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Independent Parallel CDAs (IPC)

Final report

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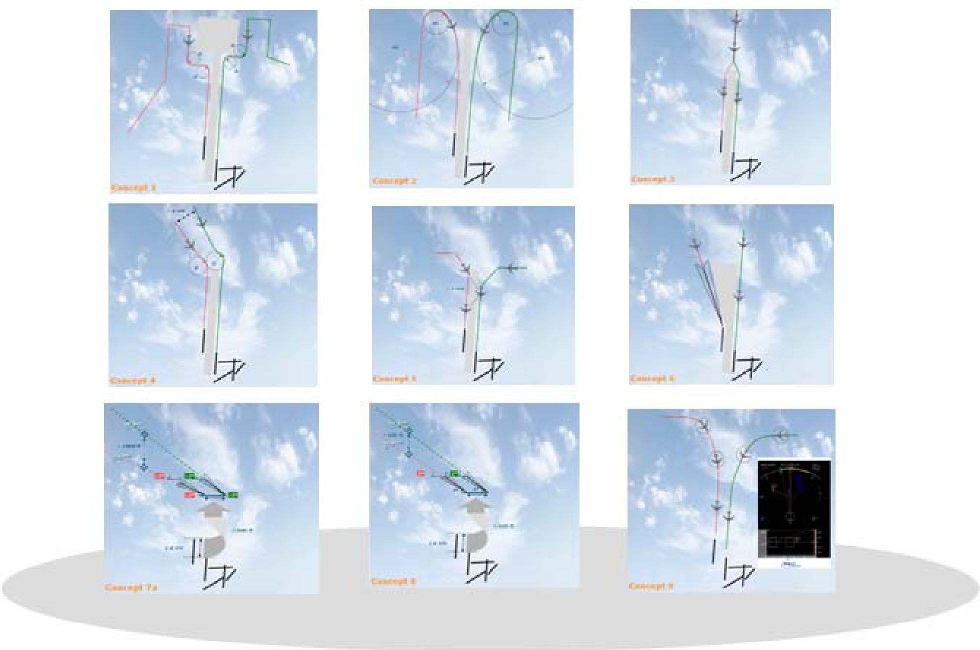

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Summary

During independent parallel approach operations ICAO prescribes a 1000 ft vertical separation requirement as long as both aircraft are not established on the ILS localiser. The primary goal of the IPC project was to derive potential solutions to abandon the need for 1000 ft vertical separation in order to facilitate the introduction of continuous descent approach operations.

For the purpose of the IPC project "independent" was defined as "the lateral and vertical profile of an aircraft approaching runway 18R is not dependent on the lateral and vertical profile of an aircraft approaching runway 18C, or vice versa". Independency is of major importance to ATC to facilitate parallel CDAs during high traffic volumes without the need for intensive monitoring and controlling.

This document describes the steps undertaken to determine and evaluate potential solutions and effectively contains the main results of four separate working documents:

1. IPC Baseline Document
2. IPC Concept Description
3. Safety Assessment Report
4. Quickscan Human Factors

The identification of solutions, concept development and evaluation was conducted via two IPC workshops in which pilots, air traffic controllers, procedure design experts, safety experts, ATM experts and concept development experts participated. The involved organisations included Eurocontrol, KLM, LVNL, AAS, NLR, TUDelft, To70 and MITRE. Through separate IPC Project Team meetings, results were structured, analysed and documented.

During the 1st IPC Workshop (September 2009) a total of 18 individual potential solutions were identified which were combined to form ten concepts. From these ten concepts, two concepts with each two alternatives were selected and worked out in more detail in terms of controller and pilot procedures and procedure design considerations.

It was concluded that the goal set for the IPC project proved to be ambitious because abandoning the vertical separation criteria set by ICAO during a critical phase of flight naturally poses complex issues to be solved. A complicating factor is that such procedures should ideally not comprise the landing capacity. Such research had not yet been performed anywhere before. Despite the ambitious goal of the IPC Project, viable solutions have been identified and integrated to form preliminary operational concepts.

The preferred lateral path concept with S-type approach and "trombones", developed within the LVNL P-RNAV CONOPS Project, was adapted. This resulted in two main concepts. Essentially, both concepts share the similar principle which is to focus on solutions in the lateral domain and both concepts have the same ATM building blocks in common.

For each of the two concepts two alternatives were used to cater for added flexibility for ATC: Alternative I which uses radar vectoring to direct aircraft towards a fixed lateral path and Alternative II where a fixed lateral path from IAF to FAP is flown.

The two concepts and alternatives have been evaluated during a 2nd IPC Workshop (December 2009) and subjected to an initial safety assessment. Evaluation of the concepts has learned that the preliminary concepts can be a starting point for further development. However, it should be noted that the preliminary concepts are dependent on progress in the fields of navigational performance (PBN) and developments with regards to regulatory aspects.

A preference for either Concept 1 (“S-type small fixed turns”) or Concept 2 (“S-type small fixed turn and straight-in”) was not explicitly expressed during the IPC Workshops. Both concepts apply the same principle. Differences mainly exist in the geographical location of the lateral path which has a bearing on which populated areas will be overflown.

Additional research with regard to the following topics is required:

- Identify the options for ATC to detect and resolve conflict situations;
- Incorporating more details in terms of procedure design, especially with regard to the vertical profile;
- In the IPC project a number of aspects were excluded in order to simplify the design of concepts; for example the interaction between inbound and outbound traffic flows and airspace requirements. These aspects need to be integrated in a more mature version of the current operational concepts.

The following actions are recommended to develop a more mature concept:

1. Address regulatory issues
   In case solutions are pursued where the value of 1000 ft vertical separation criteria during turn on final is to be reduced, or completely abandoned, ample evidence that safety is not compromised will be needed. Since this regulatory topic is expected to be scrutinised at international levels (ICAO), it should be initiated at an early stage because any amendments to standards are expected to take up at least 5-7 years. As part of the research, preferably to be conducted by, or on behalf of, an ICAO working group, the assumptions made that resulted in the value of 1000 ft for the vertical separation on turning towards parallel finals will need to be re-evaluated.
   Also when no formal vertical separation would exist during turn to parallel finals, the responsibilities of air traffic controllers (i.e. controlling versus monitoring) need to be carefully reviewed and potentially changed.
   The implementation of Performance Based Navigation (PBN) in the Schiphol TMA and associated aircraft certification aspects should be aligned with the concept in order to fly precise lateral paths.

2. Develop a safety assessment plan
   The safety assessment should determine the possibilities for ATC to detect and resolve conflict situations, assess the suitability of mitigation measures such as NTZ, determine the behaviour of TCAS, and to determine the probability of overshoots at critical waypoints.
   It is recommended to conduct real-time simulation experiments to support the safety assessment, to assess capacity figures when conducting CDAs and to support the definition of a mature concept and procedure design. Prior to the safety assessment and real-time simulations, a more detailed concept description and procedure design is needed as a starting point bearing in mind the topics listed in paragraph 5.4.

As part of the safety assessment, an analysis of flight track data to understand the potential deviations when TF and RF-leg terminators are used is recommended.

Once the concept has reached sufficient maturity, a stepwise introduction, e.g. on a single runway or non-parallel runways (06 + 36R) is recommended to gain experience and monitor aircraft behaviour in practice.

Contents

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Abbreviation	Description
AAA	Amsterdam Advanced ATC
ALARP	As Low As Reasonably Practicable
APP	Approach controller
APV	Approach with Vertical Guidance
ARR	Arrival controller
ASAS	Airborne Spacing Assurance System
ATCO	Air Traffic Controller
ATIS	Automatic terminal information service
BZO	Low Visibility Conditions (*Dutch: Bijzonder Zicht Omstandigheden)*
CDA	Continuous Descent Approach
CLB	Cloudbase
CONOPS	Concept of Operations
CRDA	Converging Runway Display Aid
DA/H	Decision Altitude/Height
DTW	Downwind Termination Waypoint
EDA	Enroute Descent Advisor
FAF/FAP	Final Approach Fix/Final Approach Point
FDR/DCO	Feeder / Departure controller
FPA	Flight Path Angle
FMS	Flight Management System
GBAS	Ground-Based Augmentation System
GP	Glide path
IAF	Initial Approach Fix
IFR	Instrument Flight Rules
ILS	Instrument Landing System
LDA	Localizer Directional Aid
LOC	Localizer
LPV	Localizer Performance with Vertical guidance
MDA/H	Minimum Decision Altitude/Height
MLS	Microwave Landing System
NOZ	Normal Operating Zone
NTZ	No-transgression zone
OPD	Optimised Profile Descent
PBN	Performance Based Navigation
PRM	Precision Runway Monitor
PTC	Precision Trajectory Clearance
(P-)RNAV	(Precision-) Area Navigation
RC	Runway Controller
RF	Radius to a Fix (ARINC coding leg type)
RNP	Required Navigation Performance
RNP APCH AR	RNP Approach Authorisation Required
RNP SAAAR	RNP Special Aircraft and Aircrew Authorization Required
RPAT	RNP Parallell Approach Transition
RTF	Radiotelephony
RVR	Runway Visual Range
RWY	Runway
SBAS	Space-Bbased Augmentation System
SOIA	Simultaneous Offset ILS Approaches
SPL	Schiphol
SUP	Supervisor
STAR	Standard Terminal Arrival Route
STCA	Short Term Conflict Alert

TA	Tailored Arrival or Transition Altitude
TAR	Terminal approach/area radar
TMA	Terminal Control Area
TOD	Top of Descent
VDV	ATC Operational Procedures Handbook (*Dutch: Voorschriften Dienst Verkeersleiding*)
VEMER	Safety Efficiency Environment Impact Report (*Dutch: Veiligheid Efficiency Milieu Effect Rapportage)*
VFR	Visual Flight Rules
VMC	Visual Meteorological Conditions

1 Setting the scene

This chapter outlines the project objectives, aim of the baseline document and provides essential background information with regard to the development of arrival/approach routes and CDA in the Netherlands.

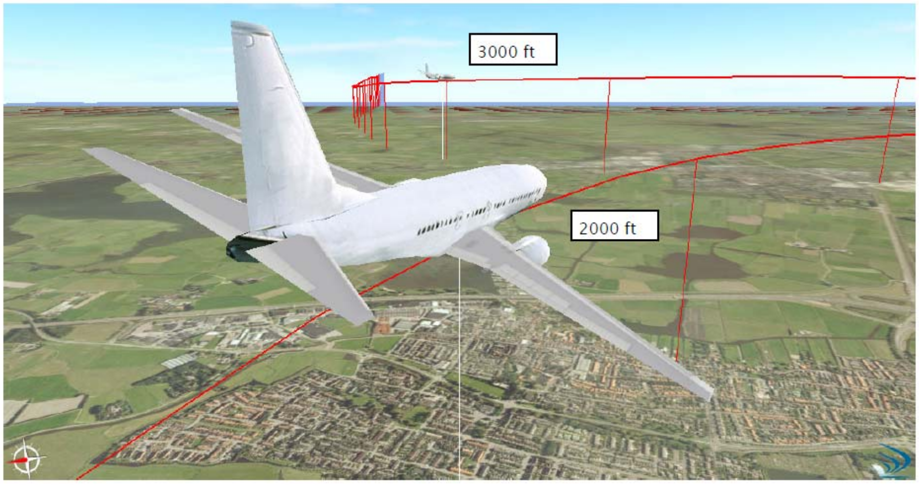
1.1 Background and rationale for project

The challenge in sustainable airport development is to seek the optimum balance between customer demands and environmental constraints whilst maintaining or even improving the safety of the operation.
Continuous descent approach (CDA) operations are considered to be an important building block in achieving such balance. Fixed lateral routes with a continuous descent segment have been implemented at Schiphol for some years now, albeit at night time and only for single runway operations.

In the last years several developments have been ongoing to facilitate an extended and/or more advanced use of CDA:

- Activities regarding the implementation of CDAs that were performed in the LVNL P-RNAV projects, as part of the LVNL ATM Vision and Strategy
- Results from the so-called “Alders table”, a mediation-like process executed under the leadership of Mr. Alders, the former Cabinet Minister of Environment
- Alignment with the European ATM Master Plan which is based on the SESAR ATM Target Concept

During independent parallel approaches on runways 18C and 18R, the lateral distance between aircraft on the two centre lines becomes less than the required radar separation minimum (3 NM). In this case, the ICAO provisions for independent parallel approaches specify that a minimum of 1000 ft vertical separation shall be provided whereby a horizontal segment[1] is flown until aircraft are established inbound on the ILS localiser course. This is to assure separation in case of e.g. an ILS overshoot.



[1] In SESAR also referred to as “platform altitude”.

In this project we are exploring possibilities that enable independent continuous descent approaches (CDA) to parallel runways at Schiphol airport. With parallel CDAs, a 3 NM lateral separation during final intercept can not be maintained and the 1000 ft vertical separation can not be guaranteed since the vertical path of the CDA is at pilot's discretion and not exactly known to ATC. A more elaborate problem description is given in Chapter 2.

This implies seeking alternatives whereby platform altitudes are no longer required to safely conduct truly independent parallel CDAs.

1.2 Objectives of project

The primary objectives of the IPC project are:

- to generate potential solutions to remove the need for the 1000 ft altitude separation requirement for independent parallel and converging approach operations, in order to facilitate the introduction of continuous descent approach operations
- to weigh the potential solutions (expert judgement) in order to create a shortlist of viable solutions
- to advise on the shortlist of viable solutions and on the means and methods to validate the most promising solutions
- to validate the most promising solutions on the basis of a VEM analysis

The secondary objective is to advise the P-RNAV follow-up project team (PRA-1734) on a solution and migration path towards a final design concept for independent parallel CDAs which can be implemented within the scope of that project. This means that this project will not be responsible for decision-making when it comes to implementation. Decision-making has to be performed by the respective bodies within the aviation sector. In this project, emphasis will be placed on viable solutions and a realistic view on migration and implementation periods.

1.3 Phasing of project

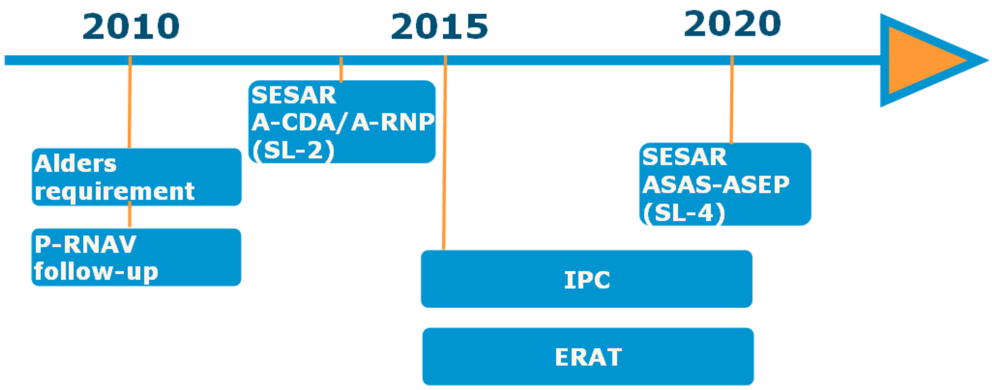
This project will consist of three phases and main activities:

1. Definition Phase	: preparation of a baseline document
2. Design Phase	: workshops for exploring solutions
3. Evaluation Phase	: detailing solutions, evaluation and classification

The purpose of the baseline document is to set the scene for the 1st expert workshop as part of the Design Phase. It contains the required background information, problem description, scope and assumptions, current state of art with regard to parallel (CDA) approach operations as well as an inventory of solutions already indentified.

1.4 Time scales

An indication of timescales regarding operational implementation is shown below. IPC focuses on implementation within the timeframe 2015-2020. IPC partially overlaps with the objectives of SESAR Service Level (SL-2) to SL-4 where Advanced CDA/RNP procedures are envisaged.



The SESAR ATM Masterplan (Deliverable D5) estimates that A-CDA[2] and A-RNP1 will be available for operations in higher traffic density TMAs from 2013, however current estimates point towards an implementation around 2018-2020.

1.5 Usage of project result

The project results will be delivered to the “WG Air”, which is a working group of AAS, KLM and LVNL regarding strategic issues. WG Air will pass the results on to its respective organisations. In the case of LVNL this will be Stratcor (Strategic Coordination team). In the preparation and execution phase of this project the LVNL Study team was informed of progress and (intermediate) results.

1.6 Starting points and assumptions

It was agreed that the IPC project should be aligned with the [Ref. 1, LVNL P-RNAV CONOPS] and its follow-up activity. IPC should build upon the results of these activities. This implies that the starting points and basic assumptions of IPC shall be compliant with the P-RNAV CONOPS and the follow-up project.

From the P-RNAV CONOPS and follow-up activity the following starting points and basic assumptions apply to IPC:

[S1] The basic design for fixed P-RNAV routes in the TMA is a “trombone” route, in which it is assumed that this trombone route will replace the current night transitions and shall be used ideally 24H (day and night)

[S2] In exceptional situations, for safety or efficiency reasons (weather, traffic mix, etc), it will be possible to switch from fixed P-RNAV routes to traditional vectoring

[S3] It is assumed that normally the first turn in the trombone can be taken (day and night). In this context it is assumed that arrival management

[2] There is no formal definition of B-CDA and A-CDA in Eurocontrol documentation. It is believed that Advanced CDA refers to CDA operations that can be performed in high density TMAs and require controller tools and 3D trajectory management.

will be such that bunching of traffic will be absent. If however in the near future arrival management will not be developed and bunching still occurs, it is up to the controller to decide whether switching to vectoring is required for safety and efficiency

[S4] In the follow-up activity it is stated that there shall be a P-RNAV obligation for aircraft in the Schiphol TMA

[S5] In the follow-up activity it is stated that a 4th IAF can be assumed for the design of the P-RNAV routes in the TMA

[S6] In the follow-up activity there is no restriction in the design process with regards to current civil airspace boundaries

[S7] Runway configuration of Schiphol Airport as today. With regards to runway combinations there will be focus on 18R+18C, but 36R+36C will also be in the scope of this project

[S8] Propeller aircraft with a cruising speed below 220kt need special attention, suggestions for handling propeller aircraft within a concept of parallel CDAs should be inside the scope of this project

[S9] Just as for the design and use of fixed P-RNAV routes, one single solution for independent parallel CDAs should be developed which can be applied in all conditions (day of year, time of day, visibility condition, traffic demand, etc)

[S10] The solutions have to comply with the requirement that the parallel approaches shall be independent

[S11] IPC focuses on inbound traffic flows and will take into consideration the location of outbound flows as proposed in other projects

[S12] No further restrictions (than above mentioned) apply beforehand with respect to the solutions and migration paths to be investigated. Emphasis should be put on viable solutions and a realistic view on migration and implementation periods should be an outcome of this project

2 Problem description

This chapter elaborates on the issues related to independent parallel approach operations that include CDA profiles.

2.1 Definitions

This project focuses on independent parallel CDA operations, hence three main definitions need to be clarified:

Independent
[Ref. 2, ICAO Doc 8168 Vol I] defines independent parallel approaches as:

"Simultaneous approaches to parallel or near-parallel instrument runways where radar separation minima between aircraft on adjacent extended runway centre lines are not prescribed".

This definition is based on runway spacing but the actual operation is still dependent since 1000 ft vertical separation needs to be maintained. Therefore, for the purpose of the IPC project "independent" is defined as:

"The lateral and vertical profile of an aircraft approaching runway 18R is not dependent on the lateral and vertical profile of an aircraft approaching runway 18C, or vice versa".

Parallel
Paragraph 3.1.12 of [Ref. 11, ICAO Annex 14] recommends that where parallel instrument runways are intended for simultaneous use subject to conditions specified in [Ref. 4, ICAO PANS-ATM] and [Ref. 2, ICAO PANS-OPS, Volume I] the minimum distance between their centre lines should be:
— 1035 m (3400 ft) for independent parallel approaches
— 915 m (3000 ft) for dependent parallel approaches

At Schiphol runways 18R/18C and 36C/36R have a spacing of approx. 6890 ft (2100 m) and 9100 ft (2775 m) respectively.

CDA
The term "CDA" used in the Netherlands is only one of the definitions currently circulating within the aviation community. For this reason ICAO is currently drafting a global definition in the ICAO Draft CD Manual. An overview of various definitions used by Eurocontrol, NATS, FAA and ICAO is given in Appendix A.
For the purpose of this project, the most widely used definition in the European ATM community is proposed. This is the definition of a "CDA" as defined in Eurocontrol's CDA Implementation Guidance Information:

"An aircraft operating technique in which an arriving aircraft descends from an optimal position with minimum thrust and avoids level flight to the extent permitted by the safe operation of the aircraft and compliance with published procedures and ATC instructions."

When considered technically, there is no difference with the CD definition in [Ref. 5, ICAO Draft CD Manual]:

"An aircraft operating technique, enabled by airspace design, procedure design and ATC facilitation, in which an arriving aircraft continuously descends by employing minimum engine thrust, ideally in a low drag configuration, prior to the Final Approach Fix (FAF)/Final Approach Point (FAP)."

For the purpose of the IPC project, it is envisaged that the CDA segment starts at approximately FL70 and ends at the FAF/FAP at the GP interception.

2.2 Standards, procedures and recommended practices

A thorough understanding of the current standards and recommended practices laid down in the ICAO, JAA/FAA, EASA and RTCA documents aid in focussing towards solutions. On the other hand, it is not ruled out an amendment of current standards and regulations is needed in order to implement a solution.

This paragraph briefly addresses ICAO recommendations for operational procedures which are relevant to the design of independent parallel approach procedures:

ICAO Doc 9643	Manual on Simultaneous Operations on Parallel or Near-Parallel Instrument Runways (SOIR) [Ref. 3]
ICAO Doc 8168	PANS-OPS, Vol. I/II [Ref. 2]
ICAO Doc 4444	PANS-ATM [Ref. 4]

Since ICAO Doc 9643 fully elaborates on parallel approaches, recommendations from this document are listed in Appendix B, but should not be necessarily be interpreted as constraints to the design.
According to ICAO Doc 9643 independent parallel approaches may be conducted to parallel runways provided at least the following conditions are met (this list is not exhaustive):

Doc 9643, Paragraph 2.2.2.1:
[1f] radar vectoring is used to intercept the ILS localizer course or the MLS final approach track

Doc 9643, Paragraph 2.2.1.4:
[4] When an aircraft is being vectored to intercept the ILS localizer course or MLS final approach track, the final vector shall enable the aircraft to intercept the ILS localizer course or MLS final approach track at an angle not greater than 30 degrees and to provide at least 2 km (1.0 NM) straight and level flight prior to ILS localizer course or MLS final approach track intercept. The vectors shall also enable the aircraft to be established on the ILS localizer course or MLS final approach track in level flight for at least 3.7 km (2.0 NM) prior to intercepting the ILS glide path or specified MLS elevation angle

Doc 9643, Paragraph 2.2.1.5:
[5] A minimum of 300 m (1 000 ft) vertical separation or, subject to radar system and radar display capabilities, a minimum of 5.6 km (3.0 NM) radar separation shall be provided at least until 19 km (10 NM) from the threshold and until aircraft are established

a) inbound on the ILS localizer course and/or MLS final approach track; and
b) within the normal operating zone (NOZ)

Note that this is the actual requirement for which we are seeking alternatives.

