Operational Safety Study

Low Level Go Around

Edition 1.0
Edition date: 19/01/2019

DOCUMENT APPROVAL

The following table identifies all management authorities who have successively approved the present issue of this documents.

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DOCUMENT CHANGE RECORD

The following table records the complete history of the successive editions of the present document.

Edition Number	Edition Date	Reason for change	Pages affected
0.1	05/03/2018	Creation of the Working Draft	All
0.2	09/03/2018	Drafting team review	All
0.3	23/04/2018	SISG review	All
0.4	21/09/2018	Drafting team review	All
0.5	24/09/2018	NM safety unit review	All
0.6	11/12/2018	NM safety unit review	All
0.9	18/12/2018	Final review	All
1.0	19/01/2019	Released Issue	All

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EXECUTIVE SUMMARY

The EUROCONTROL Safety Improvement Sub-Group (SISG), reporting to the EUROCONTROL Safety Team, was tasked with identifying safety problems of sufficient concern to warrant in-depth operational safety studies.

In 2017, following the results of the analysis of a sample of A- and B-severity incidents which had occurred in the terminal control areas (TMAs) and control zones (CTRs) around airports in EUROCONTROL Member States in the period 2014-2016,

the SISG concluded that two new problems needed to be examined with a view to NM operational safety studies:

- Conflicts on or following low-level go-arounds
- IFR and VFR conflicts in airspace classes E and D

The purpose of this report is twofold, namely:

- to document the Operational Safety Study on one of the Network Manager operational safety priorities for 2018, i.e. "conflicts on or following low-level go-arounds";
- to serve as a reference for the network actors if they undertake operational safety analysis and improvement activities regarding the risk related to conflicts on or following low-level go-arounds.

The conclusions of the study were as follows:

- This study identified six different scenario outcomes which could result in a conflict on or following a low-level go-around. The study concluded that each airport and ATC unit has different levels of risk exposure to these scenarios and therefore no "one-size-fits-all" recommendations are made.
- This study identified seven available barriers, which, if deployed and used correctly, could prevent a conflict occurring by either preventing the low-level go-around or allow action to be taken immediately following a low-level go-around. ATC defensive controlling prior to go-arounds and subsequent ATC prevention of conflicts were the barriers with the highest spread of applicability.
- The study identified five available barriers, which, if deployed and used correctly, might mitigate the collision risk of a conflict occurring during a low-level go-around. ATC ad-hoc conflict resolution and pilot-independent conflict resolution were the barriers with the highest spread of applicability.
- This study identified, and suggests, a method of weighting the potential effectiveness of each barrier depending on the prevalent types of runway configuration and traffic mix at individual aerodromes.

Recommendations are made that:

- European airport authorities and ANSPs review the identified potential barriers and the conclusions if they undertake operational safety analysis and improvement activities for conflicts on or following low-level go-around events;
- European airport authorities, ANSPs and the EUROCONTROL Safety Improvement Sub-Group (SISG) monitor occurrences involving conflicts on or following low-level go-arounds to determine changes in frequency and severity;
- European airport authorities and ANSPs note that no "one-size-fits-all" recommendations are made, and that a method of weighting the potential effectiveness of each barrier could be considered, which takes account of the prevalent types of runway configuration and traffic mix at individual aerodromes;
- ANSPs and aircraft operators should note that ATC defensive controlling and the subsequent ad-hoc resolution actions by both controllers and pilots are currently the most effective barriers. It is therefore recommended that ab-initio and continuation training be reviewed and enhanced where appropriate to heighten awareness of best practice;
- All European aviation stakeholders should note that the current most effective methods of reducing the frequency and severity of such events rely on human performance. It is therefore recommended that all European aviation stakeholders support the development of tools and procedures which increase resilience and reduce the level of reliance on human performance.

1. INTRODUCTION

1.1 What is the purpose of this document?

This purpose of this report is twofold, namely:

- to document the operational safety study on one of the Network Manager operational safety priorities for 2018, i.e. – "conflicts on or following low-level go-arounds";
- to serve as a reference for the network actors if they undertake operational safety analysis and improvement activities for safety events involving conflicts on or following low-level go-arounds.

1.2 What are the Network Manager's ATM operational safety priorities for 2018?

Risk of operation without a, or with a dysfunctional, transponder	Operations without a, or with a dysfunctional, transponder constitute a single threat with a potential of "passing" through all the existing safety barriers up to "see and avoid".
Sudden high-energy runway conflict	The scenario typically involves a runway conflict in which, once initiated, the time available to ATC to prevent a collision is likely to be less than the time needed.
Controller detection of a potential runway conflict	Some runway incursion incidents could be prevented if controllers had better means of detecting that the runway is occupied.
"Blind spot" – inefficient detection of a conflict with the closest aircraft	Loss of separation "blind spot" events are typically characterised by the controller not detecting a conflict with the closest aircraft. They usually occur when a controller is focused on a "future situation" and has filtered out the most urgent aircraft.
ACAS RA not followed	Losses of separation in the en-route environment sometimes involve cases in which ACAS RAs are not followed by one or more flight crews. Coordinated RA generation and response is an essential safety barrier, but some events include failure to follow an RA correctly or at all.
Conflicts on or following low-level go-arounds	This scenario typically involves an unsafe airborne situation when an aircraft commences a missed Approach and comes into close proximity with another aircraft.
IFR and VFR conflicts in airspace classes E and D	The scope of this operational safety priority is restricted to the risk of mid-air collision between IFR and VFR flights in airspace classes D and E.

