCEPTABLE	UNACCEPTABLE	UNACCEPTABLE	TOLERABLE
REMOTE	UNACCEPTABLE	UNACCEPTABLE	TOLERABLE	NEGLIGIBLE
EXTREMELY REMOTE	UNACCEPTABLE	TOLERABLE	NEGLIGIBLE	NEGLIGIBLE
EXTREMELY IMPROBABLE	TOLERABLE	NEGLIGIBLE	NEGLIGIBLE	NEGLIGIBLE

Accordingly, the risk associated with conflict scenario 5 is TOLERABLE or possibly UNACCEPTABLE.

2.5.6. Safety bottleneck identification for conflict scenario 5

From the frequency analysis it is clear that sub scenario 5b is the main contributor to the risk. From the expert opinions retrieved and from the assessment above it can be concluded that without this sub scenario, the risk would have been classified as TOLERABLE. Accordingly, safety bottlenecks are to be searched for in sub scenario 5b: An aircraft flies into the wake vortex of the preceding aircraft in the same approach flow.

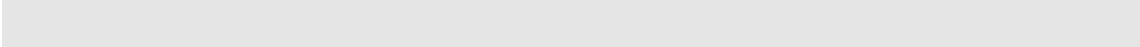
From the frequency assessment it immediately follows that the causes for the fact that the risk is classified as possibly UNACCEPTABLE are the same ones as the causes for conflict scenario 2 to be classified as UNACCEPTABLE. For conflict scenario 2 it was identified that the safety bottlenecks could lead to reduced separation and thus, ultimately, danger of collision; for the current conflict scenario 5 the same bottlenecks lead to the same decrease in separation, but here this leads to a danger of a wake vortex encounter.

Accordingly, the main conclusions from the safety bottleneck identification from conflict scenario 2 can be repeated here:

- The risk is possibly UNACCEPTABLE for both the approach procedure to runway 18C and the one to runway 18R. The reason for the risk being possibly UNACCEPTABLE is that longitudinal separation problems can occur caused by an insufficient initial separation at the IAF and by a reduced ability to provide separation in case of 34 aircraft per hour; this could ultimately lead to danger of collision; the most critical area is between passing NARSI and the runway threshold of runway 18R or similar for runway 18C.
- The reduced ability of the controllers to maintain a good is related to:
 - The aircraft have trouble flying both a vertical profile and speed, also because changing circumstances (e.g., wind predictions change differ from actual wind) are not taken into account;
 - The controllers become more reactive, and should not vector anymore while speed instructions have only limited efficacy, also because controllers do not know the exact performance and reaction of the aircraft;
 - The declared capacity of 34 aircraft per hour; and

- The non-optimal timing of the traffic entering the TMA.
- The details of the final implementation (R/T procedures, maps) are of importance for the safety of the operation.

It is noted that also more direct wake vortex related hazards could be seen as safety bottlenecks. For instance, if the wind is very weak, the wake vortex will generally not decay fast. 'Weak wind conditions' may thus also be regarded as a safety bottleneck. However, it is clear that if such a safety bottleneck would be solved (for example by using this procedure only in other wind conditions), then conflict scenario 5 may not bear UNACCEPTABLE risk anymore, but in conflict scenario 2 nothing would have changed; also, it is clear that the core of the problem would not be solved. Therefore, only aspects that cause both conflict scenario 2 and 5 to bear possible UNACCEPTABLE risk are here considered as safety bottlenecks.



3. Summary of results

The Sourdine II safety assessment for Schiphol considers an operation as foreseen in the year 2015 at Schiphol. It is expected that by then, Schiphol will accommodate 625,000 movements per year. To facilitate this amount of aircraft, 2x2-runway usage is proposed. This implies two landing and two departure runways are active simultaneously. Each runway has a capacity of 40 departures per hour or 34 arrivals per hour. The Schiphol TMA has the same size, the same partition in sectors, and the same three Initial Approach Fixes (IAFs) as in the present situation: RIVER, SUGOL, and ARTIP. For this study new approach procedures have been developed. The main goal of these procedures is to reduce noise load.

Obviously, a newly proposed concept of operation cannot be implemented if it is not sufficiently safe. Therefore, the Sourdine II project includes a safety assessment of this proposed operation. This safety assessment is documented in [S II D4.2-2a], the current D4.2-2b, and [S II D4.2-2c]. The possible hazards in the operation have been clustered into five conflict scenarios (see [S II D4.2-2a]), and each conflict scenario is assessed using either an argumentation-based approach (results described in the current document) or a simulation-based approach (results described in [S II D4.2-2c]).

It is stressed that the current part, D4.2-2b, serves as an input for [S II D4.2-2a], and that no conclusions should be drawn from the current D4.2-2b as such. In [S II D4.2-2a] the scope and context of the study, the description of the operation under study, and TOPAZ, the methodology followed, are explained. Also, the conclusions are contained in [S II D4.2-2a].