2.3 Focus area during approach

In current daytime operations at Schiphol the “independent parallel approaches” are based on a conventional stepped descent and include a level baseleg segment to assure 1000 ft vertical separation between 18R+18C. The ICAO standards prescribe that a 3 NM or 1000 ft vertical separation between aircraft as long as both aircraft are not ILS LOC established. This assures that both aircraft remain separated in case of ILS overshoot, erroneous ILS localiser selection etc.

The current RNAV night transitions at Schiphol include a CDA segment (see Chapter 4 for detailed description) and are flown to runway 18R and 06. There is however no parallel operation during nighttime operations. Since pilots are instructed to establish a continuously descending flight path without level segments, ATC does not accurately know the vertical profile only the published minimum altitudes and mandatory speeds at particular waypoints. For single runway operations this does not pose a risk to separation, however for CDAs on parallel runways this becomes an issue. It was concluded in the P-RNAV 18R+18C CONOPS that parallel CDAs can not be flown with 1000 ft vertical separation based on a 3 degree glide path.

Generally, three areas can be distinguished during any parallel approach operation:

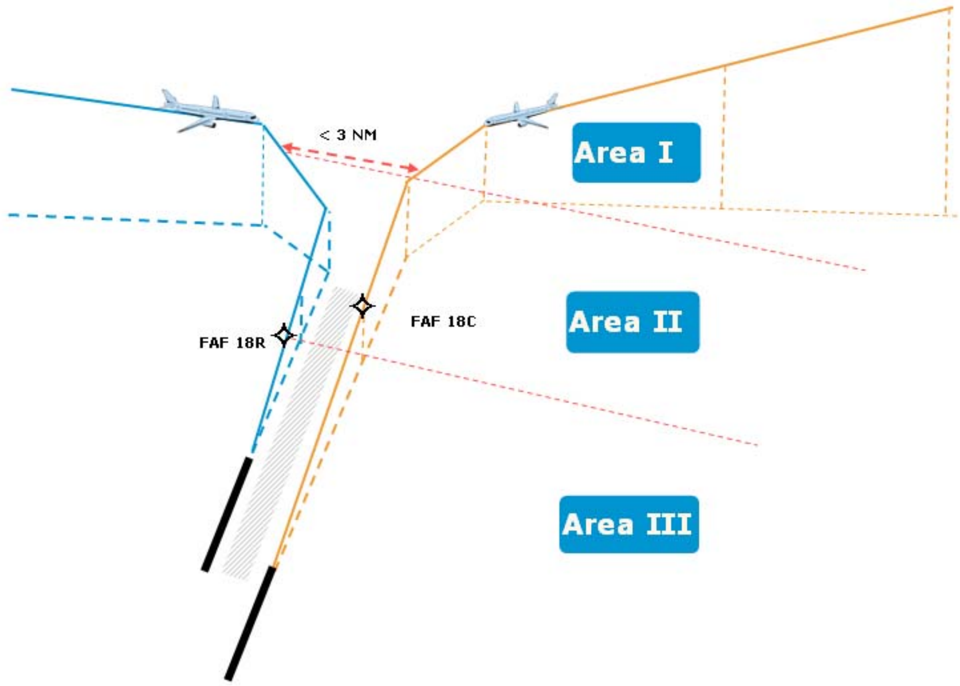
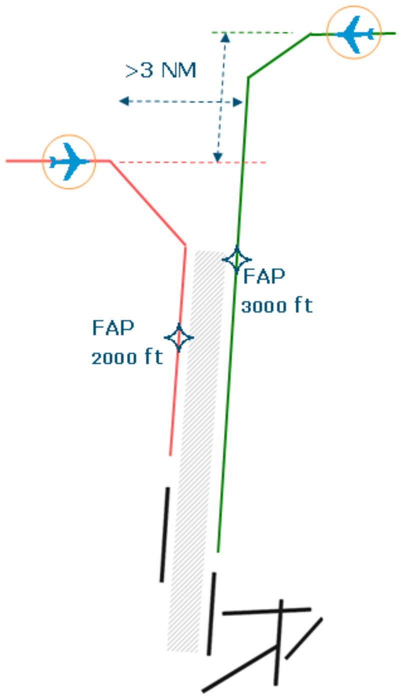
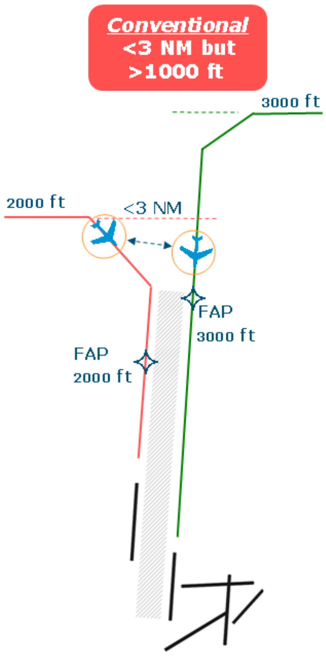


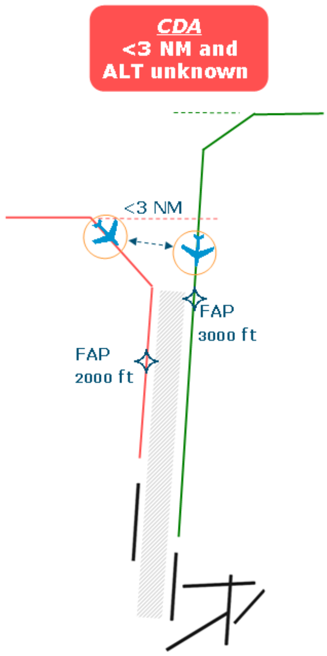
Figure 2-1 Indication of areas of separation for parallel approaches.

Area I:
In Area I the two approaching aircraft are flying in opposite direction towards two runways. The lateral separation between aircraft is larger than 3 NM in this area, however depending on the location of the turning points (see picture below), a point will come where 3 NM separation can no longer be maintained. In that case the ICAO provision for 1000 ft vertical separation assures sufficient separation. Staggering is not an option since we strive towards truly independent routes.

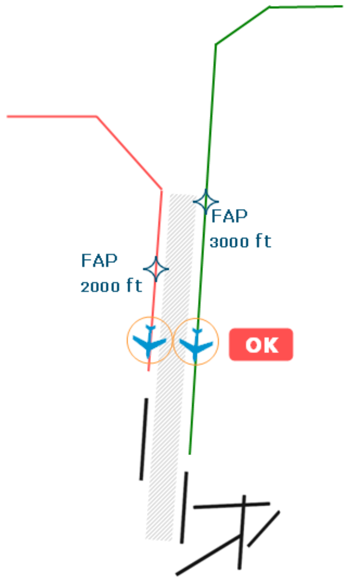


Area II:
When both aircraft follow the intercept heading for the ILS localisers, and no staggering is applied, then the lateral separation becomes smaller than 3 NM. Separation is assured by the ICAO provision of 1000 ft vertical separation.
When, during a CDA, the continuously descending flight path is at pilot's discretion, and provided that no ALT constraints would apply, then the ARR controller does not exactly know the vertical profile of each aircraft. The controller has no means to assure that 1000 ft vertical separation is maintained.





Area III:
When both aircraft are ILS localiser established then lateral track separation criteria no longer apply since it is generally assumed that following the ILS localiser will assure sufficient separation.



3 Concept development process

3.1 The path from raw ideas to complete concepts

In the 1st IPC Workshop held on 3rd September 2009 potential solutions were explored to enable independent parallel CDAs.

Five groups in which pilots (KLM), air traffic controllers (LVNL), human factor experts (LVNL) and ATM R&D experts (MITRE, Eurocontrol, AAS, LVNL, NLR, To70 and TU Delft) participated identified a total of 32 potential solutions. Solutions comprised either an individual building block or, in a few cases, a concept as a whole.

The total number of solutions was narrowed down by the IPC core team to 18 due to overlap of similar solutions (see Table 3-1).

It appeared that the solutions were based on one of three types: lateral separation, vertical separation or situational awareness:

Table 3-1 Overview of narrowed-down potential solutions.

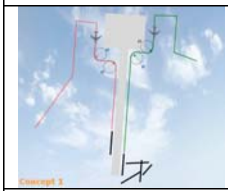
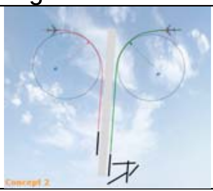
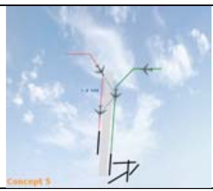
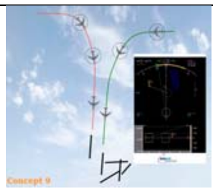
Solution ID	*Type*
	Lateral separation
1	Fixed turns with RF-legs
2	Dual oversized RF legs
4	High speed single lane approach to two runways
5	Same side intercept
12	Improve path following performance by mandatory autopilot use in approach
21	High capacity staggered dependent approaches
30	ILS offset
	Vertical separation
6	RNAV approach with differential G/S angles
7	Lower vertical separation requirement to 500ft
9	Increase stagger of runways by phyisically moving thresholds longitudinally
18a	Predefined vertical path (Barometric, Baro-VNAV)
18b	Predefined vertical path (Geometric, SBAS)
	Situational awareness
3	ASAS / Apply visual separation in VMC using ADS-B intent
11	Uplink by ATC to aircraft and downlink confirmation of selected approach route
14	Additional surveillance tools ATC to verify correct route flown
15	Intent downlink for monitoring
19	Cockpit visual reference of 'No fly zone' between runways on ND/EFB/HUD
20	Cockpit NTZ monitoring by RNP/ANP display during ILS approach

One solution (#29) entailed the use of one runway for CDA and one runway conventional step-down. This is not a solution for parallel CDAs as such but does pose a potential intermediate step towards transitioning towards CDAs on parallel runways. The solution is not pursued further and therefore not included in the Table 3-1.

3.2 Forming concepts from individual solutions

The next step involved combining one or more of the individual building blocks described in Table 3-1 to generate concepts. This was done by the IPC project team.
It was concluded that in most cases the building blocks of the type “lateral separation” and “vertical separation” provided the basis for a concept whereas the type “situational awareness” was considered to be a enabler for a concept. The only exception here was #3 which already entails a complete concept (ASAS).

This process yielded nine concepts. During preparation of this document a variation to Concept 7 was derived and in total ten concepts are described in **Annex I**:

Concept 1 “Fixed turns with RF-legs”	Concept 2 “Dual oversized RF legs”	Concept 3 “Single lane approach”	Concept 4 “Same side intercept”	Concept 5 “High capacity stagger”
				
Concept 6 “ILS offset”	Concept 7a “Different GPA”	Concept 7b “Displaced localiser capture”	Concept 8 “Modification of 1000 ft vertical separation criteria”	Concept 9 “Separation delegation to flightdeck”
				

3.3 Selection of concepts

In order to reduce the number of concepts to only the most viable set to be investigated further, a shortlist was deducted. The shortlist consisted of the top most promising concepts. In order objectify the ranking of the concepts the following methodology was applied.

Members from the extended project team were asked to score each concept on six aspects by means of scores between 1 and 5:
- Safety
- Environment

- Capacity
- Implementation
- Human factors : Air traffic controller
- Human factors : Pilot

LVNL, commissioner of the project, set the weights of certain aspects, thereby setting the balance between the importance of various aspects in the overall rating of the concepts. The end-result was a weighed score (rating) of each of the concepts. The outcome of the scoring was:

- Concept 1 “Dual oversized RF legs”
- Concept 2 “high-capacity stagger”
- Concept 3 “Same side intercept”

Note that Concept 2 makes the operation dependent which is not the objective of the IPC project. It was therefore decided to dismiss this solution. After discussions within the IPC project team, it was decided that elements in Concepts 1 and 3 were similar and were taken as a starting point to further develop concepts.

Instead of solely looking at the intermediate approach segment where the turn towards parallel final is made, it was agreed to also include the initial approach segment to gain a better idea of the concept as a whole.

3.4 Concept design considerations

A summary of the ATM improvements used in Concepts 1 and 3 is given below:

M1) defining an accurate and reliable lateral path
M2) introduce S-turns
M3) assure flexibility and predictability for ATC
M4) assure predictability for pilot
M5) increased surveillance
M6) improved trajectory planning

The improvements may allow to abandon the 1000 ft vertical separation criteria during turn towards final. M1 to M6 are discussed in subsequent paragraphs.

3.4.1 M1: Lateral path

By abandoning the 1000 ft vertical separation, we are relying on solutions in the lateral domain. It is therefore of vital importance that:

- the lateral path is flown reliably and accurately
- the geographical location of the parallel routes and turns is carefully selected to minimize hazardous situations during e.g. an ILS overshoot or when aircraft exceed the published speeds at turning waypoints

Regarding path keeping performance, the use of at least RNP 0.3 and of RF-leg functionality is proposed to assure that a precise ground track is flown.

With RF-legs a larger ILS interception angle is possible (e.g. 30 deg) which may be beneficial for the location of the lateral track. On the other hand, “Public” (i.e. non-AR) procedures with RNP 0.3 during the initial and intermediate approach phase and RF-leg capability requires a stringent PBN navigation specification which is currently not yet defined by ICAO. This is expected to become available after 2018-2020.

Alternatively, TF-leg terminators can be used provided the ILS interception angle is somewhat smaller (e.g. 20 deg) to assure an accurate lateral path. With a smaller ILS interception angle, the lateral path is positioned differently. Many aircraft are already able to fly TF legs which would make it easier to implement at an earlier stage (before 2020).
Also, a small (e.g. 20 degrees) ILS localiser intercept angle limits the prescribed minimum distance between the IF and FAF (2 NM) and reduces the probability of an ILS overshoot. The above shows that the intercept angle has a bearing on the location of the route and may be located over populated areas which is not desired.

The primary positioning sensor is GNSS and on-board performance monitoring and alerting is available to timely warn the crew that the required navigation performance cannot, or can no longer, be maintained.

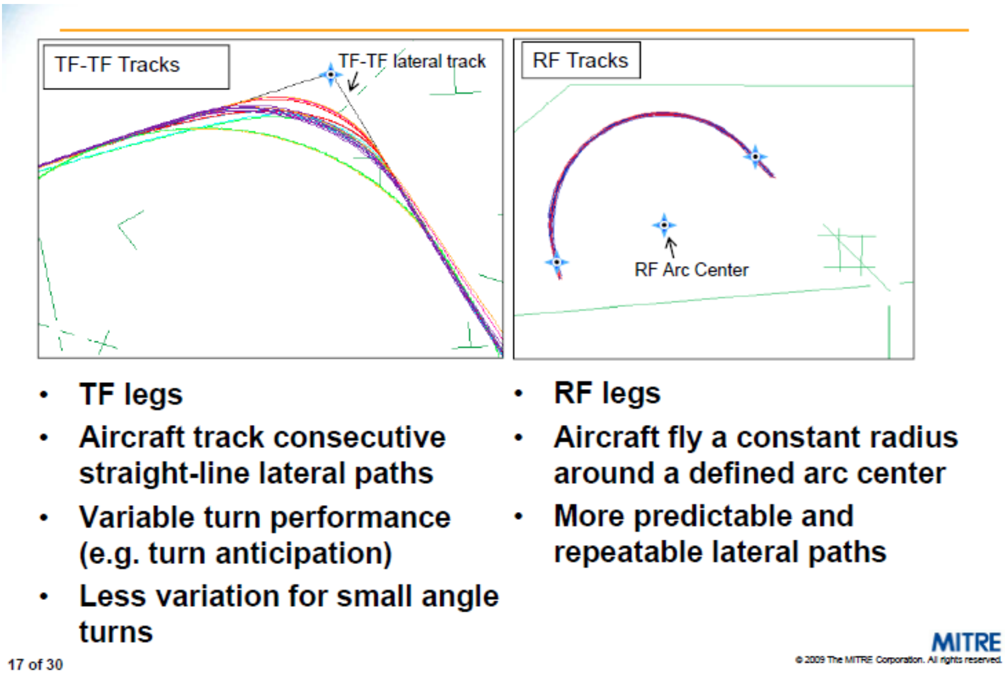


Figure 3-1 TF/RF accuracy comparison whereby GNSS is used for lateral positioning [Ref. 12, MITRE Presentation "Turns Onto Independent Final Approaches", S. Vincent Massimini].

3.4.2 M2: S-turns

S-turns are included to provide ATC cues that an aircraft is lined up for the intended runway and to increase the distance between parallel paths to maintain at least 3 NM lateral separation. The usage of S-turns was a preferred outcome of the LVNL P-RNAV CONOPS.

3.4.3 M3: Flexibility

Sufficient flexibility is important for ATC and this is achieved by:

- "trombone" with multiple transitions. The usage of S-turns in combination with trombones was a preferred outcome of the LVNL P-RNAV CONOPS (see Figure 3-2 on next page)
- SPD instructions during the transition until EH010
- For obvious reasons, it is preferred that the CDA should start as early as possible. But this depends on the need for flexibility by ATC whilst

maintaining predictability for pilots. It was therefore decided to define two alternatives for the lateral path from the IAF to EH010:

- Alternative I: Radar vectoring from IAF to towards the fixed lateral route where effectively four different transitions are defined. Apart from SPD/ALT instructions, Alternative I anticipates that ATC can also issue HDG instructions (radar vectoring) during the first part of the transition from the IAF up to 5-8 NM before EH003
- Alternative II: Fixed lateral route from IAF to FAP where effectively one transition is defined.

These alternatives will be applied to the concepts (see Chapter 4).

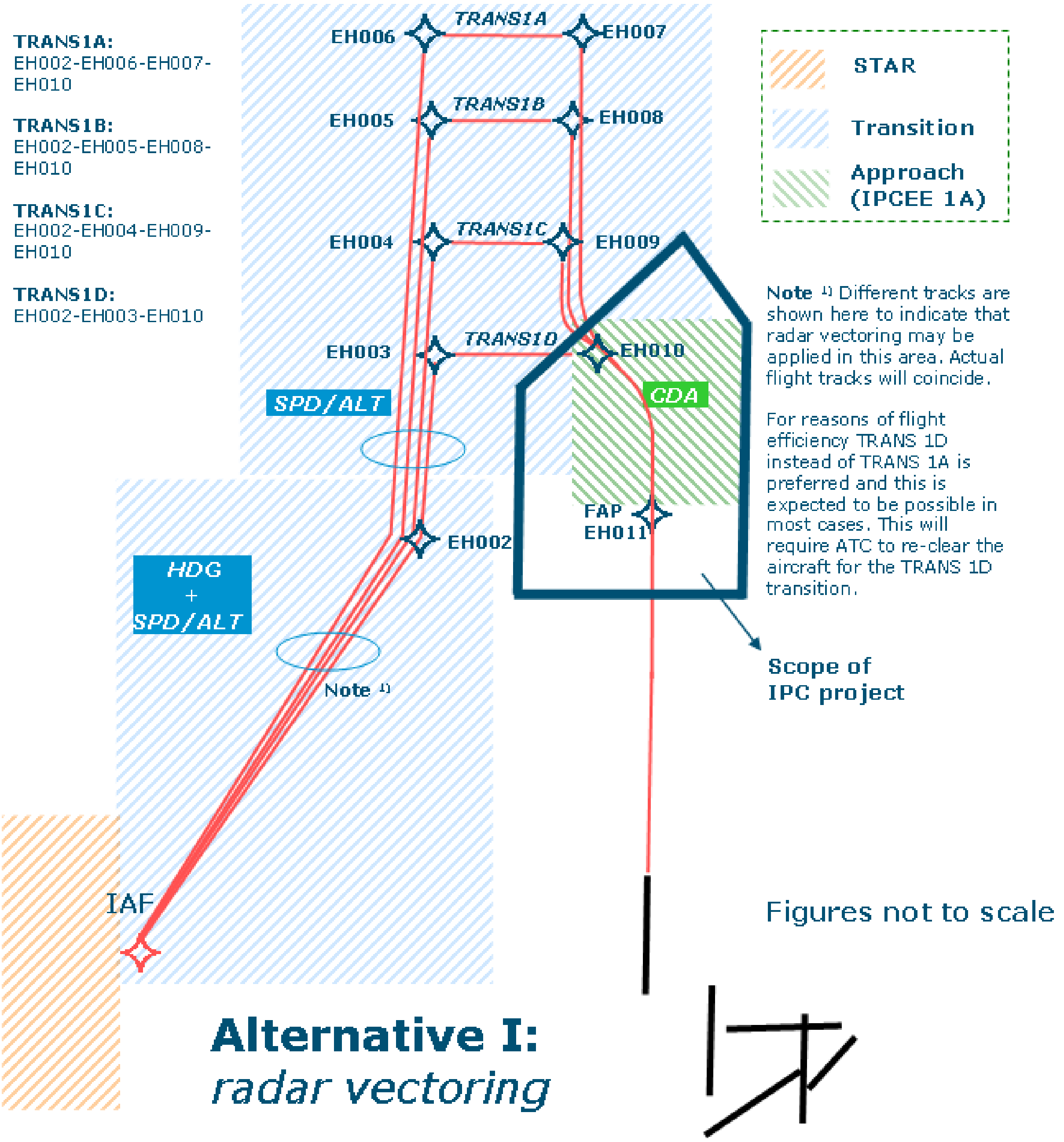


Figure 3-2 (a) General concept idea using STAR, transition and approach for Alternative I.