1.3 How are the subjects for Network Manager operational safety studies identified?

The EUROCONTROL Network Manager identifies network safety problems in order to enable aviation stakeholders to identify existing hazards and anticipate new operational risks.

The EUROCONTROL Safety Improvement Sub-Group (SISG), reporting to the EUROCONTROL Safety Team, is tasked with identifying safety problems of sufficient concern to warrant in-depth operational safety studies.

The SISG carries out a programme of event data reviews with a spread of ANSPs across Europe, which represents a large proportion of European air traffic.

Comprehensive barrier models – Safety Functions Maps (SAFMAPs) – have been developed and populated with representative data from the participating ANSPs. The incident data is for high-severity events (classified as 'A' and 'B'), which are not only thoroughly investigated but also highly informative, because the incident scenarios 'test' the majority of the available safety barriers.

As a result of the SAFMAP analysis, the following priority areas were suggested, agreed by the SISG and endorsed by the Safety Team:

- Risk of operation without a, or with a dysfunctional, transponder
- Landing without a clearance
- Controller detection of occupied runway
- "Blind spot" – inefficient detection of a conflict with the closest aircraft
- Conflict between adjacent sectors

NM operational safety studies have been published on all five of these areas of concern and can be consulted at www.skybrary.aero

In 2016, following a review of the available data, the SISG agreed that two of these safety concerns needed to be re-qualified as "being monitored", namely:

- Landing without a clearance
- Conflict between adjacent sectors

Two new subjects for operational safety studies were identified:

- Sudden high-energy runway conflicts
- Failure to follow ACAS RAs

NM operational safety studies for these two subjects were published in 2017 and can also be consulted at www.skybrary.aero.

In 2017, following the results of the analysis of a sample of A- and B-severity incidents which had occurred in the terminal control areas (TMAs) and control zones (CTRs) around airports in EUROCONTROL Member States in the period 2014-2016, the SISG concluded that two new problems needed to be examined with a view to NM operational safety studies, namely:

- Conflicts on or following low-level go-arounds
- IFR and VFR conflicts in airspace classes E and D

1.4 Incident sample of TMAs and CTR study (2017)

The study used a sample of A- and B-severity incidents involving infringement of IFR flight separation minima and inadequate separation between IFR and VFR flights which occurred in the TMA and CTR airspaces (controlled by APP and TWR ATS units) in EUROCONTROL Member States in the years 2014, 2015 and 2016. Figure 1 below provides more detailed information about the reported incidents during the three-year period in question.

	2014		2015		2016		Total
	SMI	IS	SMI	IS	SMI	IS	
A	27	5	9	10	21	7	79
B	176	53	62	45	110	28	474
Total	203	58	71	55	131	35	553

Figure 1: Separation Minima Infringements (SMI) and Inadequate Separation (IA) TMAs & CTRs (APP & TWR) 2014-2016

The incident data were collected through the "NM collaborative process for identification of operational safety hazards at network level and assessment of the associated risk" agreed by the Network Management Board in April 2016. The process defines the data requirements on the basis of the evolution of the SAFMAP model and of the NM Top 5 prioritisation process during the years 2015, 2016 and 2017.

The 3-year sample analysed, as presented in Figure 2 below, includes 187 separation minima infringement and inadequate separation incidents, of which 19 were classified as severity-A and 168 as severity-B incidents. The sample of TMA/CTR incidents analysed constitutes 33.8% of all A- and B-severity TMA/CTR separation minima infringement (SMI) and inadequate separation (IS) incidents which occurred in European airspace in the period 2014-2016 and were reported to EUROCONTROL. It can therefore be concluded that the sample of runway incursion incidents analysed is sufficiently representative of the overall population of TMA/CTR SMI and IS incidents in Europe, in particular for the years 2015 and 2016, in which this percentage was 66.7% and 48% respectively.