The argumentation-based approach is used for four conflict scenarios:

- 1 Conflict between two aircraft merging onto one route
 - a At MICOL
 - b At NARSI (after a direct-to from SUGOL)
 - c At EH708 (after an extended downwind)
- 2 Conflict between two aircraft on the same route
 - a Two aircraft on the same route before the CDA (from ARTIP, SUGOL or RIVER)
 - b Two aircraft on the same CDA (from ARTIP or the one from RIVER/SUGOL)
 - c Two aircraft on the extended downwind
 - d Two aircraft on the same ILS
- 3 Conflict between two aircraft established on their respective localizers (one for 18R and one for 18C)
- 5 An approaching aircraft encounters the wake vortex of another aircraft in approach.
 - a An aircraft flies into the wake vortex of an aircraft of the traffic flow that it is to be merged with
 - b An aircraft flies into the wake vortex of the preceding aircraft in the same approach flow
 - c On the parallel approach an aircraft flies into the wake vortex of the aircraft flying on the parallel lane
 - d While turning in for parallel approaches an aircraft flies into the wake vortex of the aircraft turning in on the parallel lane

The results are summarised in the following four risk tolerability diagrams, of which the interpretation is explained in [S II D4.2-2a]:

Table 7: Risk tolerability matrix for conflict scenario 1

Severity Frequency	ACCIDENT	SERIOUS INCIDENT	MAJOR INCIDENT	SIGNIFICANT INCIDENT
PROBABLE	UNACCEPTABLE	UNACCEPTABLE	UNACCEPTABLE	TOLERABLE
REMOTE	UNACCEPTABLE	UNACCEPTABLE	TOLERABLE	NEGLIGIBLE
EXTREMELY REMOTE	UNACCEPTABLE	TOLERABLE	NEGLIGIBLE	NEGLIGIBLE
EXTREMELY IMPROBABLE	TOLERABLE	NEGLIGIBLE	NEGLIGIBLE	NEGLIGIBLE

Table 8: Risk tolerability matrix for conflict scenario 2

Severity Frequency	ACCIDENT	SERIOUS INCIDENT	MAJOR INCIDENT	SIGNIFICANT INCIDENT
PROBABLE	UNACCEPTABLE	UNACCEPTABLE	UNACCEPTABLE	TOLERABLE
REMOTE	UNACCEPTABLE	UNACCEPTABLE	TOLERABLE	NEGLIGIBLE
EXTREMELY REMOTE	UNACCEPTABLE	TOLERABLE	NEGLIGIBLE	NEGLIGIBLE
EXTREMELY IMPROBABLE	TOLERABLE	NEGLIGIBLE	NEGLIGIBLE	NEGLIGIBLE

Table 9: Risk tolerability matrix for conflict scenario 3

Severity Frequency	ACCIDENT	SERIOUS INCIDENT	MAJOR INCIDENT	SIGNIFICANT INCIDENT
PROBABLE	UNACCEPTABLE	UNACCEPTABLE	UNACCEPTABLE	TOLERABLE
REMOTE	UNACCEPTABLE	UNACCEPTABLE	TOLERABLE	NEGLIGIBLE
EXTREMELY REMOTE	UNACCEPTABLE	TOLERABLE	NEGLIGIBLE	NEGLIGIBLE
EXTREMELY IMPROBABLE	TOLERABLE	NEGLIGIBLE	NEGLIGIBLE	NEGLIGIBLE

Table 10: Risk tolerability matrix for conflict scenario 5

Severity Frequency	ACCIDENT	SERIOUS INCIDENT	MAJOR INCIDENT	SIGNIFICANT INCIDENT
PROBABLE	UNACCEPTABLE	UNACCEPTABLE	UNACCEPTABLE	TOLERABLE
REMOTE	UNACCEPTABLE	UNACCEPTABLE	TOLERABLE	NEGLIGIBLE
EXTREMELY REMOTE	UNACCEPTABLE	TOLERABLE	NEGLIGIBLE	NEGLIGIBLE
EXTREMELY IMPROBABLE	TOLERABLE	NEGLIGIBLE	NEGLIGIBLE	NEGLIGIBLE

Accordingly, the risks of conflict scenarios 1 and 3 are assessed to be TOLERABLE, and the risks of conflict scenarios 2 and 5 are either TOLERABLE or UNACCEPTABLE. For the two conflict scenarios that have *possibly* UNACCEPTABLE risk (conflict scenarios 2 and 5), the main conclusions from the safety bottleneck identification are given:

- The risk is possibly UNACCEPTABLE for both the approach procedure to runway 18C and the one to runway 18R. The risk is possibly UNACCEPTABLE because of the last part of the approach, between passing NARSI and the runway threshold of runway 18R or similar for runway 18C. The reason for the risk being possibly UNACCEPTABLE is that longitudinal separation problems can occur caused by an insufficient initial separation at the IAF and by a reduced ability to provide separation in case of 34 aircraft per hour; this could ultimately lead to danger of collision.
- Conflict scenarios 2 and 5 feature the same safety bottlenecks; in both scenarios the reduced ability to maintain separation could lead to reduced separation. In conflict scenario 2 this could lead to reduced separation and thus, ultimately, danger of collision; for conflict scenario 5 the same decrease in separation could lead to a danger of a wake vortex encounter.
- The reduced ability of the controllers to maintain a good spacing when assuming 34 aircraft per hour is related to:
 - The aircraft have trouble flying both a vertical profile and speed, also because changing circumstances (e.g., wind predictions change differ from actual wind) are not taken into account;
 - The controllers become more reactive, and should not vector anymore while speed instructions have only limited efficacy, also because controllers do not know the exact performance and reaction of the aircraft;
 - The declared capacity of 34 aircraft per hour; and
 - The non-optimal timing of the traffic entering the TMA.
- The details of the final implementation (R/T procedures, maps) are of importance for the safety of the operation.
- Conflict scenario 5 considers wake vortex encounters and thus also more directly wake vortex related hazards could be seen as safety bottlenecks. However, it is judged that the relevant safety bottlenecks are the common causes that cause the high risk of both conflict scenarios 2 and 5. Accordingly, no more directly wake vortex related safety bottlenecks have been identified.