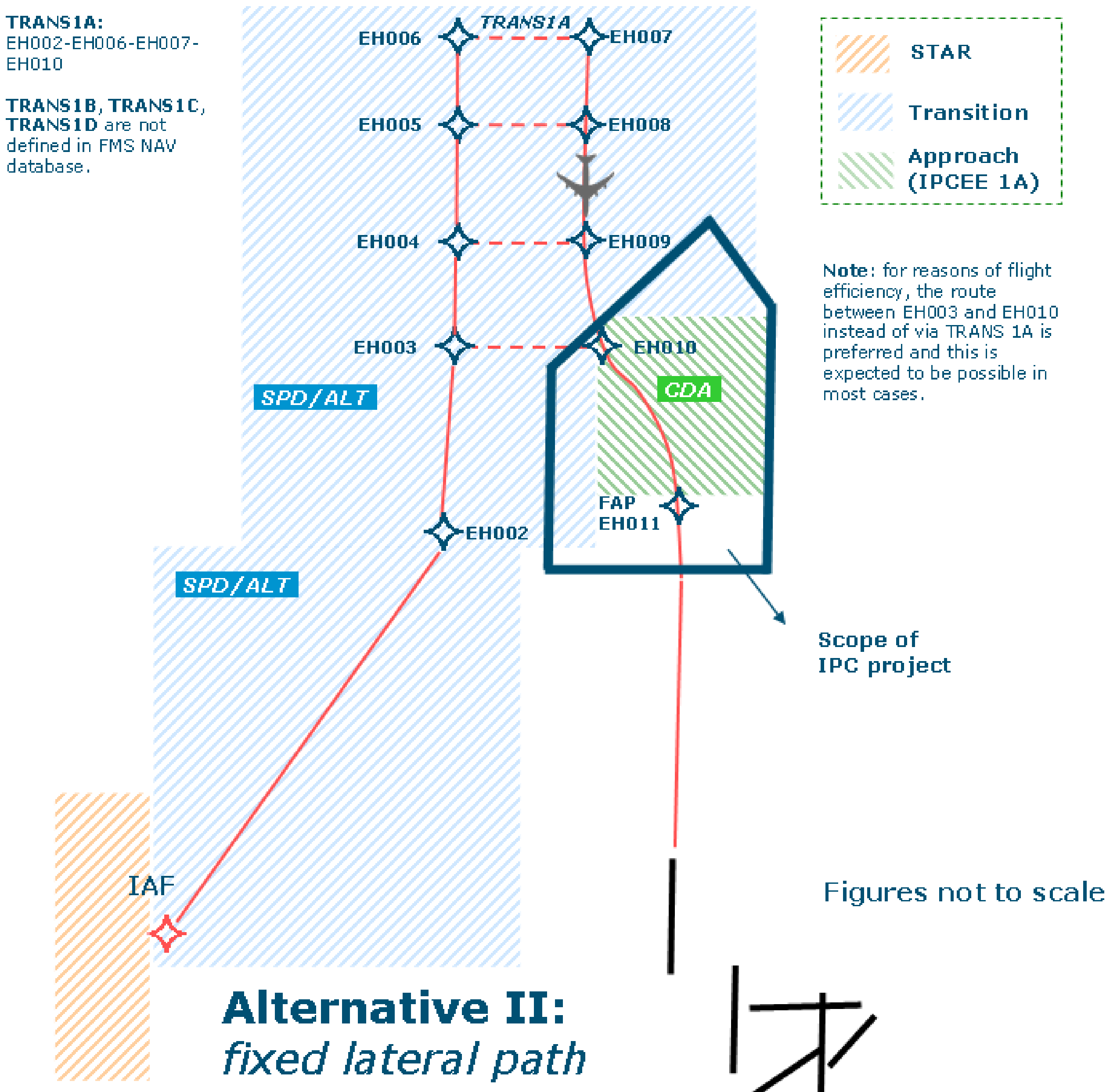


Figure 3-2 (b) General concept idea using STAR, transition and approach for Alternative II.

3.4.4 M4: Predictability

The procedure comprises a transition and an approach, similar to the current night-time RNAV transitions at Schiphol.

The initial route clearance will always be based on the long transition, i.e. TRANS 1A. This has a number of reasons:

- Most importantly, the ACC ATCo can (in principle) not decide for the APP ATCo that a short transition (e.g. via TRANS 1D) is to be flown. This would be possible, but only when ACC and APP have co-ordinated such action

- Predictable fixed lateral profile for the pilot because in all concepts aircraft initially fly the same route upon reaching the IAF. The pilot always programs the same route
- All four transitions – TRANS 1A to TRANS 1D – start at the IAF and follow the route EH001, EH002 and EH003
- When ACC/APP ATCo does not need to intervene via radar vectoring then the route is already fixed and entered in the FMS, hence predictable for pilot and ATC

The location where the CDA segment could start varies and depends on how soon ATC can provide a clearance for the fixed lateral path. However, for reasons of noise reduction, the minimum CDA segment shall start at EH010 at the latest and terminates at the EH011 (FAP). This is indicated by the green area in Figure 3-2a/b. An indication of the CDA starting altitude at EH010 is 6000 ft. The CDA segment from EH010 to the FAP will be at least 15 NM long (note that Figure 3-2a/b is not to scale).

In many cases and depending on traffic conditions, ATC is expected to be able to timely issue a lateral route clearance to facilitate a CDA segment much earlier, e.g. from EH003 or even EH002.

3.4.5 M5: Surveillance

The update rate of the radar is increased to at least 1 sec to aid the APP ATCo in timely detecting aircraft deviating from the intended track or HDG.
This may be achieved by e.g. a PRM system or ADS-B/SSR multi-lateration system. Optionally, the conventional NTZ may be extended with regard to dimension and may also be indicated on the controller's display to automatically provide an alert when an aircraft enters the NTZ.
No changes in communication between aircraft-ATC are foreseen. Downlinking of selected FMS routes or uplinking routes by ATC is thus not applied.

3.4.6 M6: Improved trajectory planning

A 2nd generation AMAN is used to schedule fixed routes and also uses real-time path conformance monitoring using actual radar track data. No datalink aircraft-ATC is applied. The accuracy over the IAF is improved from +/- 2 min. to e.g. +/- 30 sec. This may be achieved by a speed and route advisor to support the inbound planning.
Additionally, supporting tools to merge inbound traffic from different IAFs may be used by APP ATCo's.

3.4.7 General assumptions

The following general assumptions apply to each concept:

AS1	Traffic from western directions use RWY 18R and traffic from eastern directions use RWY 18C
AS2	Prerequisites for conducting parallel approaches are: A3.1 ILS 18R and 18C operational A3.2 NTZ is monitored A3.3 TAR1/4 operational
AS3	The assurance that 1000ft vertical separation during baseleg turn towards ILS localiser intercept is <u>no longer</u> valid
AS4	The timeframe of proposed operations is approximately 2020

AS5 Traffic mix 2020: 85% medium, 15% heavy aircraft

3.4.8 Concept scope

At this stage of the concept development a number of issues listed below will not be considered in order to reduce the number of constraints. In a later stage where concepts are evaluated, these constraints need to be taken into account.

SC1 No distinction is made between APP FDR/DCO and ARR tasks and responsibilities. Only ACC, APP and TWR tasks are detailed.

SC2 Interaction between inbound and outbound traffic flows are not considered.

3.4.9 Final concepts

Two concepts with two alternatives are further detailed in Chapter 4:

Combined Concept[3]	*Name*	*Combines concepts*	*Alternative*
1-I	*"S-type small fixed turns"*	#1 "Fixed turns with RF legs" #2 "Dual oversized RF legs".	**Alternative I:** Aircraft receive radar vectors from the IAF towards the point where the fixed lateral route starts
1-II		Same as 1-I	**Alternative II:** Fixed lateral route from IAF to FAP
2-I	*"S-type small fixed turn and straight-in"*	#1 "Fixed turns with RF legs" #2 "Dual oversized RF legs" #4 "Same side intercept"	**Alternative I:** Aircraft receive radar vectors from the IAF towards the point where the fixed lateral route starts.
2-II		Same as 2-I	**Alternative II:** Fixed lateral route from IAF to FAP

[3] The term "Combined Concept" has been used to avoid confusion with the earlier mentioned concepts.

4 Detailed concept description

In this section two concepts with the two alternatives are further detailed. A concept description based on the delta's to a baseline scenario is not possible because a baseline scenario does not exist:

- independent parallel approaches 18R/18C are conducted, but no fixed routes are used (radar vectoring)
- fixed-routes during night transitions are flown, but only to single runways

4.1 Combined Concept 1 "S-type small fixed turns"

Based on the design considerations listed in Chapter 3, a potential implementation is depicted below.

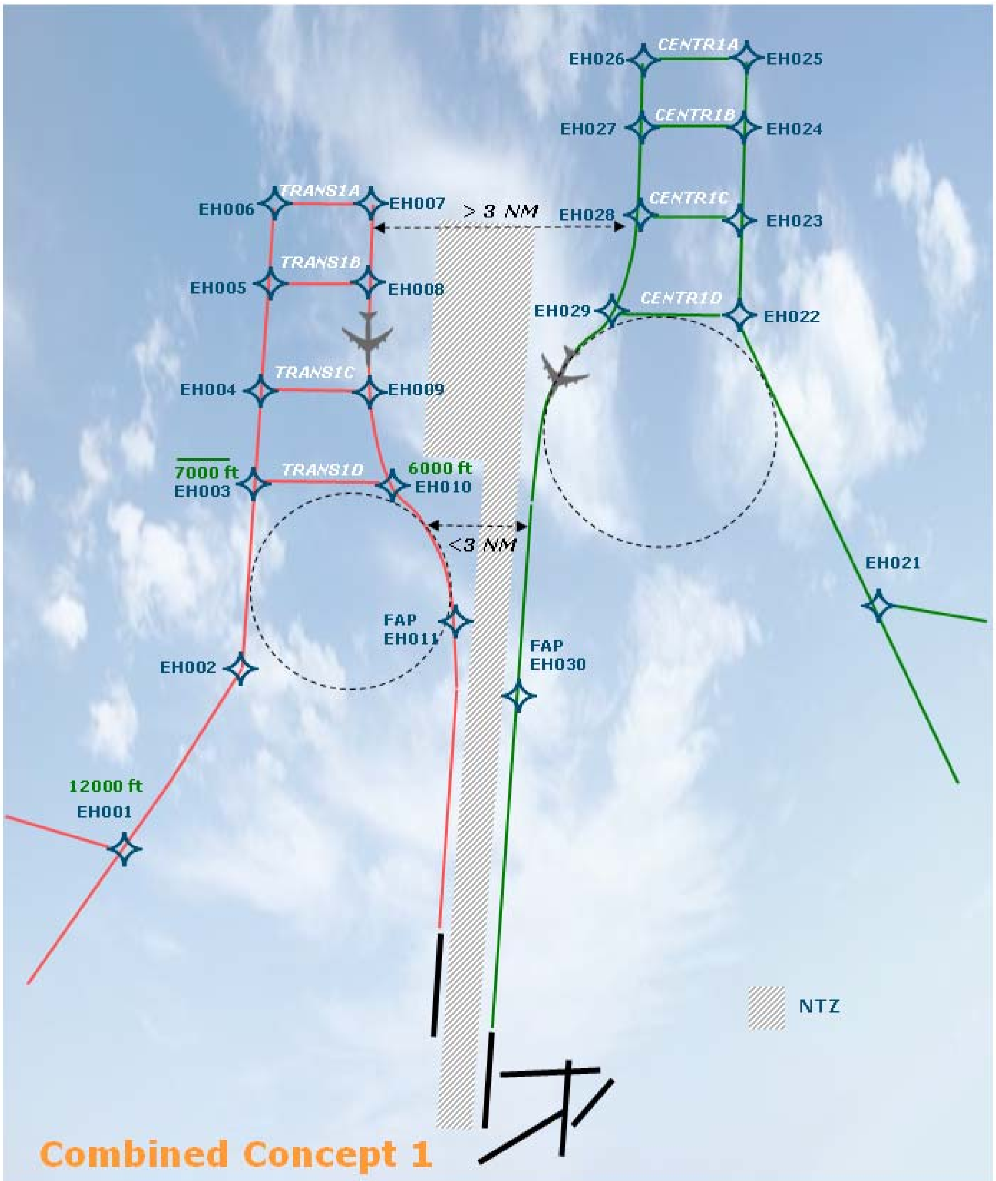


Figure 4-1 Visualisation of Combined Concept 1. Location of routes and altitudes are indicative. Note that a similar concept could also be applied to the converging runways 06+36R.

By default the route TRANS1A will be used. However, in case the route via TRANS1D would need to be flown this significantly reduces the route distance to approximately 45 NM which is comparable to the current distance of the RNAV night transitions.

Based on a 20 degree ILS localiser interception angle and minimum required segment lengths, the route design with trombones extends into airspace used by the military (Nieuw Milligen TMA A).

As mentioned earlier, two alternatives of the procedure are discussed in this section:

Alternative I: radar vectoring is applied to guide the aircraft from the IAF up to the fixed lateral route. This is done to facilitate fine-tuning and merging of traffic flows from different directions during peak periods

Alternative II: a fixed lateral route from IAF to FAP is issued based on the long lateral route and shortest vertical route

In this paragraph a description of potential ATC/pilot operations from IAF to FAP during high-volume traffic conditions is provided.

4.1.1 Alternative I: Radar vectoring towards fixed lateral route

The table below shows the proposed sequence of events upon reaching the IAF:

Before IAF	
Pilot	Upon listening out ATIS during cruise phase, pilot selects landing runway (18R) from the FMS. Upon initial contact Amsterdam ACC “KLM123, proceed HELEN arrival, expect TRANS1A transition RWY 18R, descend to FL100”. Pilot confirms STAR in FMS.
ATC	By default for RWY 18R the **TRANS1A** transition will be programmed in the FMS. ACC ATCo issues a clearance for **TRANS1A** transition. RTF example: “KLM123, cleared for TRANS1A transition RWY18R, contact Approach 121.2”
Between IAF and FAP	
ATC	It is assumed in Alternative I that APP ATCo will use radar vectoring (HDG) and/or SPD/ALT instructions to merge traffic from different directions. RTF example: “KLM123, fly heading 060, maintain SPD 220 kts”
Pilot	Pilot receives radar vectors from APP ATco to guide the aircraft towards the point where the transition is joined again (at the latest EH003).
ATC	When aircraft is conflict-free and separated, APP ATCo issues the clearance for the correct transition and the clearance for the subsequent IPCEE1A approach (starting at EH010 and flown as a continuous descent profile). The clearance for the IPCEE1A approach is the clearance for the

	lateral path, speed and altitude at own discretion and the ILS approach clearance. This clearance must be given 5-8 NM before EH003 at the latest in order to allow the aircraft to have joined the transition at EH003: - When TRANS1A is continued: RTF example "KLM123, proceed direct to EH003 and join TRANS1A transition, cleared IPCEE1A approach runway 18R" - When a shortcut, e.g. TRANS1D is possible: RTF example: "KLM123, proceed direct to EH003, join TRANS1D transition, cleared IPCEE1A approach runway 18R"
Pilot	Pilot confirms and updates the RNAV transition in the FMS (TRANS1D instead of TRANS1A). FMS calculates the vertical path based on the cleared route. Note that the vertical path is based on shortest lateral path (via TRANS1D) and includes an "at or below" altitude restriction at EH003 (e.g. 7000 ft). This is necessary to assure that aircraft have descended sufficiently (e.g. 6000ft at EH010) in case a TRANS1D transition is issued. This implies that when aircraft fly via TRANS1A/1B or 1C, aircraft will fly more or less level for a part of the transition.
ATC	APP ATCo does not intervene during the approach; only in safety related cases by e.g. extending route / HDG instructions
Pilot	Aircraft follows FMS defined lateral and FMS-calculated vertical path
Near the FAP and beyond	
Pilot	When on ILS loc intercept course, pilot arms the APPROACH or LAND mode (depending on aircraft) to execute ILS approach and landing
ATC	Contact TWR, TWR "cleared to land"

Only in safety related cases, the APP ATCo intervenes where possible actions include:

- To *extend* a previously cleared fixed route: heading instructions are issued to conduct an extended downwind leg and to continu the RNAV route towards the ILS intercept. Flight crew → HDG select and returning to LNAV when on second downwind leg towards
- To *shorten* a previously cleared path: a shortcut using a direct-to instruction. For example": RTF "KLM123, proceed direct to EH010 and continue IPCEE 1A approach". DTO instruction → flight crew select DTO WPT in FMS.
- Since the lateral path is now modified, and consequently the track-miles to runway, the vertical path is no longer optimised. However, since the intervention by ATC was performed for safety reasons, the vertical path adherence is no longer a priority.

4.1.2 Alternative II: Fixed route from IAF to FAP

The table below shows the proposed sequence of events upon reaching the IAF:

Before IAF	
Pilot	Upon listening out ATIS during cruise phase, pilot selects landing runway (18R) from the FMS. Upon initial contact Amsterdam ACC "KLM123, proceed HELEN arrival, expect TRANS1A transition RWY 18R, descend to FL100". Pilot confirms STAR in FMS'.
ATC	ACC ATCo clears aircraft for the TRANS1A transition starting at the IAF. RTF example: "KLM123, proceed HELEN arrival, cleared **TRANS1A** transition, descend to FL100".
Between IAF and EH010	
ATC	While the aircraft is on the TRANS1A transition APP ATCo clears the aircraft for the subsequent IPCEE1A approach (starting at EH010 and flown as a continuous descent profile). The clearance for the approach is also the ILS approach clearance.When TRANS 1A is continued: - RTF example: "KLM123, cleared IPCEE1A approach RWY 18R". In most cases, a shortcut will be possible. APP ATCo instructs the aircraft to proceed via alternative waypoints and clears the aircraft for the subsequent approach (including ILS approach). - RTF example: "KLM123, after EH003 direct to EH010, cleared IPCEE1A approach RWY 18R" If necessary for sequencing reasons, in addition to the assigned lateral path defined by waypoints, ATC may also give SPD and ALT instructions up to EH010. In case traffic separation is assured (e.g. in low traffic situations) the clearance for the lateral path could be followed by: "speed and altitude at own discretion" to facilitate a continuous descending path from e.g. EH003.
Pilot	Pilot confirms the modified route and approach. In the FMS the superfluous waypoints of the TRANS1A transition are deleted. FMS calculates vertical path based on the cleared route
ATC	APP ATCo does not intervene during the approach; only in safety related cases via speed control, extend route, HDG instructions.
Pilot	Aircraft follows FMS defined lateral and FMS-calculated vertical path.
Near the FAP and beyond	
Pilot	When on ILS loc intercept course, pilot arms the APPROACH or LAND mode (depending on aircraft) to execute ILS approach and landing.
ATC	Contact TWR and TWR "cleared to land"

Only in safety related cases, the APP ATCo intervenes. Possible actions include:

- Apply speed control ➔ flight crew enter instructed SPD
- To *extend* a previously cleared fixed route: heading instructions are issued to conduct an extended downwind leg and to continue the RNAV route towards the ILS intercept. Flight crew ➔ HDG select and returning to LNAV when on second downwind leg towards
- Due to the altitude constraint at the first baseleg exit (TRANS 1D) and the fact that the path is extended, the aircraft will have to fly level for a large part of the approach. However, since the intervention by ATC was performed for safety reasons, the vertical path adherence is no longer a priority.

4.1.3 Instrument approach procedure

Regarding the design of the instrument approach procedure the following applies:

- The lateral route is fixed whereby short-cuts (DTO) can be used. The procedure is coded in the FMS from IAF up to the MAWPt
- No fixed vertical path is published; this is calculated by the aircraft's FMC
- Mandatory speeds are published at the specified waypoints
- WPT ALT constraints are expected to be published and mandatory (e.g. for EH003)

4.2 Combined Concept 2 “S-type small fixed turn and straight-in”

This concept combines Concept 1 “Fixed turns with RF legs”, Concept 2 “Dual oversized RF legs” and Concept 4 “Same side intercept”.
The main difference with Combined Concept 1 is here a straight intermediate segment is flown for RWY 18C. Aircraft lined-up for RWY18C do not need to turn in an area where there is no 3 NM lateral separation and no 1000 ft vertical separation. In Combined Concept 1, aircraft for 18R and 18C both have to turn in an area where the minimum lateral and vertical separation is not available.

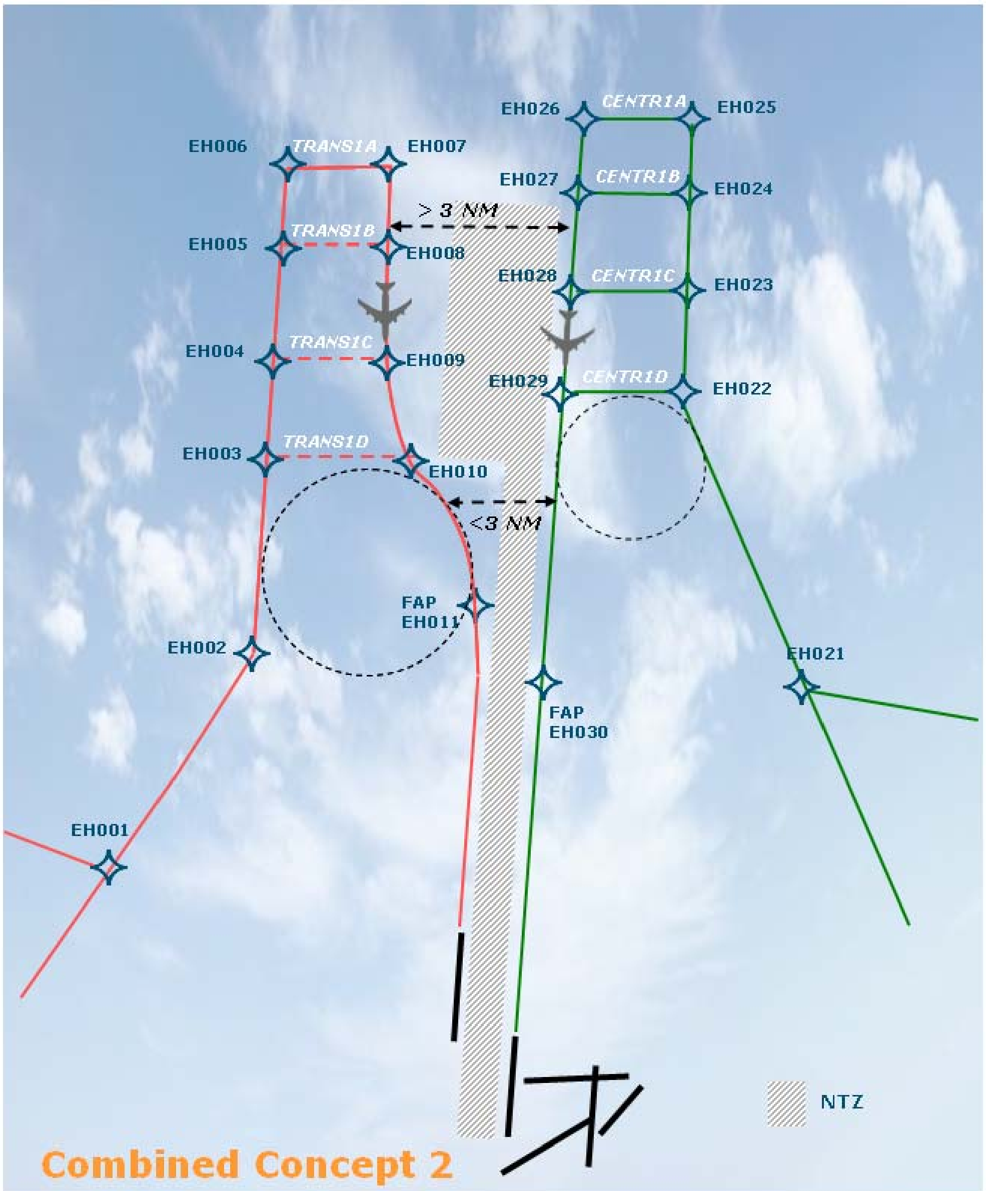


Figure 4-2 Visualisation of Combined Concept 2. Location of routes and altitudes are indicative. Note that a similar concept could also be applied to the converging runways 06+36R.