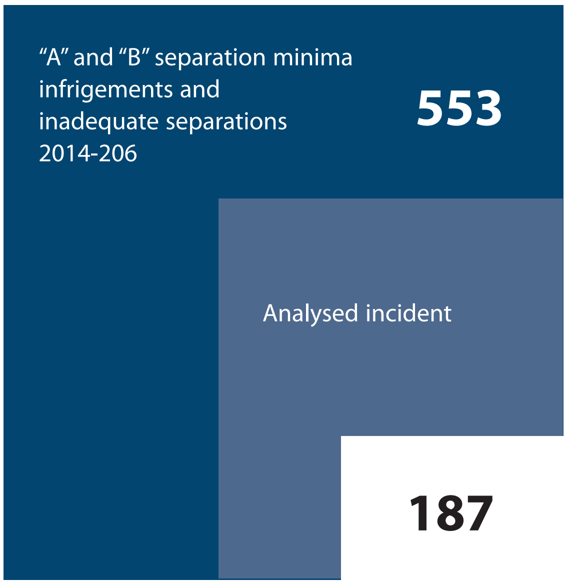

Figure 2

1.5 SAFMAP approach

SAFMAPs are barrier models based on structured documentation of the available defences against particular unwanted accident outcomes. These barriers are either part of the ATM system (ground and/or airborne component) or they can have an impact on the safety performance of ATM and/or aircraft navigation. Each discrete barrier is considered as a safety function. The functions used are rather generic, for example the function "Alert of potential deviation from clearance or instruction" does not specify the actual (technical) means to implement this function, such as for example the conformance monitoring tools (MONA) implemented at ATS units.

SAFMAPs are hierarchical structures in which each higher-level structure (function) can be decomposed into several lower-level structures (sub-functions). The top levels are called basic safety functions. The basic safety functions for the prevention of mid-air collisions are presented in Figure 3.

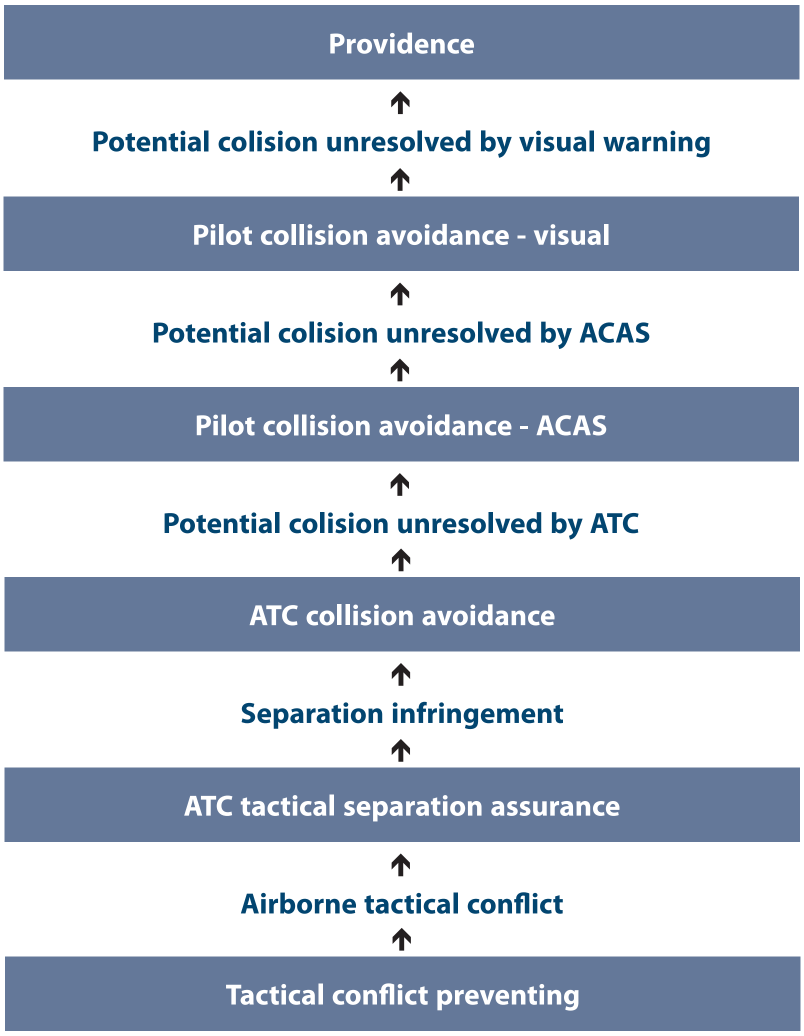

Figure 3

1.6 Low-level go-around data

The sample of 187 incidents was analysed using the same approach applied by EUROCONTROL for the identification of Network Manger Top 5 safety priorities and in the analysis of en-route separation minima infringement incidents. It is based on plotting the incident information on the TMA Safety Functions Map (SAFMAP) barrier structure depicting the defences against mid-air collision accidents in the TMA and CTR airspaces. The model version used was the "Safety Functions Map Configuration Description Model" of 18 November 2016.

The data sample of 187 severity events included 8 (4.3%) which involved conflicts on or following low-level go-arounds. This does not in itself seem to be significant, but of the six events recorded in the data sample as being resolved only by providence, i.e. good fortune, two involved conflicts on low-level go-arounds. A third of all events which did not result in mid-air collisions thanks only to good fortune therefore involved a low-level go-around. This is why this type of event was selected for further study.