The procedure for the pilot and ATC is identical to the way it was described in Combined Concept 1. Differences only exist in the way the lateral path is defined.

5 Evaluation of concepts

5.1 General evaluation

During the 2nd IPC Workshop held on 15 December 2009, the two concepts with each Alternative I and II were explained and evaluated by the participants. Since the two concepts and its two alternatives are to a large extend similar, remarks during the evaluation applied to most concepts. Hence, no specific remarks were made for a specific concept and/or alternative.

Points of attention	Potential solution
Safety	
▪ A separate Safety Assessment was conducted. See Section 5.2 for the main results.	-
ATCo and human factors	
▪ Speed control is required for maintaining arrival capacity	-
▪ Responsibilities: ATCO cannot legally allow something to be below separation minima.	▪ create some form of dependency, such as a “dependency box” in which only one aircraft may be present at a given time. Since IPC does not want to introduce dependency, this solution is not regarded as feasible.
▪ Clear criteria for ATC today for when monitoring becomes controlling	▪ create an alert zone around routes/RF-legs/turn-to-final in HMI for ATCO to improve monitoring task ▪ make use of a procedural call-out of pilot to ATC upon turning into final, for confirmation of turning to correct ILS.
▪ Flexibility is lost due to separation of traffic East/18C, West/18R	-
▪ Are mitigating measures in case over overshoot sufficient?	▪ vertical separation assurance by making the 18C intercept at 4000ft and 18R at 3000ft
Pilot and human factors	
▪ Aircraft needs to be back in LNAV for conducting turns. From safety point of view LNAV intercept as early as possible.	-
Procedure design	
▪ The proposed route is too far West over the North Sea and also requires airspace in Military TMA North. project.	▪ use a tilted trombone. Note that the use of TRANS 1A/1B/1C (trombone idea) is a result of the P-RNAV project and does not directly relate to CDAs as part of IPC
▪ The airspace design of outbound traffic is affected by the inbound CONOPS	-

▪ Is an overshoot on change-over point during turn via TRANS 1C possible?	-
▪ Due to different radii in TF-leg (and thereby different track-miles), the spacing between aircraft is not very predictable, making high-capacity operations difficult. Experience in vectoring is required	-
Performance	
▪ IPC pursues CDAs on fixed routes, but how can capacity be maintained?	-
Systems, technology and controller tools	
▪ Unclear how TCAS will perform (logic and TCAS criteria)	-
▪ Speed control =/= optimal FMS vertical path (this is an energy issue)	-
▪ How to deal with non-RNAV/RNP aircraft whilst maintaining independent approach operations?	-
▪ SARA is not accurate enough (+/-30s at the IAF) to sequence with the required accuracy (+/-5s at the RWY threshold)	▪ consider the use of a point merge system instead of relying on SARA. Point merge to EH010 to have better spacing initially (@EH001), leads to less intervention beyond EH001
Regulatory	
▪ RF vs TF-leg: fleet readiness issue	-
▪ Modification of ICAO PANS-OPS	-
▪ Definition of ATC/pilot responsibilities when 1000ft *and* 3NM is no longer guaranteed	-

Problems for which obvious solutions existed (e.g. head-on turns) have been incorporated in the current operational concept descriptions.

5.2 Safety assessment

A safety assessment has been carried out on the preliminary design of the IPC procedure (details in **Annex II**). As such, the safety indications have a preliminary nature as well and include uncertainty. The safety criticality of the IPC procedure will depend on the final design.

In the current assessment, no unacceptable safety risks were identified and from that perspective, there is no reason not to continue developing this procedure.

Yet, safety bottlenecks that have been identified and that require attention in the further design of the procedure are:

- Naming and publication of the procedure and procedure elements (waypoints, transitions)
- Definition of the default procedure and possible extensions or short-cuts via transitions
- (Relative) location of the trombones
- Interception of the CDA after radar vectoring (in Alternative I)
- Interception of the ILS localizer after the S-turn
- ATC opportunities to detect/resolve conflicts

- Unnecessary/unwanted TCAS TAs/RAs

What has become clear in the assessment is that this concept in fact is a compromise between flexibility for ATC and predictability for flight crew; a further design of the procedure should therefore look for a good balance between these two.

It is recommended to investigate the potential of TCAS TAs/RAs given a more detailed design of the routes in combination with a realistic traffic flow. This will gain insight in how often and in which route segment(s) TAs or RAs may occur. In a next step, simulations with Air traffic controllers involved may be conducted to study the possibilities for ATC to detect/resolve conflict situations and how alerting systems such as an NTZ may be of help.

As TF and RF-legs are used in practice already today, analysis of track measurement data will help to understand the potential deviations. This is considered to be an important input in the final definition of the S-turns.

Once the concept is mature enough, stepwise introduction, e.g. on a single runway or non-parallel runways (06 + 36R) is recommended to gain experience and monitor aircraft behaviour in practice.

5.3 Quick-scan Human Factors

For each concept, the changes in human factors for both ATC and pilots were analysed (refer to **Annex III** for details). The main findings are:

General issues

Monitoring and attention distribution	*ATCo:* improvement due to more structure and therefore attention focused on route and few hot spots on route. *Pilot:* with fixed routes, pilot is fully aware of the route to be flown and therefore more aware of the energy situation of the aircraft.
Controllability and timing	*ATCo:* reduction in flexibility, if requirements on TMA entry are met, than improvement for APP. *Pilot:* FMS use becomes more important to support the operation. When ATC instructions deviations, most likely radar vectors will be applied.
Problem detection and resolution opportunities	*ATCo:* timing is crucial regarding detection and resolution. Will require attention during detailed design. *Pilot:* The probability of incorrect flight deck input increases. However, the design of the lateral RNAV route is intended to allow for early detection of incorrect pilot selections.
Number of instructions	*ATCo:* improvement due to reduction of R/T. Unambiguous procedures are required to avoid misunderstanding ATCo *Pilot:* less instructions needed

Issues regarding concept 1 and 2

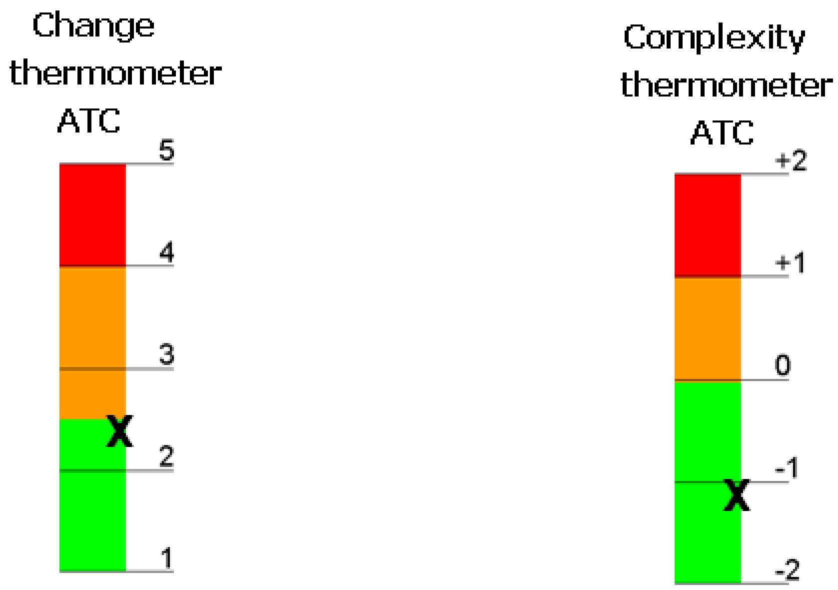
Concept 1 vs 2	Difference mainly for for ARR 18C, no significant HF differences between 1 and 2.
RF vs TF	Route adherence/deviation monitoring expected easier with RF.
Fully closed route vs vectoring area	Fully closed route preferred from monitoring perspective.
	Vectoring area preferred from flexibility perspective.

In case of a disturbed operation (weather for example), the CDA profile cannot be maintained and fall back to vectoring is needed. The issue of ATCo competency needs to be resolved.

Task change and complexity

- The changes are relevant for the current population ATCos (transfer training)
- The complexity is relevant for student and future ATCos
- It is estimated that both change and complexity are in the "green zone" (see figure below)

Changes in competencies: (1 = very small; 2 = small; 3 = average; 4 = large; 5 = very large)	Easier ATM system: (-2 = a lot easier; -1 = easier; 0 = no change; 1 = more complex; 2 = lot more complex)



5.4 Proposed topics for research

Based on the preliminary concept descriptions, several questions and uncertainties remain. In order to further develop the concepts, a number of research topics were identified during the 2nd IPC Workshop as well as from the IPC Safety Assessment:

Safety

- Investigate the potential of TCAS TAs/RAs given a more detailed design of the routes in combination with a realistic traffic flow
- Study the possibilities for ATC to detect/resolve conflict situations and how alerting systems such as an (modified) NTZ may be of help

ATCo and human factors:

- Research the likelihood of ATCo's detecting overshoots during monitoring. Possibly through simulator tests
- When and how to apply speed control which is required depending on the (required) capacity
- More insight is needed in the tromboning versus the controlling task

Pilot and human factors:

- More detailed definition of the default procedure and possible extensions or short-cuts via transitions
- Interception of the CDA after radar vectoring (in Alternative I)
- Interception of the ILS localizer after the S-turn

Procedure design:

- Investigate how to deal with the vertical transition between transition and ILS glide slope intercept. Also the interception point is not unambiguously defined due to of barometric altitude differences which depend on ambient conditions
- Research the transition from the fixed route to the ILS localizer intercept. Route is exactly defined, localizer signal can be somewhat distorted.
- Research the likelihood that trombone actually needs to be used. If the occurrence is small there may be no need for trombones and radar vectoring could suffice
- Research on what nominal transitions would be used for different traffic densities. A potential solution was suggested, with increasing traffic densities: 1) Always TRANS1D, EH010 start CDA, 2) Prior EH010 speed control by ATCO, 3) CENTR1D, vectoring in between Direct-To's, 4) Vectoring
- Naming and publication of the procedure and procedure elements (e.g. waypoints, transitions)
- Review current airspace design including its historical restrictions
- Validate whether 20 degrees is small enough to be used for ILS interception angle with TF-legs
- (Relative) location of the trombones with respect to airspace in use by the military

Systems, technology and controller tools

- More insight in how TCAS performs during parallel approaches
- Research into the likelihood of overshooting using TF turns
- TF-leg: separation between changes due to different routes flown. For small turns track adherence most likely will be good

- As TF and RF-legs are used in practice already today, analysis of track measurement data will help to understand the potential deviations. This is considered to be an important input in the final definition of the S-turns
- Determine applicability of point merge system and whether is will be robust enough until threshold
- controller tools for route conformance monitoring

Performance

- Moving the trombones closer to the mainland to reduce the track miles
- What are the options for (potentially non-optimal) continuous descends at fixed speed to maintain arrival capacity
- Capacity and separation issues due to difference in aircraft performance. Related topics include whether or not to use speed control and what the initial spacing over the CDA starting point is

Environment

- Research the environmental impact of moving the trombones closer to the mainland

Regulatory

- Research standards for NTZ display on flight deck
- operating responsibilities due to abandoning 1000 ft vertical separation criteria

6 Conclusions and recommendations

6.1 Conclusions

During independent parallel approach operations ICAO prescribes a 1000 ft vertical separation requirement as long as both aircraft are not established on the ILS localiser. The primary goal of the IPC project was to derive potential solutions to abandon the need for 1000 ft vertical separation in order to facilitate the introduction of continuous descent approach operations.

The following conclusions can be drawn:

- The goal set for the IPC project proved to be ambitious because abandoning the vertical separation criteria set by ICAO during a critical phase of flight naturally poses complex issues to be solved. A complicating factor is that such procedures should ideally not comprise the landing capacity. Such research had not yet been performed anywhere before;

- Despite the ambitious goal of the IPC Project, viable solutions have been identified and integrated to form preliminary operational concepts;

- The preferred lateral path concept with S-type approach and “trombones”, developed within the LVNL P-RNAV CONOPS Project, was adapted. This resulted in two main concepts. Essentially, both concepts share the similar principle which is to focus on solutions in the lateral domain and both concepts have the same ATM building blocks in common;

- For each of the two concepts two alternatives were proposed to cater for added flexibility for ATC: Alternative I, which uses radar vectoring to direct aircraft towards a fixed lateral path, and Alternative II where a fixed lateral path from IAF to FAP is flown;

- Evaluation of the concepts has learned that the preliminary concepts can be a starting point for further development. However, it should be noted that the preliminary concepts are dependent on progress in the fields of navigational performance (PBN) and developments with regards to regulatory aspects;

- A preference for either Concept 1 (“S-type small fixed turns”) or Concept 2 (“S-type small fixed turn and straight-in”) was not explicitly expressed during the IPC Workshops. Both concepts apply the same principle. Differences mainly exist in the geographical location of the lateral path which has a bearing on which populated areas will be overflown;

- Additional research with regard to the following topics is required:
    - Clarify the assumptions that were made during the development of the criteria for 1000 ft vertical separation set by ICAO;
    - Identify the options for ATC to detect and resolve conflict situations;
    - Incorporating more details in terms of procedure design, especially with regard to the vertical profile;
    - In the IPC project a number of aspects were excluded in order to simplify the design of concepts; for example the interaction between inbound and outbound traffic flows and airspace requirements. These aspects need to be integrated in a more mature version of the current operational concepts.

6.2 Recommendations and proposed way forward

The following actions are recommended to develop a more mature concept:

1. Address regulatory issues
   In case solutions are pursued where the value of 1000 ft vertical separation criteria during turn on final is to be reduced, or completely abandoned, ample evidence that safety is not compromised will be needed. Since this regulatory topic is expected to be scrutinised at international levels (ICAO), it should be initiated at an early stage because any amendments to standards are expected to take up at least 5-7 years. As part of the research, preferably to be conducted by, or on behalf of, an ICAO working group, the assumptions made that resulted in the value of 1000 ft for the vertical separation on turning towards parallel finals will need to be re-evaluated.
   Also when no formal vertical separation would exist during turn to parallel finals, the responsibilities of air traffic controllers (i.e. controlling versus monitoring) need to be carefully reviewed and potentially changed.
   The implementation of Performance Based Navigation (PBN) in the Schiphol TMA and associated aircraft certification aspects should be aligned with the concept in order to fly precise lateral paths.

2. Develop a safety assessment plan
   The safety assessment should determine the possibilities for ATC to detect and resolve conflict situations, assess the suitability of mitigation measures such as NTZ, determine the behaviour of TCAS, and to determine the probability of overshoots at critical waypoints.
   It is recommended to conduct real-time simulation experiments to support the safety assessment, to assess capacity figures when conducting CDAs and to support the definition of a mature concept and procedure design. Prior to the safety assessment and real-time simulations, a more detailed concept description and procedure design is needed as a starting point bearing in mind the topics listed in paragraph 5.4.
   As part of the safety assessment, an analysis of flight track data to understand the potential deviations when TF and RF-leg terminators are used is recommended.

Once the concept has reached sufficient maturity, a stepwise introduction, e.g. on a single runway or non-parallel runways (06 + 36R) is recommended to gain experience and monitor aircraft behaviour in practice.

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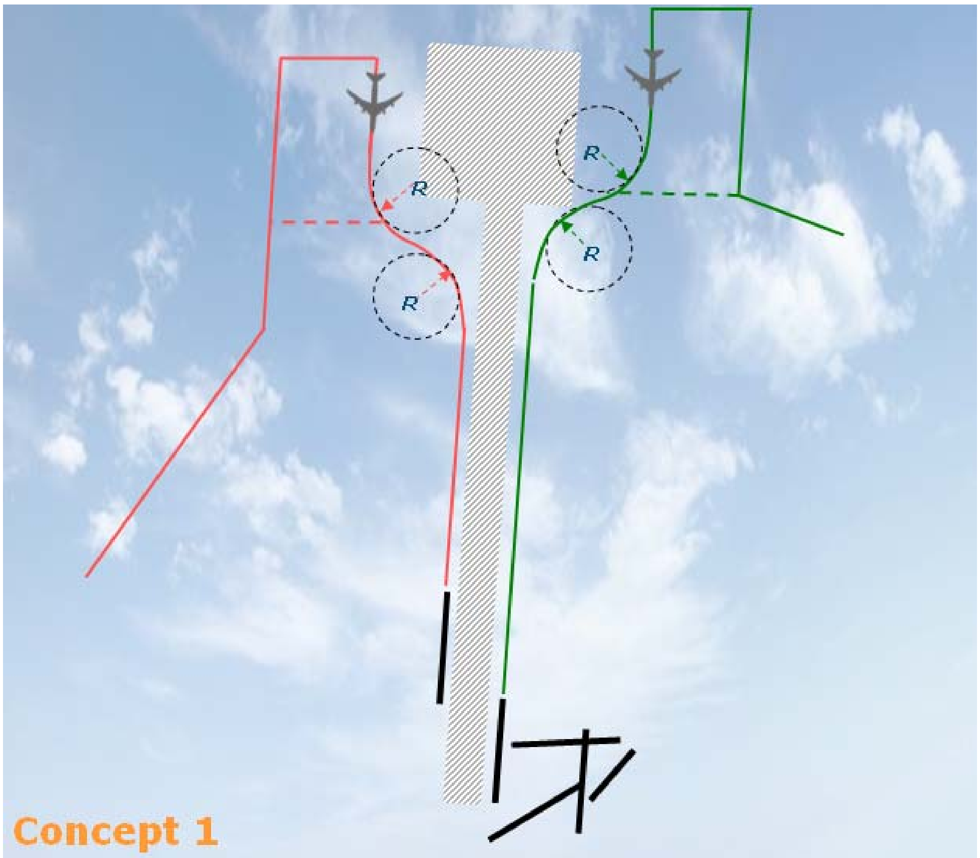
Annex I IPC Concept development process

The contents of Annex I was taken from [Ref. 7].

Concept 1 "Fixed turns with RF-legs"
Concept 1 is based on the premise that the aircraft accurately and reliably follows a pre-defined ground path using multiple RF-legs. The accurate path following performance would reduce the probability of flying towards the unintended runway. In turn, this reduces, or potentially eliminates, the need for the 1000-ft vertical separation criteria when turning towards baseleg whilst not ILS established. The purpose of the "offset final leg" aids ATC in knowing that the aircraft is headed for the intended runway. During lower traffic density levels, a shorter route can be flown (dotted-line). The concept assumes RNAV to ILS transition but in the longer term the RNAV routes may be extended down to touchdown.



In Concept 1 the following elements are combined:

#1:	"Fixed turns with RF-legs"
#12:	"Improve path following performance by mandatory autopilot use in approach"
#14:	"Additional surveillance tools ATC to verify correct route flown". In support of separation assurance during close traffic, surveillance tools such as PRM, MLAT, modified NTZ on ATCo display, etc. are needed.

Optional elements include:

#18a: "Predefined vertical path (Barometric, Baro-VNAV)"
#18b: "Predefined vertical path (Geometric, SBAS)"
The rationale for including #18a/b as optional is that the approach could be flown using APV Baro-VNAV or SBAS down to the runway threshold thereby eliminating the transition from RNP to arm ILS approach.

#15: "Intent downlink for monitoring". In order to timely detect e.g. a blunder scenario, the flight paths and aircraft intent are downlinked to ATC.
#19: "Cockpit visual reference of 'No fly zone' between runways on ND/EFB/HUD". This should prevent pilots from wandering from the intended ILS towards the other. Similar to #20.
#20: "Cockpit NTZ monitoring by RNP/ANP display during ILS approach". In order to improve pilots' situational awareness, the NTZ-area is displayed on the NAV display as well the TSE accuracy (e.g. ANP). This should prevent pilots from wandering from the intended ILS towards the other.

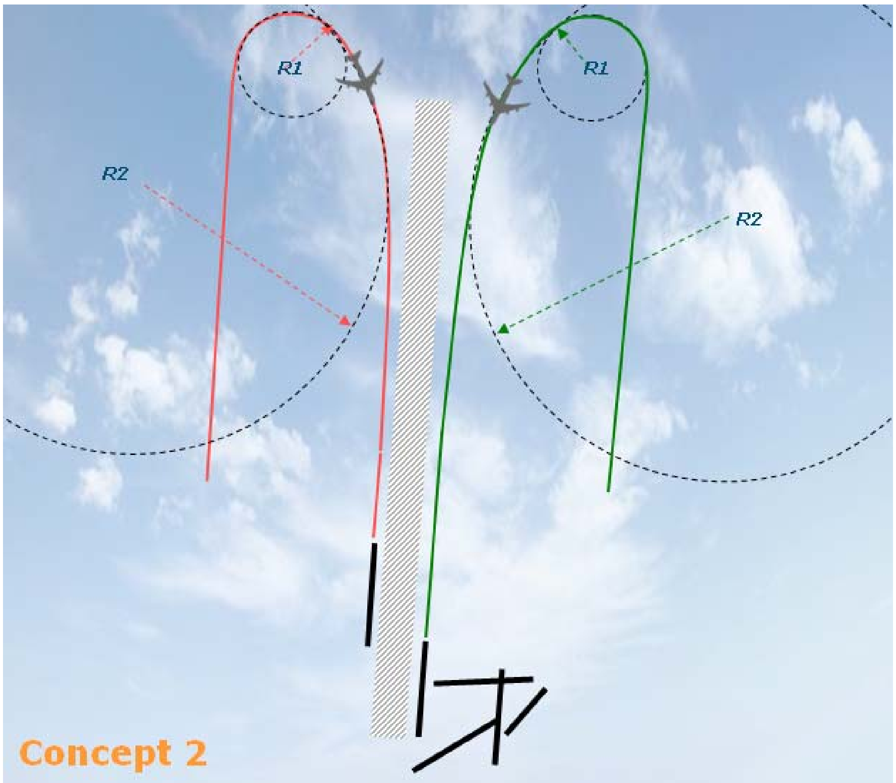
Evaluation concept 1.

Concept 1 "Fixed turns with RF-legs"		
Evaluation Parameter	*Positive impact*	*Negative impact*
Safety	▪ Possibility of automatic monitoring of the NTZ (USA) ▪ Very accurate track keeping performance ▪ S-type approach aids in timely confirmation aircraft is lined-up for intended runway	▪ Effects on TCAS (nuisance alerts, false positives) need to be checked ▪ testing of routes is required ▪ does not resolve the physical 1000ft/3NM separation criteria
Efficiency	▪ 30 CDAs per hour per runway should be possible	
Environment	▪ During low traffic density the route can be shortened significantly by bypassing trombone ▪ Concentration of traffic (minimal track dispersion)	▪ Concentration of traffic
Requirements/enablers		
System	▪ navigation performance of RNP 0.3 or better onwards from reaching IAF is required. This could be achieved by Advanced-RNP APCH functionality ▪ in ECAC approx. 50% of aircraft has RF navigation capability ▪ In support of separation assurance during close traffic, surveillance tools such as PRM, MLAT, modified NTZ on ATCo display, etc. are needed	
Procedure	▪ Effects on inbound/outbound altitudes need to be checked ▪ To be checked whether mandatory autopilot use is required	
Human ATCo		
Human Pilot		
Regulatory aspects (incl standards)	▪ PBN standards for A-RNP still to be defined by Eurocontrol and ICAO	

Implementation aspects	
Time-scale	>2018 due to mandatory RF-leg capability. RF functionality is currently (2009) only prescribed for RNP AR APCH operations.
Additional remarks	
▪ Concept 1 has the potential for transitioning through initially only operating a CDA at high side approach and RNP stepdown at low side approach	

Concept 2 "Dual oversized RF legs"
The rationale for Concept 2 is to utilise a combination of small and large RF legs; the small RF reg facilitates an accurate and compact baseleg turn and the a large RF leg (e.g. in the order of 15 NM or larger) facilitates a smooth and shallow localiser intercept. Such large intercept radius provides ATC ample time to intervene for an impending conflict.

The concept assumes RNAV to ILS transition but in the longer term the RNAV routes may be extended down to touchdown.



In Concept 2 the following elements are combined:
#2: "Dual oversized RF legs"
#12: "Improve path following performance by mandatory autopilot use in approach"
#14: "Additional surveillance tools ATC to verify correct route flown".

Optional elements include:
#18a: "Predefined vertical path (Barometric, Baro-VNAV)".
#18b: "Predefined vertical path (Geometric, SBAS)"
The rationale for including #18a/b as optional is that the approach could be flown using APV Baro-VNAV or SBAS down to the runway threshold thereby eliminating

the transition from RNP to arm ILS approach.

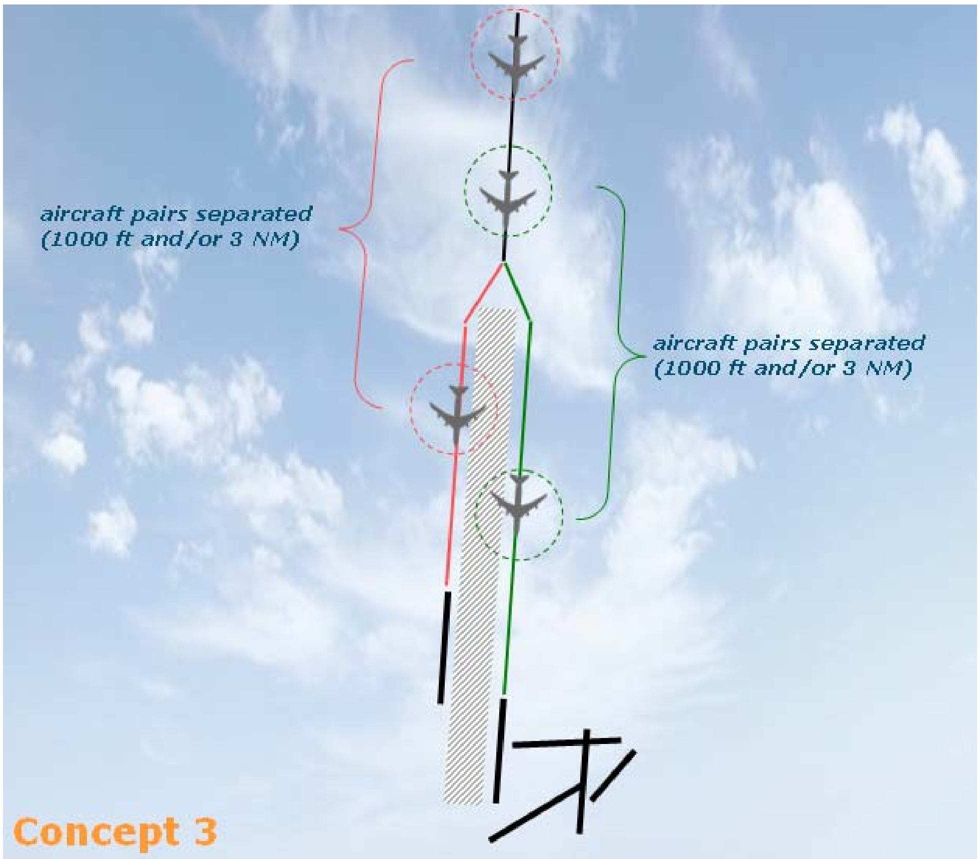
#15: "Intent downlink for monitoring"
#19: "Cockpit visual reference of 'No fly zone' between runways on ND/EFB/HUD"
#20: "Cockpit NTZ monitoring by RNP/ANP display during ILS approach"

Evaluation concept 2.

Concept 2 "Dual oversized RF legs"		
Evaluation Parameter	*Positive impact*	*Negative impact*
Safety	▪ Due to slow convergence of traffic flows, ATC has ample reaction time in case of potential conflicts ▪ ATC confirmation of correct track selection due to long fixed route	▪ Concept 2 does not resolve the physical 1000ft/3NM separation
Efficiency	▪ Limited or no effect	
Environment	▪ Potential for CDA to start high and far away from airport ▪ Optimal CDA is possible	▪ Also in low-density the complete large arc has to be flown which may be longer than actually needed ▪ Limited optimisation of ground track
Requirements/enablers		
System	▪ Navigational performance of RNP 0.3 or better onwards from reaching IAF is required. This could be achieved by Advanced-RNP APCH functionality. In ECAC approx. 50% of aircraft has RF navigation capability ▪ In support of separation assurance during close traffic, surveillance tools such as PRM, MLAT, modifed NTZ on ATCo display, etc. are needed	
Procedure	▪ To be checked whether mandatory autopilot use is required ▪ Contigency procedures needed to cater for the event that aircraft are getting (too) close	
Human ATCo		
Human Pilot		
Regulatory aspects (incl standards)	▪ PBN navigation specification for A-RNP still to be defined by Eurocontrol and ICAO.	
Implementation aspects		
Time-scale	>2018 due to mandatory RF-leg capability	
Additional remarks		

Concept 3 "Single lane approach"
The rationale for Concept 3 is to maintain vertical separation up to point of divergence. The diverging paths reduce the need for a vertical separation criteria. Aircraft are sequenced such that a 3 NM lateral separation can be achieved to enable high traffic rates.

The concept assumes RNAV to ILS transition but in the longer term the RNAV routes may be extended down to touchdown.



In Concept 3 the following elements are combined:

#4: "High speed single lane approach to two runways"

#12: "Improve path following performance by mandatory autopilot use in approach"

#14: "Additional surveillance tools ATC to verify correct route flown"

No further elements are expected to be required for Concept 3.

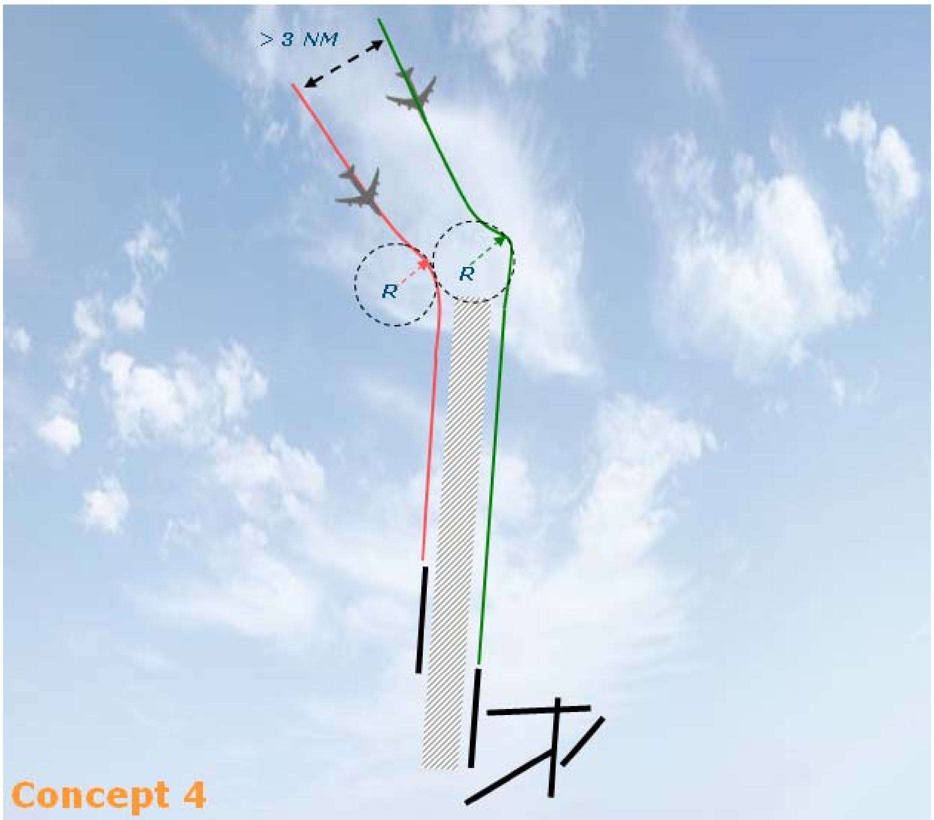
Evaluation concept 3.

Concept 3 "Single lane approach"		
Evaluation Parameter	*Positive impact*	*Negative impact*
Safety	▪ No converging tracks	▪ No 3 NM lateral separation??
Efficiency		▪ Possibly capacity is reduced when aircraft are vertically staggered which adds complexity for ATC
Environment		▪ Increased track miles due to long

		straight segment (more fuel burn)
Requirements/enablers		
System	▪ Navigational performance of RNP 0.3 or better onwards from reaching IAF is Single lane approach required. This could be achieved by Advanced-RNP APCH functionality. ▪ In support of separation assurance during close traffic, surveillance tools such as PRM, MLAT, modifed NTZ on ATCo display, etc. are needed ▪ ATC planning tools to optimise optimise aircraft pairs, vertical staggering.	
Procedure	▪ To be checked whether mandatory autopilot use is required ▪ Concept 3 requires a side-step manoeuvre and for Schiphol Airport this would be a large side-step (spacing 18R/18C of 1.1 NM) ▪ Completely new procedure	
Human ATCo	▪ New way of operating; requires significant training/certification	
Human Pilot	▪ New way of operating; requires significant training/certification	
Regulatory aspects (incl standards)	▪ PBN navigation specification for A-RNP still to be defined by Eurocontrol and ICAO. ▪	
Implementation aspects		
Time-scale	>2018 due to RNP 0.3 capability requirement.	
Additional remarks		

Concept 4 “Same side intercept”
The rationale for Concept 4 is to reduce the probability that an aircraft flies towards the unintended runway prior to ILS localizer intercept by intercepting the ILS localiser from the same side. A potential blunder scenario is then only possible for aircraft approaching RWY 18R. This concept reduces the level of ATC monitoring compared to conventional approach paths.
The approach (obviously) starts with an initial 3 NM lateral separation but decreases to near-parallel operations. Fixed approach paths are required to facilitate CDAs but RNP functionality is not required for concept 4.

The concept assumes RNAV to ILS transition but in the longer term the RNAV routes may be extended down to touchdown.



In Concept 4 the following elements are combined:
#5: “Same side intercept”
#12: “Improve path following performance by mandatory autopilot use in approach”
#14: “Additional surveillance tools ATC to verify correct route flown”.

Optional elements include:
#18a: “Predefined vertical path (Barometric, Baro-VNAV)”.
#18b: “Predefined vertical path (Geometric, SBAS)”
The rationale for including #18a/b as optional is that the approach could be flown using APV Baro-VNAV or SBAS down to the runway threshold thereby eliminating the transition from RNP to arm ILS approach.

#15: “Intent downlink for monitoring”

#19: “Cockpit visual reference of 'No fly zone' between runways on ND/EFB/HUD”

#20: “Cockpit NTZ monitoring by RNP/ANP display during ILS approach”

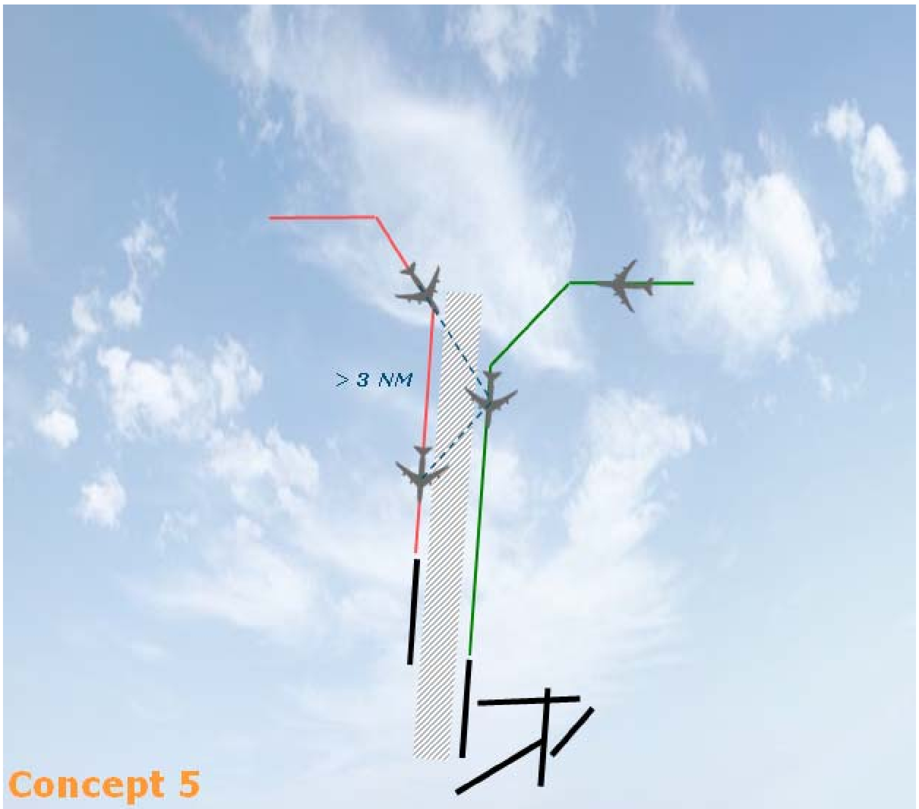
Evaluation concept 4.

Concept 4 “Same side intercept”		
Evaluation Parameter	*Positive impact*	*Negative impact*
Safety	▪ Reduced observation rate ▪ Reduced probability of blunder scenario (effectively halve)	▪ No 3 NM separation completely up to FAF
Efficiency	▪ Potentially independent operations	▪ CDAs on both runways may limit capacity
Environment	▪ Traffic is concentrated	▪ Increased track miles (more fuel burn) ▪ Traffic is concentrated
Requirements/enablers		
System	▪ Navigational performance of RNP 0.3 up to the IAF is required ▪ In support of separation assurance during close traffic, surveillance tools such as PRM, MLAT, modifed NTZ on ATCo display, etc. are needed	
Procedure	▪ To be checked whether mandatory autopilot use is required	
Human ATCo	▪ Close monitoring in convergence area is required	
Human Pilot		
Regulatory aspects (incl standards)	▪ PBN navigation specification for A-RNP still to be defined by Eurocontrol and ICAO.	
Implementation aspects		
Time-scale	>2018 due to mandatory RF-leg capability	
Additional remarks		

Concept 5 "High capacity stagger"

The rationale for Concept 5 is to use the conventional staggering technique but with an increased arrival capacity through employing supporting tools for ATC. Separation and sequencing of aircraft is done by ATC.
On one hand this concept does not need alleviation of the 1000-ft vertical separation but on the other hand the concept makes the parallel operation dependent which is not in line with the objective of the IPC project.
Fixed approach paths are required to facilitate CDAs but RNP functionality is not required for concept 5. Aircraft intercept the ILS and follow ILS path.

This concept shows similarity with the proposed concept recently published for Seattle-Tacoma International Airport.



In Concept 5 the following elements are combined:
#21: "High capacity staggered dependent approaches"
#14: "Additional surveillance tools ATC to verify correct route flown".

No further elements are expected to be required for Concept 5.

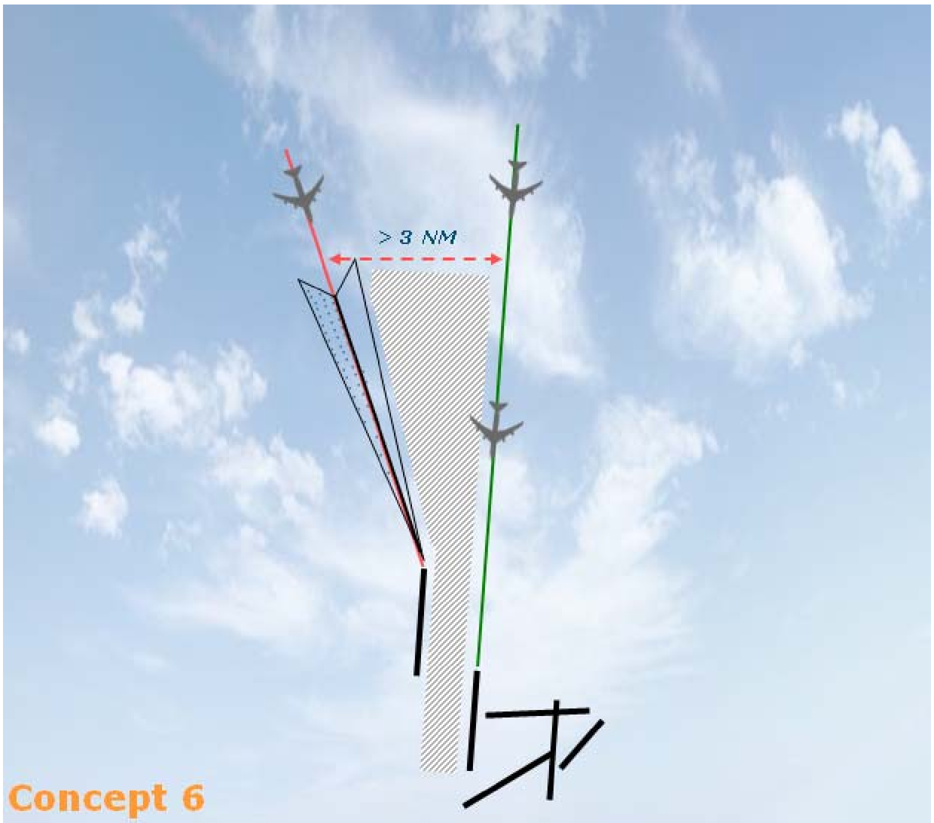
Optional elements include:
#15: "Intent downlink for monitoring"

Evaluation concept 5.

Concept 5 "High capacity stagger"		
Evaluation Parameter	*Positive impact*	*Negative impact*
Safety	▪ Lateral separation of 3 NM is maintained	
Efficiency		▪ Operation is dependent hence capacity will decrease (unknown how much)
Environment	▪ Concept enables optimal CDA	▪ Speed control, so non-optimal thrust setting
Requirements/enablers		
System	▪ In support of separation assurance during close traffic, surveillance tools such as PRM, MLAT, modifed NTZ on ATCo display, etc. are needed ▪ Systems are already developed; local (ground) investment ▪ ATC tools to support separation, sequencing? AMAN? CRDA?	
Procedure		
Human ATCo	▪ Tight sequencing required which may result in high workload ATCo.	
Human Pilot		
Regulatory aspects (incl standards)		
Implementation aspects		
Time-scale	>2010 without ATC planning tools >2012 with ATC planning tools?	
Additional remarks		

Concept 6 "ILS offset"
The rationale for Concept 6 is to bring forward the ILS 18R localiser intercept whilst maintaining a minimum 3 NM from ILS 18C. This requires an offset Localizer-Type Directional Aid (LDA) approach with glideslope. Concept 6 shows similarity with the SOIA (Simultaneous Offset Instrument Approaches)-procedure performed at San Francisco International Airport. Aircraft landing on RWY 18C also use ILS.

The concept assumes RNAV to ILS transition but in the longer term the RNAV routes may be extended down to touchdown.