These events have various initiating factors, but inadequate synchronisation of departing and arriving aircraft is the dominant one.

More detailed information of the exact occurrence scenarios is provided in Figure 4 below.

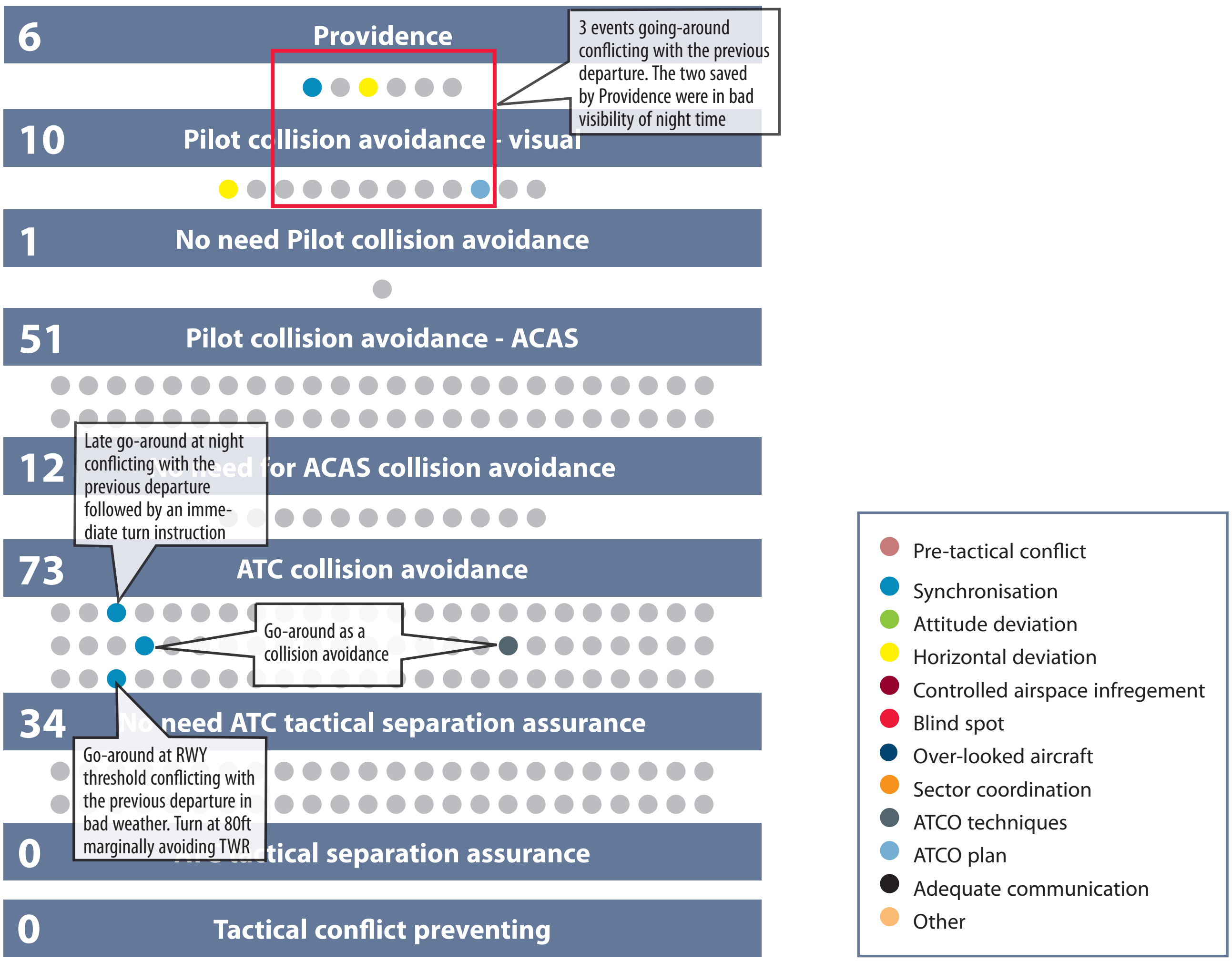

Figure 4

A brief analysis of the seven events involving actual conflicts on or following low-level go-arounds revealed the following common factors:

- Both of the events where a collision was avoided only by providence were in bad visibility or at night.
- One pilot visual avoidance event involved a conflict with the previous departure.
- Four events were resolved by ATC collision avoidance.
- A late go-around at night conflicted with the previous departure followed by an immediate turn instruction.
- A go-around at the runway threshold conflicted with the previous departure in bad weather. ATC instructed an early turn. The pilot commenced the turn at 80 ft marginally avoiding hitting the TWR building.
- Two go-arounds were initiated by ATC to avoid a runway collision.