In Concept 6 the following elements are combined:

#30:	"ILS offset"
#14:	"Additional surveillance tools ATC to verify correct route flown". Tools may include amongst others PRM, modified NTZ on ATCo display
#20:	"Cockpit NTZ monitoring by RNP/ANP display during ILS approach"

Optional elements include:

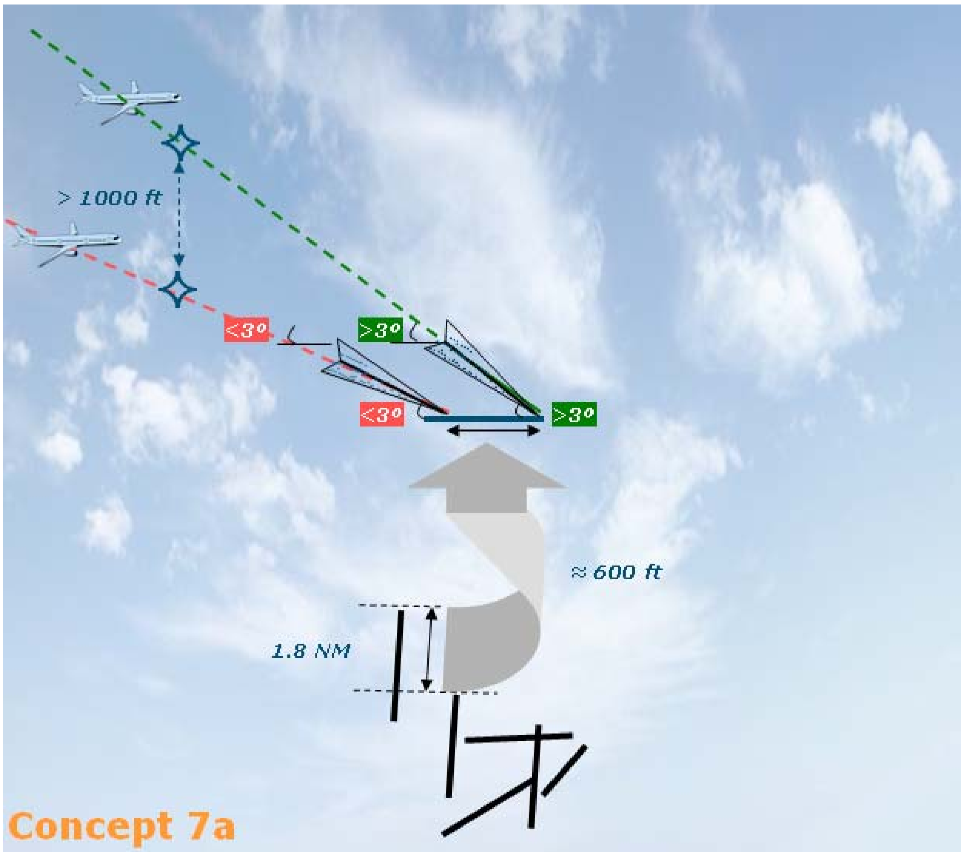
#15:	"Intent downlink for monitoring"

Evaluation concept 6.

Concept 6 "ILS offset"		
Evaluation Parameter	*Positive impact*	*Negative impact*
Safety	▪ Increased lateral separation	▪ Only feasible during VMC
Efficiency		▪ Limited applicability during deteriorating meteorological conditions.
Environment	▪ Optimal CDA possible	
Requirements/enablers		
System	▪ In support of separation assurance during close traffic, surveillance tools such as PRM, MLAT, modifed NTZ on ATCo display, etc. are needed ▪ Relocation of ILS localiser and glideslope equipment ▪ NTZ monitoring on flight-deck	
Procedure		
Human ATCo		
Human Pilot		
Regulatory aspects (incl standards)		
Implementation aspects		
Time-scale	>2010 provided cockpit NTZ monitoring is possible.	
Additional remarks		

Concept 7a “Different GPA”

The rationale for Concept 7 is to use the staggering of runway 18R/18C since it introduces a height difference of approximately 600 ft.
By slightly varying the GPAs, e.g. 2.8º and 3.1º prior to ILS localiser intercept an additional 400 ft can be achieved to maintain 1000 ft vertical separation along the intermediate segment.



In Concept 7a the following elements are combined:

#6: “RNAV approach with differential G/S angles”
#18a: “Predefined vertical path (Barometric, Baro-VNAV)”
#18b: “Predefined vertical path (Geometric, SBAS)”

For Concept 7a it is deemed required that a fixed vertical path is flown, hence the need for #18a/b.

Optional elements include:

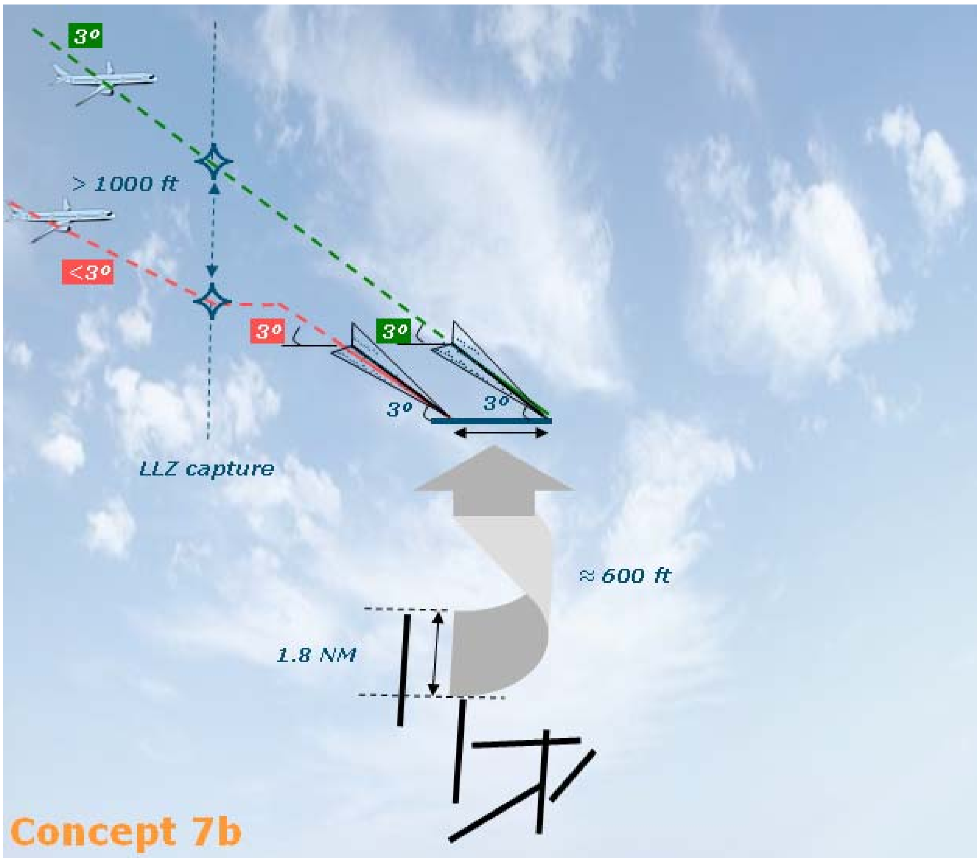
#7: “Lower vertical separation requirement to 500ft”. If the 1000 ft vertical separation criteria could be relaxed to 500 ft then the differing GPAs would not be required.

#9: “Increase stagger of runways by physically moving thresholds longitudinally”. Changing the position of the thresholds 18R/18C introduces a modest height difference.

Evaluation concept 7a.

Concept 7a "Different GPA"		
Evaluation Parameter	Positive impact	Negative impact
Safety	▪ 1000 ft separation established at FAF G/S intercept ▪ Larger certainty regarding vertical profile	▪ G/S intercept from above (false G/S angle) ▪ High rate of descent
Efficiency	▪ Due to fixed vertical profile inbounds potentially easier interaction departure routes thereby increasing TMA capacity	▪ Potential reduction as limited speed control is available
Environment	▪ One aircraft higher on approach	▪ One aircraft lower on approach ▪ Lower GPA can lead to higher noise load on ground ▪ Non-optimal CDA; since a fixed vertical profile is used the CDA will not be optimal for all aircraft types
Requirements/enablers		
System	▪ VNAV required; BARO and/or geometric (SBAS) ▪ Vertical specification in FMS is required; this is currently not possible ▪ To further increase runway staggering, one runway can be physically shifted (400 ft extra height difference to achieve 1000 ft would require approx. 1.2 NM)	
Procedure	▪ Non-standard ILS G/S angle ▪ Too high GPA values prevent autoland feature of aircraft ▪	
Human ATCo	▪ ATC has to rely on pilot for vertical profile ▪ Improved vertical predictability ▪ Increased workload on flight deck	
Human Pilot		
Regulatory aspects (incl standards)	▪ Potential aircraft/FMS certification issues when larger changes of GPA are considered.	
Implementation aspects		
Time-scale	>2010 but only flyable by aircraft that have Baro-VNAV capability. Implementation is more realistic when e.g. 90% Baro-VNAV capability level is reached, 2016?	
Additional remarks		

Concept 7b “Displaced localiser capture”
During drafting this document a alternative to Concept 7a was derived. The rationale for Concept 7b is to bring forward the ILS LLZ intercept of RWY18R. Conventional 3° ILS G/S angles for RWY 18R/18C are used, however for RWY18R a lower GPA (2.5-3.0°) is used to ensure a minimum of 1000 ft vertical separation prior to LLZ capture. In order to facilitate the preceding vertical path, a short level segment has to be flown before descending along ILS18R G/S.



Concept 7b uses the same elements as used in Concept 7a.

Evaluation concept 7b.

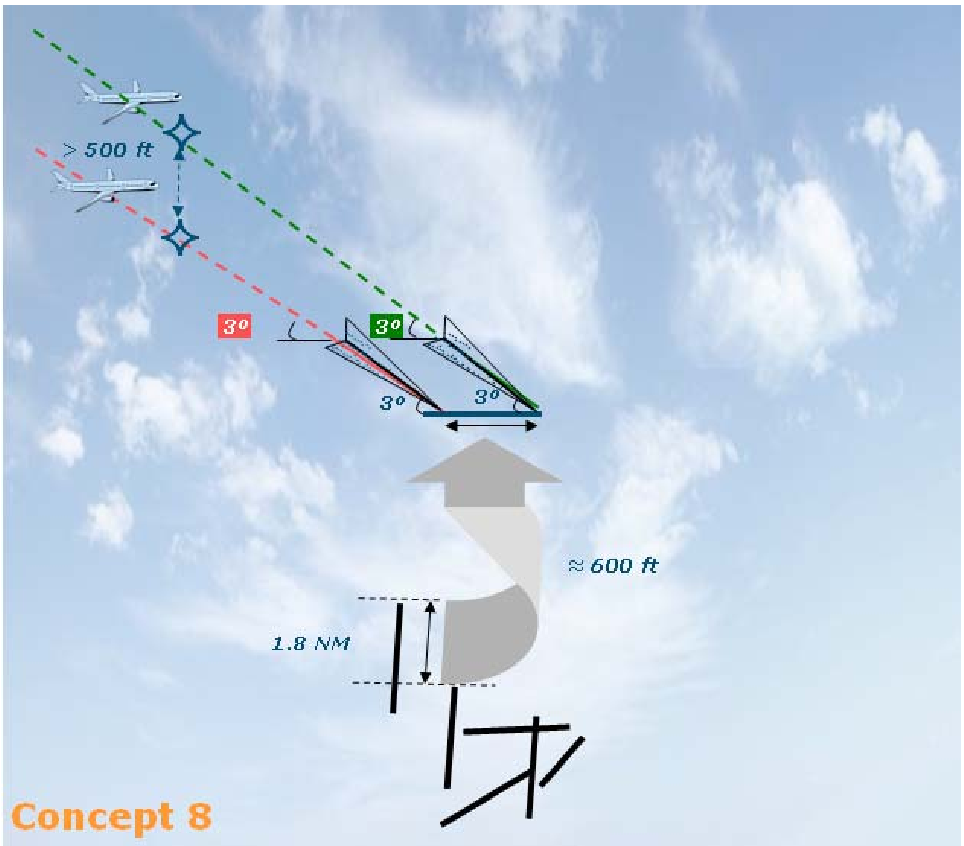
Concept 7b “Displaced localiser capture”		
Evaluation Parameter	*Positive impact*	*Negative impact*
Safety	▪ Standard ILS G/S angle ▪ 1000 ft maintained until LLZ capture ▪ Larger certainty regarding vertical profile	▪ Incorrect setting of barometric when Baro-VNAV is used.
Efficiency	▪ Due to fixed vertical profile inbounds potentially easier interaction departure routes thereby increasing TMA capacity	
Environment	▪ CDAs to both runways possible.	▪ For one runway a short level flight

		segment is required. This will require an increased thrust setting. ▪ Approaches to runway with lower GPA can lead to higher noise load on ground ▪ Non-optimal CDA; since a fixed vertical profile is used the CDA will not be optimal for all aircraft types

Requirements/enablers	
System	▪ VNAV required; BARO and/or geometric (SBAS) ▪ Vertical specification in FMS is required; this is currently not possible ▪
Procedure	
Human ATCo	▪ Improved vertical predictability
Human Pilot	
Regulatory aspects (incl standards)	
Implementation aspects	
Time-scale	Same as Concept 7a. >2010 but only flyable by aircraft that have Baro-VNAV capability. Implementation is more realistic when e.g. 90% Baro-VNAV capability level is reached, 2016?
Additional remarks	
▪ …	

Concept 8 "Modification of 1000 ft vertical separation criteria"
The rationale for Concept 8 is to relax the ICAO 1000 ft vertical separation criteria to 500 ft. It is believed that the current 1000 ft criteria was defined in the early nineties and advancements in e.g. conflict detection (TCAS), accuracy of aircraft altimetry and navigational performance may warrant revising the criteria.

In combination with the staggering of runway 18R/18C this would directly satisfy a 500 ft vertical separation.



In Concept 8 the following elements are combined:
#7: "Lower vertical separation requirement to 500 ft"
#18a: "Predefined vertical path (Barometric, Baro-VNAV)"
#18b: "Predefined vertical path (Geometric, SBAS)"
For Concept 8 it is deemed required that a fixed vertical path is flown, hence the need for #18a/b.

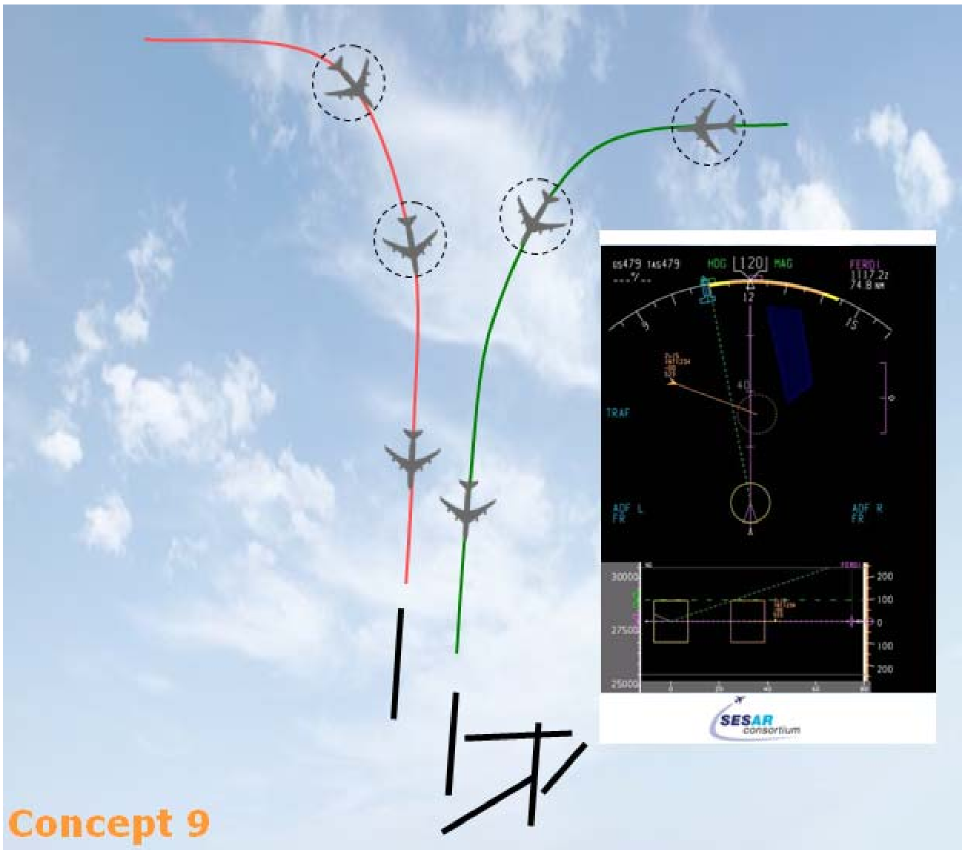
Optional elements include:
#15: "Intent downlink for monitoring"

Evaluation concept 8.

Concept 8 "Modification of 1000 ft vertical separation criteria"		
Evaluation Parameter	*Positive impact*	*Negative impact*
Safety	▪ Thorough safety case needed to evaluate 500 ft criteria ▪ Larger certainty regarding vertical profile	▪ Potential for TCAS issues (e.g. false positives) ▪ Incorrect setting of barometric when Baro-VNAV is used.
Efficiency	▪ Due to fixed vertical profile inbounds potentially easier interaction departure routes thereby increasing TMA capacity ▪ Full independent use of both runways thereby increasing landing capacity	
Environment	▪ CDAs to both runways possible	▪ Non-optimal CDA; since a fixed vertical profile is used the CDA will not be optimal for all aircraft types
Requirements/enablers		
System	▪ VNAV required; BARO and/or geometric (SBAS) ▪ Vertical specification in FMS is required; this is currently not possible	
Procedure		
Human ATCo		
Human Pilot		
Regulatory aspects (incl standards)	▪ Modification ICAO standards	
Implementation aspects		
Time-scale	>2017 due to amendment of ICAO standards.	
Additional remarks		
▪ ...		

Concept 9 "Separation delegation to flight deck"
The rationale for Concept 9 is to delegate the separation of the aircraft to the pilot using ASAS separation during VMC. This concept fundamentally differs from all the previous concepts but is in line with the concept for parallel approaches as proposed in SESAR.

Separation assurance by the two initial checks of both airplanes' FMS is improved with an independent 3rd check. In SESAR it is foreseen that this check is performed by both ASEP (ASAS Separation) to alert pilots and by the ATC system (STCA) which alerts ATCo's. In combination with a shallow intercept, or slowly converging, parallel path a "platform altitude" is no longer needed.



In Concept 9 the following element are combined:
#3: "ASAS / Apply visual separation in VMC using ADS-B intent"

Evaluation concept 9

Concept 9 "Separation delegation to flightdeck"		
Evaluation Parameter	*Positive impact*	*Negative impact*
Safety	▪ Improvement of traffic situational awareness	▪ Potential for TCAS nuisance alerts (false positives)
Efficiency		▪ Concept 9 assumes VMC; it is not known how to operate in IMC.
Environment		
Requirements/enablers		
System	▪ Advanced flight deck avionics (e.g. CDTI, ADS-B in/out) ▪ 100% ADS-B in/out capability required	
Procedure	▪ Change of responsibilities	
Human ATCo	▪ Shift of monitoring task from controller to pilot ▪ Increase workload flight deck (pilots)	
Human Pilot	▪ Shift of monitoring task from controller to pilot ▪ Increase workload flight deck (pilots)	
Regulatory aspects (incl standards)		
Implementation aspects		
Time-scale	>2020 due to need for amongst others advanced flight deck avionics (CDTI, ADS-B in/out, etc).	
Additional remarks		

Annex II Evaluation of safety effects

This Annex reports the activities undertaken in the IPC project to assess the safety effects of several concepts and has been taken from [Ref. 8]. It first describes the followed safety assessment approach and then the evaluation of safety effects, first for a set of identified hazards on an individual basis and secondly for groups of hazards that relate to a certain topic.

II.1 Safety assessment approach

From the perspective of ATC, generally speaking, the risk of an operation can be expressed in the probability of an accident or collision between two aircraft.
The probability of a collision to occur depends on four conditions:

1. An aircraft deviates due to an error of a controller or pilot or due to a system failure;
2. Due to the deviation, a conflict occurs with other traffic in the neighbourhood;
3. Timely detection and resolution of the resulting conflict fails;
4. The geometry of the conflict is such that a collision occurs if the abovementioned safety barriers fail.

This is illustrated in Figure II-1.

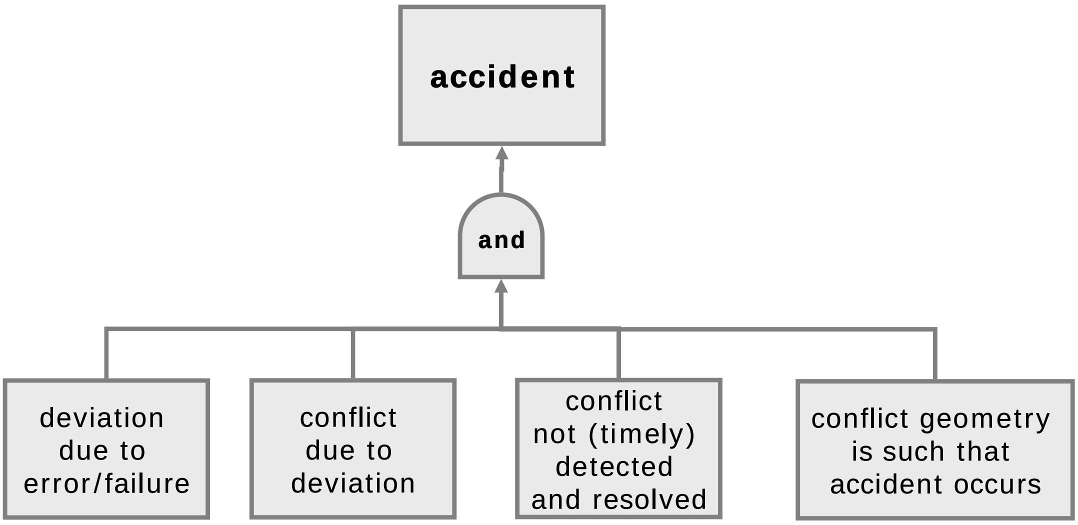


Figure II-1 Conditions for an accident to occur

As it is usually difficult to assess the probability of an accident, the risk in terms of frequency and severity of the precursors of an accident can be used as well to evaluate the safety of a concept. I.e., assessing the risk of a deviation itself, assessing the risk of a conflict due to a deviation, etc.

Generally speaking, the severity of an accident precursor increases the closer it gets to an accident, as illustrated in Figure II-2.