2. STUDY SCOPE

2.1 Go-around safety risk

There are five major go-around outcome safety risks – loss of control in flight (LOC), controlled flight into terrain (CFIT), mid-air collision (MAC), runway collision (RC) and collision between airborne aircraft and vehicle on the ground (GND). The purpose of the present operational safety study on the scope of the go-around safety risk is confined to:

- mid-air collisions (MACs)
- runway collisions (RC), including collisions between airborne aircraft and a vehicle on the ground

2.2 Low-level go-arounds

This operational safety study regards low-level go-arounds as those initiated below 400 feet AGL.

There are two reasons for this study criterion.

- It aligns with the criteria of recent studies and safety initiatives driven by the Flight Safety Foundation.
- Since 1972, in the United Kingdom and some other countries, a limit of "not below 400 feet AGL" has been in use for planned go-arounds with the runway obstructed. This was the result of an accident in 1971 when a Trident aircraft which was intending to go around not below 100 feet, hit the tail of a Comet lined up on the runway threshold[1].

It is suggested that the corollary to "a low-level go-around" is therefore "below 400 feet AGL".

2.3 What is a conflict in the aerodrome environment?

There are no defined separation minima infringement measurements in the aerodrome control environment. Colloquially, ATC staff and flight crew staff may talk of a "loss of separation". It is, however, more correctly termed an "erosion of safety margins".

The European Risk Assessment Tool (RAT) defines a conflict as «a reduction in normal safety margins». There is guidance which helps classify conflicts as minor, medium, significant and critical.

RAT guidance states that a go-around event in which all parties act within the bounds of normal operating procedures are outside the scope of the tool. As an example, it states that an unexpected go-around which is correctly handled by flight crew and by ATC, without any subsequent reduction in safety margins, is a normal operational procedure.

This study uses RAT guidance as its definition of the initiation of a conflict.

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1 AAIB report 4/72 into accident at Thurleigh Aerodrome, Bedford, 19 January 1971

3. THE GENERIC PROCESS

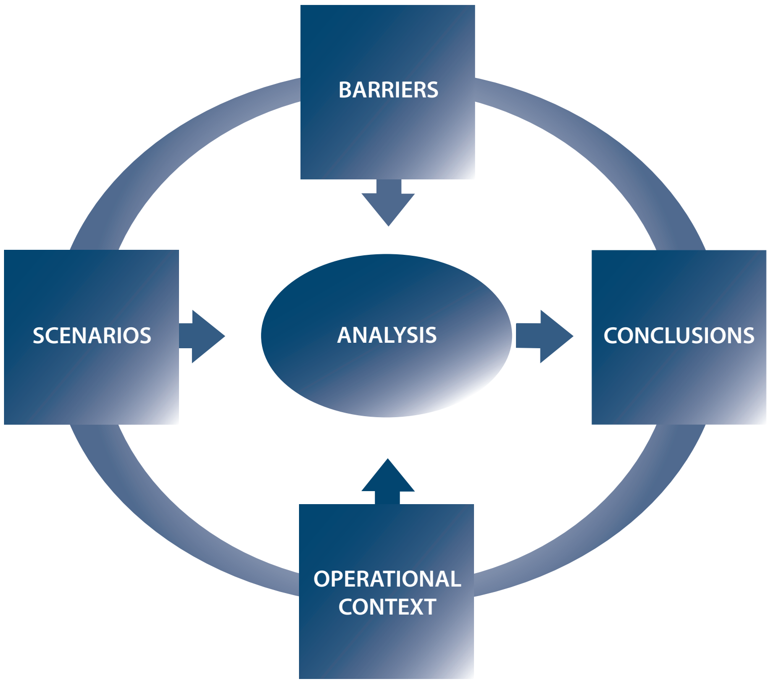

Figure 5

A generic process was designed to analyse ATM operational safety priorities (the Top 5) in order to provide a common methodology for assessment and evaluation (see Figure 5). The process starts with three preparatory steps:

- Identification of the operational context pertaining to the operational area considered
- Definition of the operational scenarios
- Identification of safety barriers (both preventing and mitigating the effect of the event)

Once all this data is collated, an analysis of the effectiveness of barriers against the identified operational scenarios will be made and correlated with analyses of real-life occurrences. Once the analysis is complete, the study will provide the conclusions.

4. SCENARIOS

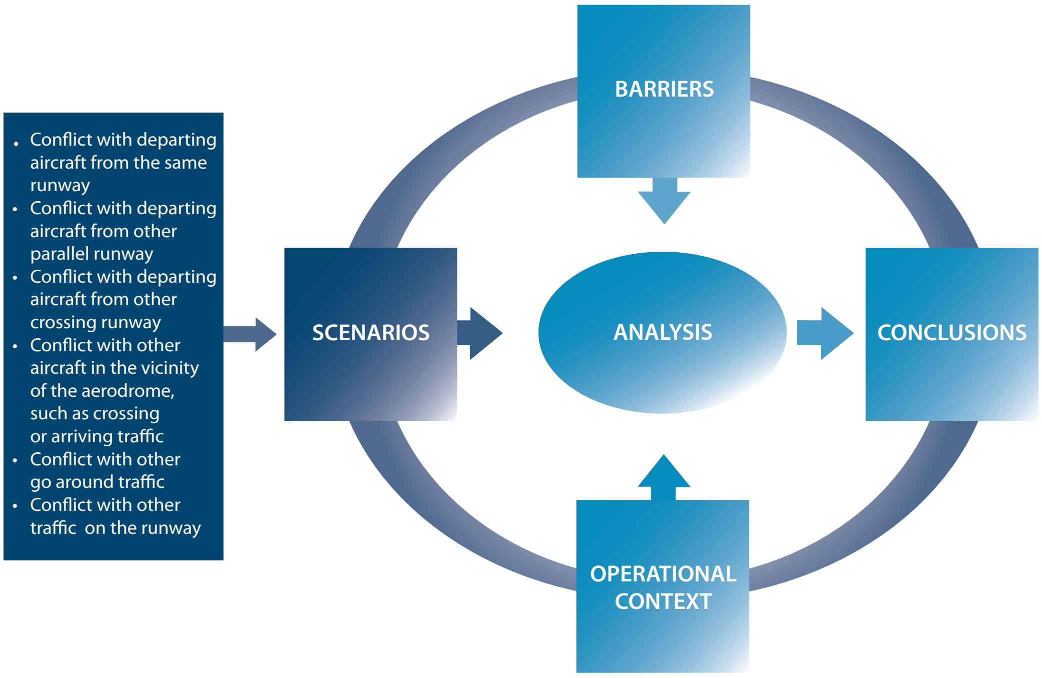

Figure 6

4.1 How should operational scenarios be defined?

Generic operational scenarios are needed in order to deconstruct the complexity of analyses. The definition of the scenarios is specific in order to help decide the efficiency of the safety barriers whilst at the same time being generic enough to keep their number relatively small. The definition of generic operational scenarios takes the form of a synthesis of two sources of information:

- A systematic analytical breakdown of the operational scenario into sub-scenarios. This is based on all theoretically possible combinations of the scenario (1) sources, (2) mechanisms and (3) outcomes.
- A review of the information publicly available from investigation reports of accidents and serious incidents investigated in line with the provisions of ICAO Annex 13 and confidentially provided data in respect of less significant incidents.

4.2 Analytical deconstruction of low-level go-around scenarios

The reasons for go-arounds are known as scenario sources. There are many reasons for go-arounds, some being initiated independently by a pilot, others on instructions from ATC. Below are the most common reasons for go-arounds, as derived from analysis of actual events.

4.3 Scenario sources

- Low-level go-arounds initiated by ATC
  - Inappropriate spacing with preceding aircraft
  - Runway still occupied by previous landed/departing/crossing traffic
  - Runway still occupied by authorised vehicle
  - Runway incursion

- Low-level go-arounds initiated by flight crew
  - Unstable approach
  - Aircraft lateral position relative to landing runway
  - Height/speed at threshold
  - Wind shear
  - Wake turbulence
  - Runway visual range limits or concern
  - Landing wind limits exceeded or a concern
  - Landing gear indications
  - Late awareness of inadequate runway braking action
  - Potential loss of control or runway excursion during landing
  - Cabin not secure
  - Lack of landing clearance
  - Flight crew take independent action having observed a vehicle on the runway

4.4 Scenario mechanisms

There are three go-around mechanisms, i.e. three principle ways in which the go-around trajectory can be flown:

A. The go-around follows the published MAP trajectory
B. The go-around follows the ATC instructions, which differ from the published MAP (prior to go-around initiation or on or after go-around initiation)
C. The go-around does not follow the required trajectory (either published or instructed by ATC) – deviation

4.5 Scenario outcomes

Within the defined context, there are six major scenario outcomes associated with go-around safety:

1. Conflict with departing aircraft from the same runway
2. Conflict with other traffic on the same runway
3. Conflict with departing aircraft from another parallel runway
4. Conflict with departing aircraft from another crossing runway
5. Conflict with other aircraft in the vicinity of the aerodrome, such as crossing or arriving traffic
6. Conflict with other go-around traffic

Illustrative examples of these scenario outcomes are presented in Chapter 7.