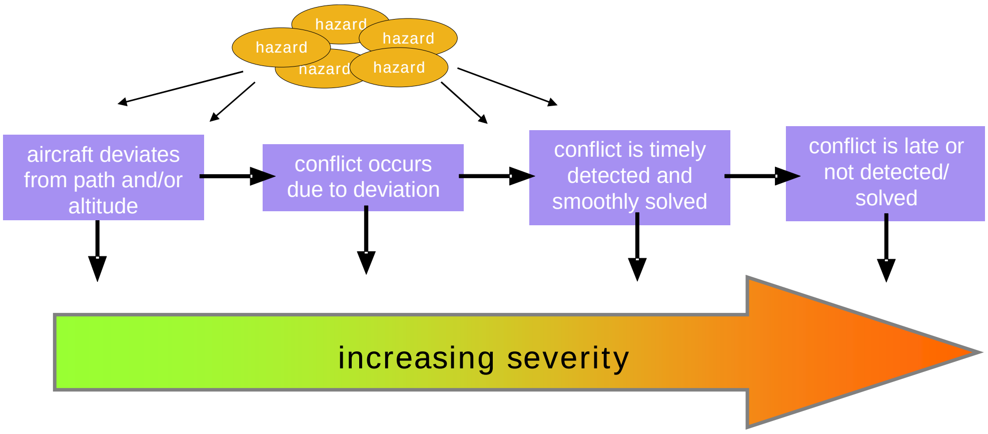


Figure II-2 Accident precursors with increasing severity

Given the early state of development of the concepts selected, the risk has been evaluated in a qualitative way.

In the safety assessment, the following steps have been taken:

- Hazard identification, what are the hazards / non-nominal conditions related to the accident conditions?
- How can these hazards play a role in a scenario that leads to an incident or accident?
  - What is the likelihood of the hazards to occur?
  - What is the magnitude of the resulting deviation due to the hazard?
  - In what segment of the approach does the deviation occur? (I.e., is it likely to result in a conflict with other traffic)
  - How likely is it for ATC and/or flight crew to timely detect/resolve this conflict, taking into account specific hazards that influence detection and resolution?
- As an indication, the associated risk, the combination of the severity and frequency, of an incident/accident scenario will be expressed in terms of:
  - Low: acceptable without further measures
  - Medium: acceptable when measures as far as reasonably practicable are taken to mitigate the hazard
  - High: unacceptable; hazard must be mitigated

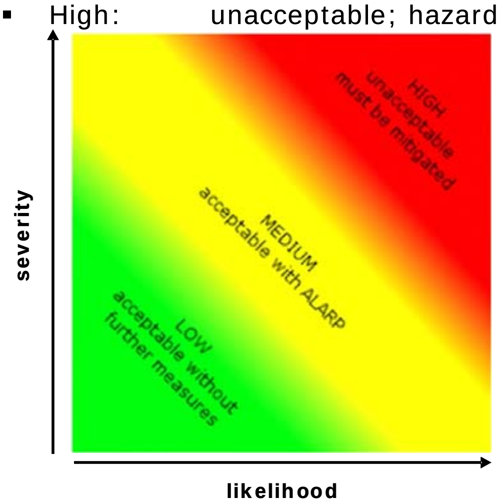


Figure II-3 Risk classification matrix (ALARP = As Low As Reasonably Practicable)

Main input for the safety assessment has been an interview with a pilot and a safety workshop with participation of LVNL, KLM and NLR experts. In this workshop, a beforehand prepared list of hazards has been discussed in order to find answers on the abovementioned questions.

The results of this workshop have been worked out by the authors of this report.

The findings have been presented and discussed in the 2nd KDC-IPC project workshop. These discussions have been taken into account into the final version of this report.

II.2 Hazard identification and assessment

Relevant hazards have been identified primarily using previous studies of similar topics such as VEMER P-RNAV[4]. Some additional hazards came up during the definition of the concepts and in the safety workshop.

For those hazards that could induce a deviation from the flight track, it has been evaluated how large the deviation could be, how likely it is to occur and in what flight phase it most likely could occur. The following classifications were used:

- How large is the deviation due to the hazard?
  - ❑ small
  - ❑ medium
  - ❑ large
- What is the likelihood for the hazard to occur?
  - ❑ low (very unlikely to occur)
  - ❑ medium (likely to occur sometimes)
  - ❑ high (likely to occur many times)
- In what segment of the concept will this deviation occur?
  - ❑ before transition (a)
  - ❑ during transition (b)
  - ❑ during S-turn (c)
  - ❑ during ILS intercept (d)

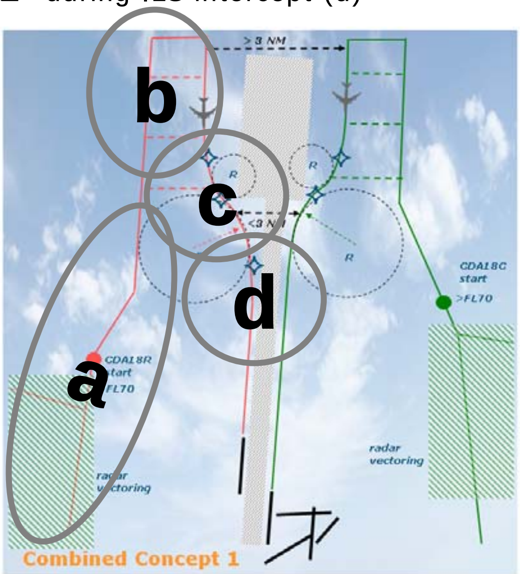


Figure II-4 Flight segments a to d

[4] VEM Effect Report P-RNAV approaches Runway combination 06+36R; Volume I: Main document. D/R&D 08/001 version 1.0, Version date: 04-09-2008

For the assessment of the hazards a classification matrix is used that is structured corresponding to segments a to d. Rationale behind this distinction is that a conflict in segment a is considered to have a lower risk than in segment b which is considered to have a lower risk than in segment c or d. The resulting classification matrices are given in Figure II-5.

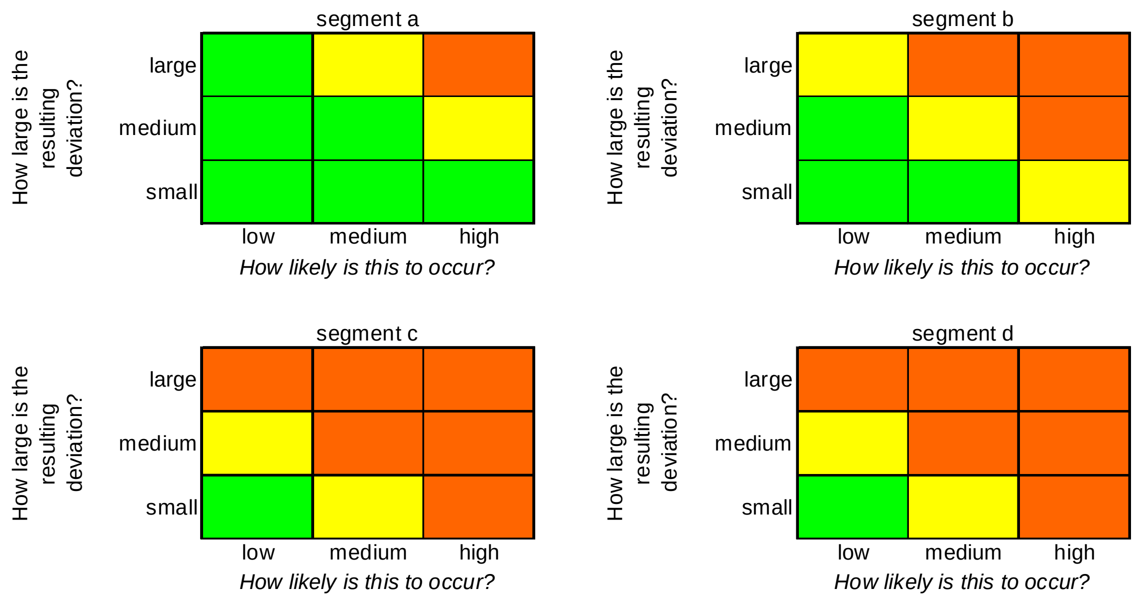


Figure II-5 Risk classification matrices per segment

Table II-1 shows the assessment per hazard and the associated risk indication. The hazards were originally structured by topic: Aircraft, Flight crew, Air Traffic Controller, and Environment as indicated in the left column. The x and y indicate the assessment as performed in the safety workshop (x) and in the interview (y); x* indicates that the classification has been done by the NLR safety expert based on the input in the workshop. The associated risk indications are shown in the two rightmost columns.

			Deviation						**Conflict**				**Risk indication**	
			How large is the resulting deviation			How likely is this to occur?			Where will the deviation occur and is most critical?					
Related to:	**#**	**Description:**	Small	Medium	Large	Low	Medium	High	Before transition	During transition	During S-turn	During ILS intercept	x	y
Aircraft	1	Errors in intercepting the route (e.g. non-intercept course)		xy		x	y		xy					
Aircraft	2	Differences and inconsistencies in FMS (different data suppliers/manufacturers)	y		x	x	y				xy			
Aircraft	3	FMS database contains erroneous or old waypoints (outdated database version)			xy	xy				y	x			

Related to:	#	Description:	Deviation: How large is the resulting deviation – Small	Medium	Large	Deviation: How likely is this to occur? – Low	Medium	High	Conflict: Where will the deviation occur and is most critical? – Before transition	During transition	During S-turn	During ILS intercept	Risk indication – x	y
Aircraft	4	FMS displays "unable RNP" halfway during transition / ANP larger than RNP	xy			y	x			y	x			
Aircraft	5	FMS unserviceable		y	x	x				x	y			
Aircraft	6	Energy problem in case of shortcut (too much height to lose)	y		x	x	y			xy				
Aircraft	7	Overshoot in turn		x*y		x*	y				x*y			
Aircraft	8	Error/difficulty in intercepting ILS		x*y		x	y					xy		
Aircraft	9	Too high speeds			x	x				x				
FC	10	Flight crew not competent though does fly RNAV	xy			x	y			xy				
FC	11	Aircraft not capable though flight crew flies RNAV	xy			xy				y	x*			
FC	12	Flight crew error in FMS programming		y	x	x	y				x*y			
FC	13	Flight crew confused about clearance/instruction		y	x	x	y			xy				
FC	14	Flight crew selects wrong transition/approach			xy		xy			xy				
FC	15	Flight crew confused about transition/waypoint names		y	x	x	y			xy				
FC	16	Flight crew error due to late clearance/instruction		y	x	x	y			xy				
FC	17	Flight crew error due to late RWY change			x	x			x					
FC	18	Flight crew selects wrong ILS			xy	x	y					xy		
FC	19	Flight crew error in mode switch to ILS interception			xy	x	y					xy		
FC	20	Flight crew flies route using LNAV/VNAV-mode up to threshold	xy			xy						xy		
FC	21	Flying route without auto-pilot	xy					xy			xy			
FC	22	Confusion about procedure in use		y	x		xy			x*y				
FC	23	Flying HDG SEL instead of LNAV		x		x			x*					
FC	24	Because of transition altitude, flight crews may switch at different points.	x*				x*			x*				
ATC	29	Instructing wrong transition			x	x				x*				
ENV	35	Weather / CB or showers on the cleared route			y	y					y			
ENV	36	Crosswind		y				y				y		
ENV	37	TCAS warnings			y	y					y			
ENV	38	Failure of GNSS infrastructure	y			y					y			

Table II-1 Assessment of hazards that could induce a deviation. Hazards organised by topic (Aircraft, FC = Flight Crew, ATC = Air Traffic Controller, and ENV = Environment)

Other hazards identified are more likely to hamper the timely detection and/or resolution of a conflict. These hazards are:

Related to:	#	Description:
ATC	25	Confusion about aircrafts RNP capability
ATC	26	Confusion whether aircraft flies LNAV or HDG SEL
ATC	27	Lower alertness due to shift in Air Traffic Controller task from controlling to monitoring
ATC	28	Error in NTZ monitoring / interpretation
ATCsys	30	Radar/surveillance failure
ATCsys	31	Communication system failure
ATCsys	32	Failure of NTZ alert
ATCsys	33	NAVAIDS/ILS unavailable
ATCsys	34	Failure of ATC tools (inbound planning tools, SARA)

Table II-2 Hazards that could hamper detection and/or resolution of a conflict. Hazards organised by topic (ATC=Air Traffic Controller and ATCsys = ATC systems)

II.3 Grouping of hazards; assessment per topic

Although the assessment per hazard gives a first indication of the potential critical elements in the concepts, the hazards are further grouped here in order to analyse the risks of the hazards in their coherence and in the context of typical topics.

The topics that are used to group the hazards and associated sub-topics are:

- Definition of the route
  - Rigourness or flexibility of the route definition
  - Waypoints, transitions
  - Intercept angles
- Provision of information/instructions by ATC
  - Sharing of tasks and responsibilities between Air traffic controller's
  - Timing of instructions
- Aircraft and flight crew capabilities and performance
  - Aircraft capable of flying RNP, RF-legs, TF-legs
  - Flight crew competence and experience
  - Aircraft system failures
  - Flight crew errors
  - Navigation aid failures
- Detection and resolution of conflicts
  - Definition of the NTZ
  - Change in Air traffic controller responsibilities and taskload
  - TCAS
- Robustness and predictability of the traffic flow
  - Impact of frequency of route changes
  - Impact of TCAS alerts and resolution advisories

The rationale for this list of topics is that it covers both the static (definition of route) as the dynamic part of the concept, covers both the ATC and flight crew perspective, covers both the human and system elements, covers both the individual flight and the traffic flow, covers both the occurrence of conflicts and the opportunities to detect and resolve these.

Note that the topics may partially be dependent and/or overlapping.

The following subsections discuss each of the topics and also list those hazards that are allocated to that topic.

II.3.1 Definition of the route

The hazards that are assigned to this topic are listed in Table II-3.

Related to	#	Description	Risk indication	
Aircraft	1	Errors in intercepting the route		
Aircraft	3	FMS database contains erroneous or old waypoints (outdated database version)		
Aircraft	8	Error/difficulty in intercepting ILS		
Flight crew	15	Flight crew confused about transition/waypoint names		
Flight crew	22	Confusion about procedure in use		

Table II-3 Hazards related to 'definition of the route'

Route interception

The definition of the route should be such that the interception of the CDA as well as of the ILS is feasible and clear for the flight crew. Interception of the CDA concerns either interception from the CDA starting point (in concept alternative I) or from the IAF (in concept alternative II).

Particularly in alternative I, where the Air traffic controller will provide the aircraft an interception course by radar vectoring, it should be considered how to ensure a radar vector that smoothly connects to the CDA part. It is expected that it will be a learning curve for an Air traffic controller to get used to appropriate radar vectors. This is a point of attention for Air traffic controller training later on. Considering the route segment where this will occur, it is unlikely to become a conflict with other traffic.

The interception angle with the ILS is dependent on the orientation of the route segment preceding the final approach on the extended runway centerline. As stated in Section 3, the expected interception angle is 20 degrees. In concept 2, where the approach to RWY 18C is straight-in, the problem is absent for this RWY. At this point it is not clear whether such a shallow interception angle will have additional negative effects. The ILS interception issue will be discussed further in section II.3.3 in view of the aircraft capabilities.

Given the assessment of individual hazards 1 and 8 and the discussion above, it is assessed that the associated risk to interception of the CDA is LOW and to interception of the ILS is MEDIUM, provided that Air traffic controller's are trained and depending on the interception angles to the ILS.

Route elements and naming

It should be thoroughly thought over how to construct the route and how to name the different elements. Interest from a safety point of view is that illogic naming or a long list of transitions or waypoints may cause confusion for the flight crew and will become more prone to errors in the FMS database.
Questions to be answered are:

- Will it be one route which can be altered by specifying a transition?
- Or will each transition function as a different route?
- What are appropriate names for the route and/or the transitions?
- How to minimize the number of required waypoints?

Another issue in this area is that flight crew and/or ATC may be confused about the applicability of the procedure. It does happen today that aircraft try to fly RNAV night transitions during the day. It should therefore become perfectly clear whether the procedure is a full CDA (or partially radar vectoring as in alternative I), is a CDA only under certain conditions, etc.

The assessed risk for hazards in this area is MEDIUM. As far as reasonably practicable, the risk needs to be mitigated. This can be done by good consideration of the above issues and consequently optimum definition of the route as well as by an extensive information program towards FMS database suppliers and airlines to minimize database errors and confusion.

The resulting risk classification for this topic is shown in Figure II-6.

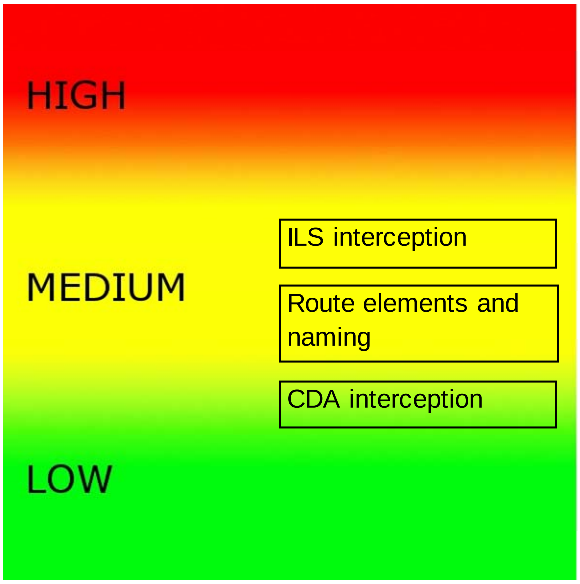


Figure II-6 Risk classification for 'definition of the route'

II.3.2 Provision of information by ATC

The hazards that are assigned to this topic are listed in Table II-4.

Related to	#	Description	Risk indication	
Flight crew	13	Flight crew confused about clearance/instruction		
Flight crew	16	Flight crew error due to late clearance/instruction		
Flight crew	17	Flight crew error due to late RWY change		
Flight crew	22	Confusion about procedure in use		
ATC	29	Instructing wrong transition		

Table II-4 Hazards related to 'provision of information by ATC'

Within this topic, distinction is made between the content of the information and the timing of the information provision.

<u>Content of the information provided by ATC</u>
This topic relates to the discussion in section II.3.1 on the naming of the route and route elements. The phraseology used to inform flight crew on which route to follow should be clear and unambiguous. The naming and number of transitions is

also of importance in order not to confuse the Air traffic controller possibly resulting in an erroneous instruction.
Another issue here is the way the procedure is published. The name and scope of the procedure should be such that confusion is avoided.
The associated risk is assessed to be MEDIUM, where mitigation is to be sought in good definitions.

Timing of the provision of information by ATC
As shown in the description of the procedure in Section 4, it is foreseen that the route information is initially received via ATIS, then the ACC controller may announce that a CDA is expected, the FDR DCO controller issues the approach clearance including the transition and then the ARR controller may instruct to follow a certain transition in order to short-cut or extend the route.

It should be studied in further detail what is acceptable in terms of the frequency and number of changes and the times at which these occur, in order not to frustrate an individual flight as well as the sequence of flights.

From a flight crew point of view, it is preferable to have the shortest lateral path as default and to receive an extension when deemed necessary by ATC, instead of having the longest lateral path as default and receiving a shortcut whenever possible. As long as the shortest path is planned on, it is not a problem for a pilot regarding energy management to receive an extension, not even in a late stage.
From an ATC point of view this seems to reduce flexibility; ATC would like to have the flexibility to handle the traffic in case of e.g. a communication failure.

Clear choices have to be made on what the default transition will be, which controller announces what and to what point along the trajectory the Air traffic controller may alter the route.

The defined concept is a compromise between on the one end radar vectoring with total control and predictability by ATC and on the other end a free flight situation with total control and predictability by the flight crew.
The associated risk is assessed to be MEDIUM, where mitigation should be sought in finding a good balance between required flexibility for ATC and stability for the flight crew.

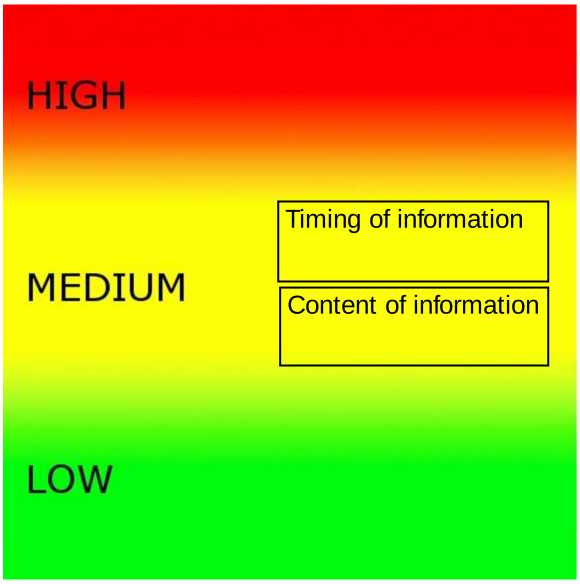


Figure II-7 Risk classification for 'provision of information by ATC'

II.3.3 Aircraft and flight crew capabilities and performance

The hazards that are assigned to this topic are listed in the table below.

Related to	#	Description	Risk indication	
Aircraft	1	Errors in intercepting the route		
Aircraft	2	Differences and inconsistencies in FMS (different data suppliers/manufacturers)		
Aircraft	3	FMS database contains erroneous or old waypoints (outdated database version)		
Aircraft	4	FMS displays "unable RNP" halfway during transition / ANP larger than RNP		
Aircraft	5	FMS quits		
Aircraft	6	Energy problem in case of shortcut (too much height to lose)		
Aircraft	7	Overshoot in turn		
Aircraft	8	Error/difficulty in intercepting ILS		
Aircraft	9	Too high speeds		
Flight crew	10	Flight crew not competent though does fly RNAV		
Flight crew	11	Aircraft not capable though flight crew flies RNAV		
Flight crew	12	Flight crew error in FMS programming		
Flight crew	13	Flight crew confused about clearance/instruction		
Flight crew	14	Flight crew selects wrong transition/approach		
Flight crew	15	Flight crew confused about transition/waypoint names		
Flight crew	16	Flight crew error due to late clearance/instruction		
Flight crew	17	Flight crew error due to late RWY change		
Flight crew	18	Flight crew selects wrong ILS		
Flight crew	19	Flight crew error in mode switch to ILS interception		
Flight crew	20	Flight crew flies route using LNAV/VNAV-mode up to threshold		
Flight crew	21	Flying route without auto-pilot		
Flight crew	22	Confusion about procedure in use		
Flight crew	23	Flying HDG SEL instead of LNAV		
Flight crew	24	Because of transition altitude, flight crews may switch at different points.		
ATC	25	Confusion about aircrafts RNP capability		
ATC	29	Instructing wrong transition		

Related to	#	Description	Risk indication	
ATC sys	33	NAVAIDS/ILS unavailable		
ATC sys	34	Failure of ATC tools (inbound planning tools)		
Environment	35	Weather / CB or showers on the cleared route		
Environment	36	Crosswind		
Environment	38	Failure of GNSS infrastructure		

Table II-5 Hazards related to 'Aircraft and flight crew capabilities and performance'

<u>Lateral deviation from flight path [hazards 1, 2, 3, 4, 5, 7, 8, 9, 10, 11, 12, 13, 16, 17, 18, 19, 20, 21, 22, 23, 25, 29, 33, 34, 36, 38]</u>

As navigation in the proposed concept heavily relies on the predefined route stored in the aircrafts FMS, FMS system failures and/or flight crew handling errors of FMS or other aircraft systems become more important than in current operations where the aircraft is provided radar vectors. In combination with the assumption that there is no longer vertical separation assurance (see section 3.4.7), lateral deviations due to any cause are more likely to evolve into a traffic conflict with traffic on the parallel approach.