4.6 Combining the scenario sources and mechanisms result in operational scenario outcomes

The analytical scenarios to be used to assess the operational safety risk, including the efficiency of barriers, are defined by combining the scenario mechanisms and the scenario outcomes:

1. Conflict with departing aircraft from the same runway	**1A**	Conflict with departing aircraft from the same runway after a go-around whilst following the MAP
	1B	Conflict with departing aircraft from the same runway after a go-around whilst following an ATC instructed trajectory
	1C	Conflict with departing aircraft from the same runway after a go-around, pilot deviating to follow own trajectory
2. Conflict with other traffic on the same runway	**2A**	Conflict with other traffic on the same runway, on or after a go-around, whilst following the MAP
	2B	Conflict with other traffic on the same runway, on or after a go-around, whilst following an ATC instructed trajectory
	2C	Conflict with other traffic on the same runway, on or after a go-around, pilot deviating to follow own trajectory
3. Conflict with departing aircraft from another parallel runway	**3A**	Conflict with departing aircraft from another parallel runway after a go-around whilst following the MAP
	3B	Conflict with departing aircraft from another parallel runway after a go-around whilst following an ATC instructed trajectory
	3C	Conflict with departing aircraft from another parallel runway after a go-around, pilot deviating to follow own trajectory
4. Conflict with departing aircraft from another crossing runway	**4A**	Conflict with departing aircraft from another crossing runway after a go-around whilst following the MAP
	4B	Conflict with departing aircraft from another crossing runway after a go-around whilst following an ATC instructed trajectory
	4C	Conflict with departing aircraft from another crossing runway after a go-around, pilot deviating to follow own trajectory
5. Conflict with other aircraft in the vicinity of the aerodrome, such as crossing or arriving traffic	**5A**	Conflict with other aircraft in the vicinity of the aerodrome, such as crossing or arriving traffic after a go-around whilst following the MAP
	5B	Conflict with other aircraft in the vicinity of the aerodrome, such as crossing or arriving traffic, after a go-around whilst following an ATC instructed trajectory
	5C	Conflict with other aircraft in the vicinity of the aerodrome, such as crossing or arriving traffic, after a go-around, pilot deviating to follow own trajectory
6. Conflict with other go-around traffic	**6A**	Conflict with other go-around traffic after a go-around whilst around following the MAP
	6B	Conflict with other go-around traffic after a go-around whilst following an ATC instructed trajectory
	6C	Conflict with other go-around traffic after a go-around, pilot deviating to follow own trajectory

5. OPERATIONAL CONTEXT

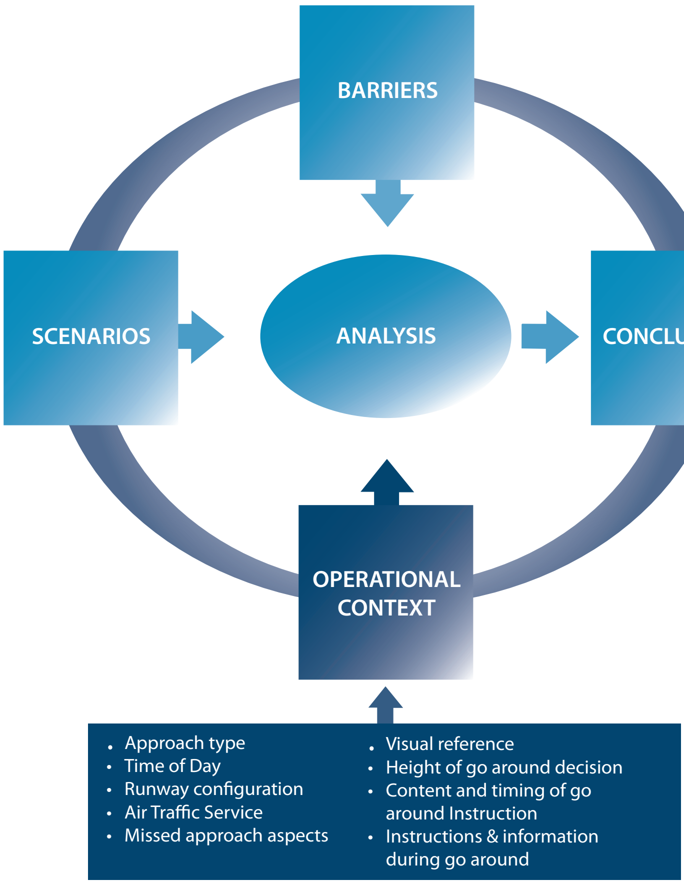

Figure 7

The operational context outlines those factors which can influence the availability and efficiency of preventive or mitigating barriers for any of the defined analytical scenarios. For example, if the presence of daylight influences the efficiency of some of the barriers, then we have to consider it as part of the analysis and this comes by reflecting it in the operational context.

Network actors may wish to make use of the following list of operational contexts, as an aid in the analysis of their safety events.