Referring to Figure II-4, lateral deviation is most critical at the end of a transition, while converging in the S-turn, and during ILS intercept.

Lateral deviation at end of transition

When an aircraft deviates from the route at the end of a transition, from baseleg to S-turn, in the worst case by completely missing the turn, the aircraft will fly in the direction of the parallel approach. However, the lateral separation between the trombone and the parallel path is assumed to be at least 3 Nm.

With 3 Nm separation and an aircraft speed of say 220 kts, the time separation to the parallel approach path is 49 s. Assuming that the aircraft fly above 5000 ft in this segment, and if the aircraft on the parallel approach has already made the turn towards the S-turn, such that the aircraft are not in opposite direction, this situation will not trigger a TCAS TA or RA (see Appendix B for some more information on the working of TCAS and definitions of TCAS limits).

In the case that both trombones are mirrored, there is the possibility that aircraft fly in opposite directions. In that case, the closing speed could be 440 kts. the vertical separation – which cannot be assured – a TCAS TA can then be triggered once the separation becomes less than approximately 4.9 Nm (40 seconds) or an RA once the separation becomes less than approximately 3.1 Nm (25 seconds). I.e., a TA could occur even if both aircraft are still on baseleg and an RA if one of the aircraft overshoots the turn from baseleg to S-turn.

Although the occurrence of a TCAS TA or RA may be far from a real accident, a TA or RA may cause disturbance for the flight crew or traffic flow (to be discussed in section II.3.5), and it can be used as an indication of accident probability. Therefore, the design of mirrored transitions requires attention for this aspect and further study.

Lateral deviation in the S-turn

Again, the occurrence of a TCAS alert can be used here as an indication of accident probability. Assuming that the S-turn in fact consists of a route segment that has an angle of 20 degrees with the extended centreline, and assuming that the deviation is about 10 degrees such that the angle of the trajectory of the deviating aircraft with the extended centreline is 30 degrees, the time separation before the aircraft reaches the extended centreline of the other runway (at a minimum distance of 0.9 Nm which is the distance between the two runways) in case of a speed of 160 kts equals (0.9 Nm / (160xsin(30)) x 3600 =) 40.5 seconds. According to the definition of TCAS as described in Appendix B, and provided that the aircraft is flying between 2350 and 5000 ft in this segment, a TA or RA will be triggered if the time to Closest Point of Approach (CPA) is less than 40 or 25 seconds respectively. A deviation of 10 degrees can therefore almost instantly trigger a TA or 15 seconds later an RA.

In the derivation of minimum required distances between parallel runways (Ref. X), a worst-case blunder scenario assumed a break-out angle of 30 degrees. With a deviation of 30 degrees, the time separation would reduce to (0.9 Nm / (160xsin(50)) x 3600 =) 26.4 seconds, which is slightly above the RA limit. In other words, a deviation of 30 degrees can almost instantly trigger an RA.

To put it otherwise, the separation distance where a TA might be triggered in the above scenario equals (40 x (160xsin(30)) / 3600 =) 0.89 Nm while an RA might be triggered at (25 x (160xsin(30)) / 3600 =) 0.56 Nm.

Apparently, deviations up to 10 degrees may result in a TA shortly after the deviation begins. Then, there is 15 seconds for ATC and flight crew to detect the deviation before an RA could be triggered.
It is expected that the NTZ is present in this area, which will help ATC to detect the deviation. It is to be studied in further detail to what extent 15 seconds are sufficient for ATC and/or flight crew to resolve such a situation.

Note that in the above discussion, it is indirectly assumed that the other aircraft is both longitudinally and vertically in the area threatened by the deviating aircraft. The stagger of the runways will contribute to vertical separation between the two aircraft. It is recommended to study this in further detail, to get more insight in the potential for TAs or RAs and as such in the accident probabilities.

Lateral deviation around ILS intercept
Almost the same reasoning as for lateral deviation in the S-turn applies here. Assuming that the intercept angle from S-turn onto the ILS localizer is around 20 degrees, problems with ILS intercept most likely result in a continuation of the trajectory, i.e., approaching the parallel path under an angle of 20 degrees. As in the discussion above already a minimum separation of 0.9 Nm was considered, which equals the distance between the two runways, the same initial separation applies here. Therefore, the same conclusions can be drawn.

<u>Longitudinal deviation from flight path [14, 15, 29]</u>
If an aircraft takes the wrong transition, either due to an error in the FMS data, a flight crew error or erroneous ATC instruction, the separation with a preceding or following aircraft may decrease. It is expected that ATC will quickly notice such a deviation and will fall back to radar vectoring to resolve the situation.

<u>Vertical deviation from flight path [6, 24]</u>
Because of the assumption that there is no longer vertical separation assurance (see section 3.4.7), vertical deviation from flight path is not really of interest.

<u>Lining up for the wrong RWY and ILS [17, 18]</u>

Given the assumption that traffic from western directions use RWY 18R and traffic from eastern directions use RWY 18C (see section 3.4.7), it is not very likely that the wrong RWY will be selected or that a change of RWY occurs once the CDA has started.
In some aircraft, the ILS is automatically selected based on selected runway. In 2020 the amount of aircraft with this feature is expected to be increased. Therefore, the possibility of a wrongly selected ILS given the correct CDA is or will become limited. Next to that, it is questionable at all whether the ILS of the other runway can be captured. This is to be analysed further.

<u>Deviations due to weather conditions [35, 36]</u>
Deviations of the prescribed path due to wind or turbulence are considered to be covered in the above discussions. Deviations in the sense that the aircraft needs to circumnavigate a CB or thunderstorm will be conducted in consultation with ATC. Moreover, as in the application of RNAV night transitions, ATC will be reluctant in applying such concept in these weather conditions. In such case, the CDA procedure is cancelled and ATC will fall back to radar vectoring. This will affect the robustness of the traffic flow which will be discussed further in section II.3.5.

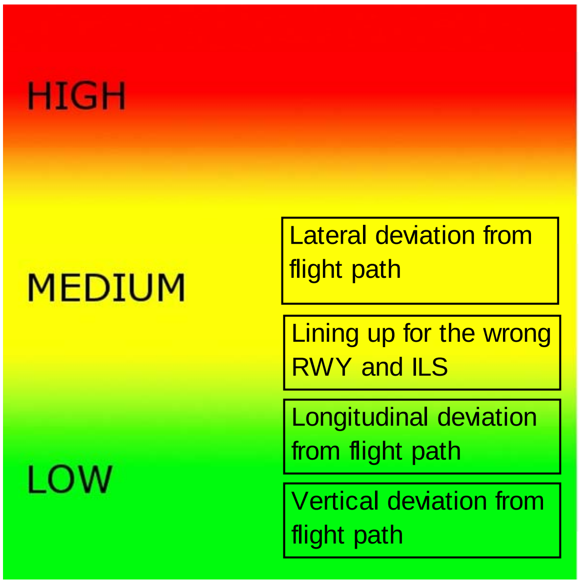


Figure II-8 Risk classification for 'aircraft and flight crew capabilities and performance'

II.3.4 Detection and resolution of conflicts

The hazards that are assigned to this topic are listed in Table II-6.
Note that for these hazards, there is no risk indication as these hazards will not induce a conflict situation on its own but will rather have an effect on the risk associated to the hazards discussed in the previous subsections.

Related to	#	Description
ATC	25	Confusion about aircrafts RNP capability
ATC	26	Confusion whether aircraft flies LNAV or HDG SEL
ATC	27	Lower alertness due to shift in Air Traffic Controller task from controlling to monitoring
ATC	28	Error in NTZ monitoring / interpretation
ATC systems	30	Radar failure
ATC systems	31	Communication system failure
ATC systems	32	Failure of NTZ alert
Environment	37	TCAS warnings

Table II-6 Hazards related to 'Detection and resolution of conflicts'

The following topics are distinguished:

- ATC confusion about aircraft capability or behaviour
- ATC system failures
- ATC detection/resolution of a conflict
- Flight crew detection/resolution of a conflict

ATC confusion about aircraft capability or behaviour

If ATC is not aware that an aircraft is not capable to conduct the IPC procedure, the aircraft may show larger deviations from the route than expected. As the deviations of an aircraft flying RNAV while not capable [h 11] are expected to be small, this may not really be an issue. Once ATC detects that the aircraft is not capable it may decide to fall back to radar vectoring. In case of alternative I where radar vectoring is applied before the start of the CDA, it may take longer before this is detected and the deviation could therefore result in a conflict in a more critical route segment.

If an aircraft flies HDG SEL instead of LNAV, it will continue to fly on the set heading. This may for example occur in alternative I if an aircraft does not switch from the last radar vector to the CDA. However, in this stage of the flight, it is not likely to directly lead to a critical conflict while ATC will quickly notice the deviation.

If the aircraft continues to fly LNAV all the way down to the runway threshold, because the flight crew did not arm the ILS interception mode, it will be more difficult to detect for ATC, but this behaviour is not expected to cause such large deviations that could imply a conflict.

ATC system failures

On one hand, ATC system failures such as radar or other surveillance failures or communication failures can occur today as well. And actually, because of the shift from radar vectoring towards a fixed route, one could say that ATC system failures will have a smaller effect on the safe operation of the flight: The flight will continue to conduct its CDA and is not dependent on ATC instructions.

On the other hand, because of the loss of vertical separation assurance, the role of ATC systems becomes more important in the detection and resolution of conflicts. If a conflict situation develops in a lateral sense, it is more likely to also become a conflict in vertical sense.

ATC detection/resolution of a conflict

The role of the ARR controller shifts from controlling (providing radar vectors) to monitoring. This reduced task load may be positive for conflict detection, as the controller can focus his attention to certain hot spots. Furthermore, increased lateral navigation accuracy, particularly if RF-legs are used, implies less spread in lateral deviations. This makes it easier to detect significant deviations timely. Real time simulations should help to gain more insight in this issue.

Flight crew detection/resolution of a conflict
Although – as discussed before – a TCAS TA or RA may be an unwanted event, in case of a conflict, it will help the flight crew to detect and resolve the situation.

II.3.5 Robustness of the traffic flow

The hazards that are assigned to this topic are listed in Table II-7.

Related to	#	Description
Flight crew	14	Flight crew selects wrong transition/approach
ATC	29	Instructing wrong transition
ATC systems	34	Failure of ATC tools (inbound planning tools)
Environment	35	Weather / CB or showers on the cleared route
Environment	37	TCAS warnings

Table II-7 Hazards related to 'Robustness of the traffic flow'

Introduction of the IPC procedure may in different ways pose a threat to the traffic flow:

- The possibility that the route is extended or shortened using the transitions provides ATC some flexibility to handle the traffic flow smoothly. However, this opportunity for ATC results in a less predictable situation for the flight crew. And if an aircraft flies a wrong transition due to any cause, it may corrupt the traffic flow and ATC may need to fall back to radar vectoring.
- As discussed in section II.3.4 the IPC procedure may lead to an increase in TAs and/or RAs, depending on the exact definition of the routes. This may disturb the traffic flow.
- The need to circumnavigate CBs or thunderstorms exists today as well. The difference is that nowadays ATC can prepare and provide the traffic with suitable radar vectors. If traffic is on a predefined route as foreseen in IPC, it would not be possible (unless by falling back to radar vectors) to control the traffic around the CB or thunderstorm. As today for RNAV night transitions, it is expected that ATC will be reluctant in applying the IPC procedure in case of these weather situations.

II.4 Summary of findings

This safety assessment has been carried out on the preliminary design of the IPC procedure. As such, the safety indications have a preliminary nature as well and include uncertainty. The safety criticality of the IPC procedure will depend on the final design.

In the current assessment, no unacceptable safety risks were identified. Yet, safety bottlenecks that have been identified and that require attention in the further design of the procedure are:

- Naming and publication of the procedure and procedure elements (waypoints, transitions);
- Definition of the default procedure and possible extensions or short-cuts via transitions;

- (Relative) location of the trombones;
- Interception of the CDA after radar vectoring (in alternative I);
- Interception of the ILS localizer after the S-turn;
- ATC opportunities to detect/resolve conflicts; and
- Unnecessary/unwanted TCAS TAs/RAs.

What has become clear in the assessment is that this concept in fact is a compromis between flexibility for ATC and predictability for flight crew; a further design of the procedure should therefore look for a good balance between these two.

Annex III Quick-scan Human Factors

The contents of Annex III has been taken from [Ref. 9].

III.1 Short project description

The primary objectives of the project is to generate potential solutions to remove the need for the 1000ft altitude separation requirement for independent paralllel and converging approach operations, in order to facilitate the introduction of continuous descent approach operations.
The definition of a CDA as described here is more limited than the ICAO definition which applies from top of descent. As described here a CDA is starting at FL70 until the G/S, vertical path is not predefined and flexible for the flight crew to optimise.

III.2 Affected functions

The affected functions are:

- Approach controllers (both APP (FDR) and ARR position);
- Cockpit crew.

III.3 Expected HF impact in brief

The following potential solutions are described:

1. S type shallow fixed turns
2. S type shallow fixed turn and straight in

Both 1) and 2) can contain either

a) RF legs or
b) TF legs

Both 1) and 2) can be:

I. radar vectoring from IAF to the *CDA starting point*
II. closed RNAV route from IAF to ILS

III.3.1 Concept 1, S type shallow fixed turns

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Monitoring and attention distribution (Situation Assessment)

With respect to monitoring, the controller task will be focussed on the fixed route rather than the current flexible radar vectoring area. This in itself would means a reduction in monitoring effort. For monitoring the route, a few spots can be identified which will require most attention: intercepting the route, taking the correct turn in the trombone and the turn to the ILS. For the first one, intercepting the route, it depends whether the route starts at the IAF or *CDA starting point*. In case the route starts at the IAF there is no route interception to monitor.
It can be stated that distributing attention with respect to arriving traffic it will be limited on the aforementioned hot-spots rather than the current flexible radar vectoring area which is an advantage. In case the RNAV starts at the CDA staring point the FDR controller will instruct aircraft to intercept the CDA starting point and monitor correct interception of the route.

Applying RF legs (alternative b) compared to TF legs (alternative a) provide the advantage that deviations might be detected easier since normally every aircraft follows exactly the same route with very little deviations.

Controllability and timing (Planning and Decision making)

As stated above the current APP working method consists of issuing radar vectors which is very flexible and tactical. Introducing fixed routes with a CDA profile removes flexibility and limits the controllability for the controller. Therefore this concept of fixed RNAV routes will not be introduced as isolated ATM concept element but also a more accurate planning for TMA entrance (IAF) with tools like SARA are assumed.

Regarding controllability the alternative I (RNAV route starting at CDA starting point preceded by vectoring area) and alternative II (RNAV route starting at the IAF) differ. Alternative I includes flexibility for both the FDR controller who can vector aircraft to the CDA starting point. The ARR controller can use the trombone. In alternative I the FDR controller has very limited control options.

Issuing instructions regarding a fixed route requires slightly more time for the flight crew to process than a radar vector instruction and the controller should issue those instructions well in advance. In addition, since the routes will be CDA's, the speed of an aircraft can hardly be influenced and speed instructions are as good as not available for the controller.

Problem detection and resolution opportunities

What if the normal operation is disturbed? As stated before, the current operation with radar vectors is very flexible. So, in case of a CB close to the airport, controllers can vector traffic around it. A fixed route offers no solution. And reverting to radar vectoring is in fact the only solution. Other disturbances caused by either controller error, pilot error or communication error can lead to taking the wrong turn in the trombone or taking the wrong route to the wrong runway. Each of these require fast corrective action. Taking the wrong turn in the trombone can lead to a conflict situation requiring immediate action. In those situations the detection is of vital importance and as stated above under monitoring the controller will be more focussed on the specific spots such as the trombone turning points. However, taking the wrong turn is not expected by the controller and will likely not occur very often. Early detection support tools may be considered.

A last but not least disturbance is an overshoot of the LOC course or missing the turn to the ILS. The procedure design with a shallow turn to final is intended to create detection time for the controller to observe a route non conformance. Here the application of RF (alternative a) vs TF (alternative b) legs has its consequences. With RF legs the number of route deviations will be significantly less than for TF legs. In addition it will be easier to detect an aircraft not turning to the localiser when using RF legs since there is no room for confusion whether the turn will not be made of just be overshot. Time criticality is high for this disturbance, immediate action is essential and detection times should be minimal. The route design itself is creating time, detection tools might be considered. Early detection of deviation from the route will increase if the operation become the new standard and will be applied very often. If this kind of operation is applied by exception the chance of early detection of route deviation becomes less.

Number of instructions (R/T and actions)

The number of instruction will be less than the current radar vectoring instructions. However, instructions will contain more information and will be longer and even more important instructions will have to be issued more in advance. The current radar vector instructions are very tactical, route instructions for the CDA's require more time to process for the flight crew and therefore can be less last minute. This means that the controller should be anticipating more than in the current radar vectoring operation.

Pilot

Monitoring and attention distribution

In the current operation pilots have a very rough expectation of the route between the IAF and the localiser of the ILS system, however the exact route will become clear only in a very late stage when the base-leg turn is initiated. When using the fixed route, the pilot is fully aware of the route to be flown and therefore more aware of the energy situation of the aircraft for the arrival. Since the vertical profile is a CDA, the energy management can be optimised for the individual aircraft compared to the current stepwise descent by means of vector instructions. This means that monitoring is required for the profile of the flight, which is not different as it is today. The unknown element of the route is the lateral location and the length of the trombone (if applied). For the pilot it is important to receive an instruction from the controller which turn to use sufficiently in time to set up de FMS for the base-leg turn.

Controllability and timing

The lateral path is well defined, The vertical is contained within certain boundaries. The pilot will have to rely on the FMS.The FMS is less in use during the current operation, mostly based on radar vectors (apart from the night transition) considering SPL A lot of experience has been gained during the night transitions at SPL and is a process which is still on-going. Being able to use the FMS, controllability of the flight is well supported. In case lateral or vertical deviations of the route is instructed, due to operational disturbances (CB for example), the pilot will not likely be able to continue the CDA but will ask for radar vectors to the localiser of the ILS.

Number of instructions (R/T and actions)

The number of instructions will be less, the length of an instruction may be more. Compared to radar vectors the action to be taken are more FMS related rather than basic autopilot actions and will require slightly more time to process.

Problem detection and resolution opportunities

Problems to be detected for the pilot are for example occurrence of insufficient navigation performance, or incorrect selections route (element) made earlier in the flight. Compared to the current operation the chance of incorrect flight deck input increases. The design of the lateral RNAV route is intended to allow for early detection of incorrect pilot selections.

III.3.2 Concept 2, S type shallow fixed turn and straight in

Since concept 1 and 2 are very similar. For the ARR of 18R the situation is identical to concept 1. For ARR 18C the operation is characterised by a long final segment. For the FDR the operation is hardly different, the difference is characterised by the traffic fed to the ARR of 18C.

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Monitoring and attention distribution

Regarding monitoring ARR 18C has to monitor traffic on a long straight in final which in itself is not complex and deviations from this straight in leg should be relatively easy to detect. For ARR 18R the description of concept 1 applies.

Controllability and timing

Depending on the length of the straight in leg compared to the S-type procedure the controllability might be impacted. At this moment in the design process the route length of the S-type RNAV route and the straight in RNAV route are almost identical in length. Therefore no impact of controllability and timing is to be expected.

Problem detection and resolution opportunities
The possibilities of errors and the detection of these identical to those relevant for concept 1 except for ARR of 18C, the possible overshoot of the turn to the ILS does not apply.

Number of instructions (R/T and actions)
Since the lateral route is part of a published RNAV route there layout of the lateral path is of no consequence for the number and length of the R/T instructions.

Pilot
Monitoring and attention distribution
Concept 2 does not differ to concept 1 except the monitoring of the turn to the ILS is a monitoring task irrelevant for the arrival runway 18C.

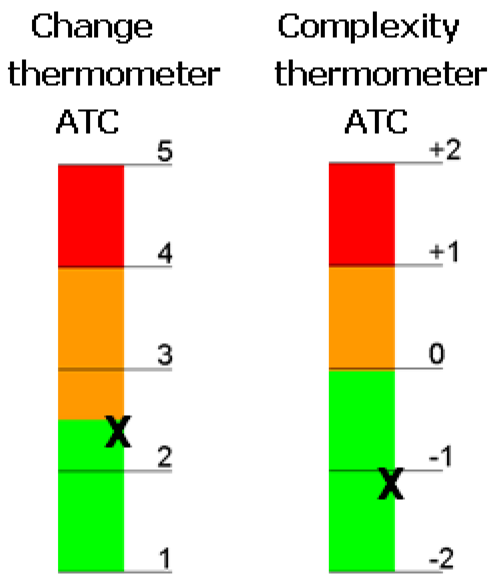
Number of instructions (R/T and actions)
Since the lateral route is part of a published RNAV route there layout of the lateral path is of no consequence for the number and length of the R/T instructions.

Controllability and timing
Concept 2 does not differ from concept 1 regarding controllability and timing for the pilot.

Problem detection and resolution opportunities
As indicated under monitoring and attention distribution the turn to final on 18C is no critical element in the procedure. Further more the same applies as described for concept 1.

Since for ATC the task complexity is highly relevant to take into account in the decision to initiate changes in the LVNL ATM system, the magnitude of the change (for the current population of ATCos) and the impact on the task complexity (for future ATCos) the table below is included here.

Independent Parallel CDAs Function group: *[APP]*	**Changes in competencies:** (1 = very small; 2 = small; 3 = average; 4 = large; 5 = very large)	**Easier ATM system:** (−2 = a lot easier; −1 = easier; 0 = no change; 1 = more complex; 2 = lot more complex)
Situation assessment	*3*	*-2*
Planning & decision making	*4*	*-1*
Actions	*3*	*-1*
Influencing factors	*1*	*0*
Weighted total	*2.3*	*-1.2*


Change
thermometer
ATC
5
4
3
X
2
1
Complexity
thermometer
ATC
+2
+1
0
-1
X
-2