5.1 Approach type

- RNAV (LNAV, LP, LNAV/VNAV, LPV)
- RNP
- Straight in precision approach
- Straight in non-precision approach
- Visual
- Circling
- Instrument approach changed to visual below 2000 ft AAL

5.2 Time of the day

- Day
- Night

5.3 Runway configuration

- Single runway in use
- Parallel runways in use
- Non-parallel runways in use
- Intersecting runways in use

5.4 Air traffic services

- FIS
- ATC with no surveillance capability
- ATC with basic primary-only surveillance
- ATC with advanced surveillance, e.g. A-SMGCS
- Integrated tower working positions incorporating conformance and clearance alerts

5.5 Missed approach aspects

- First stop altitude in the MAP
- First turn instruction in the MAP
- Any conditional go-around/MAP procedures, e.g. "after xxx but not later than yyy…"
- Any procedural de-confliction of the missed approach path from other traffic and wake turbulence exposure, especially for late go-arounds

5.6 Visual reference

- Required visual reference available for at least 500 feet prior to DA/MDA
- Visual to instrument transition during go-around
- Instrument to visual transition during go-around
- Go-around flown solely by reference to flight instruments

5.7 Height of go-around decision

- After landing gear runway contact
- Airborne but below 50 ft AAL
- Below DA/MDA but not below 50 ft AAL
- At DA/MDA
- Above DA/MDA but below 400 ft AAL

5.8 Content and timings of go-around instruction

- ATC specify a non-standard MAP during the approach
- Go-around instruction is in a separate transmission to the reason for the go around
- Once a go-around is initiated, unnecessary RTF is avoided
- ATC issue non-standard MAP during the go-around

5.9 Time available and awareness between initiation of go-around and erosion of safety margins

- Conflict commences on initiation of go-around: no pre-awareness for crews or ATC
- Conflict commences on initiation of go-around: crew/s or ATC able to take mitigation action
- Conflict commences within 1 NM of upwind runway threshold
- Conflict commences more than 1 NM of upwind runway threshold
- Conflict commences below 1000 ft AAL
- Conflict commences 1000 ft or more above AAL

6. BARRIERS

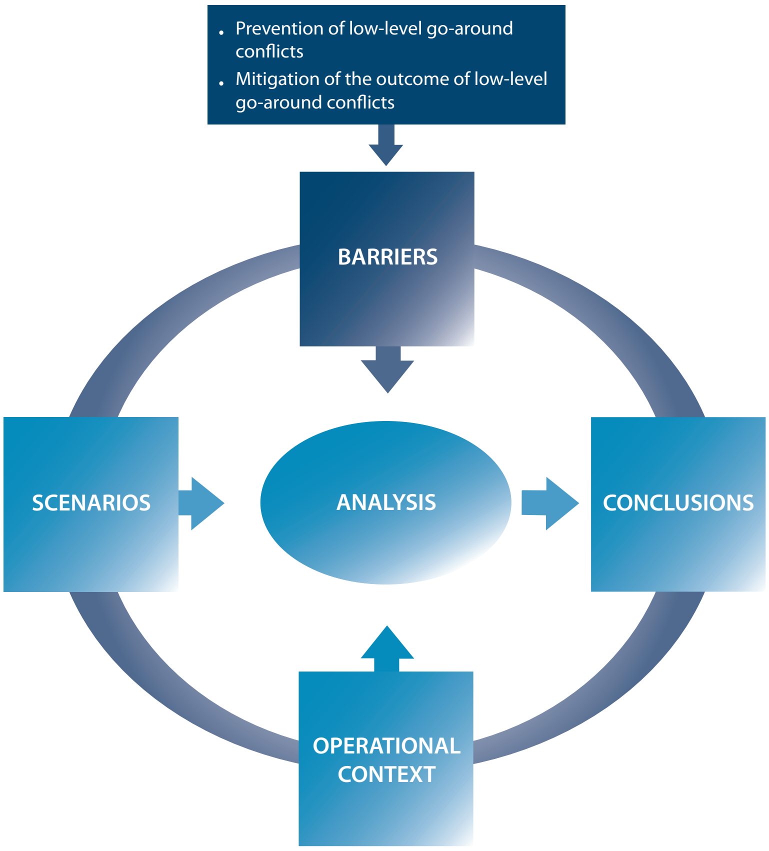

Figure 8

6.1 Barriers are opportunities

The barriers included in this risk review have been identified as possible ways in which detection of a potential low-level go-around event could be employed and/or the consequences mitigated.

Their inclusion does not imply that they are relevant to all situations nor does it mean that promotion of their adoption by airport operators or ANSPs would necessarily be appropriate. It may be possible to identify more potentially useful barriers than are included here.

6.2 Two types of barriers

There are two major types of barriers which can reduce the risk associated with runway safety events. These barriers have been identified on the basis of a broad literature search and consultation and are as follows:

- **Prevention of a conflict on or following a low-level go-around**
  These barriers, when deployed and employed correctly, are capable of alerting ATC, pilots and drivers in time to prevent normal safety margins from being eroded.

- **Mitigation of the collision risk of a conflict on or following a low-level go-around**
  These barriers, when deployed and employed correctly, are capable of alerting ATC, pilots and drivers to the initial stages of a low-level go-around conflict in sufficient time to act in order to prevent a collision.

6.3 Sets of barriers preventing a conflict on a low-level go-around

Figure 9 shows that there are three sets of barriers which become available for use at different chronological points in the sequence which may lead to a conflict.

For example, conflict-free ATC procedures may be pre-set but are not called upon to contribute until the go-around has commenced.

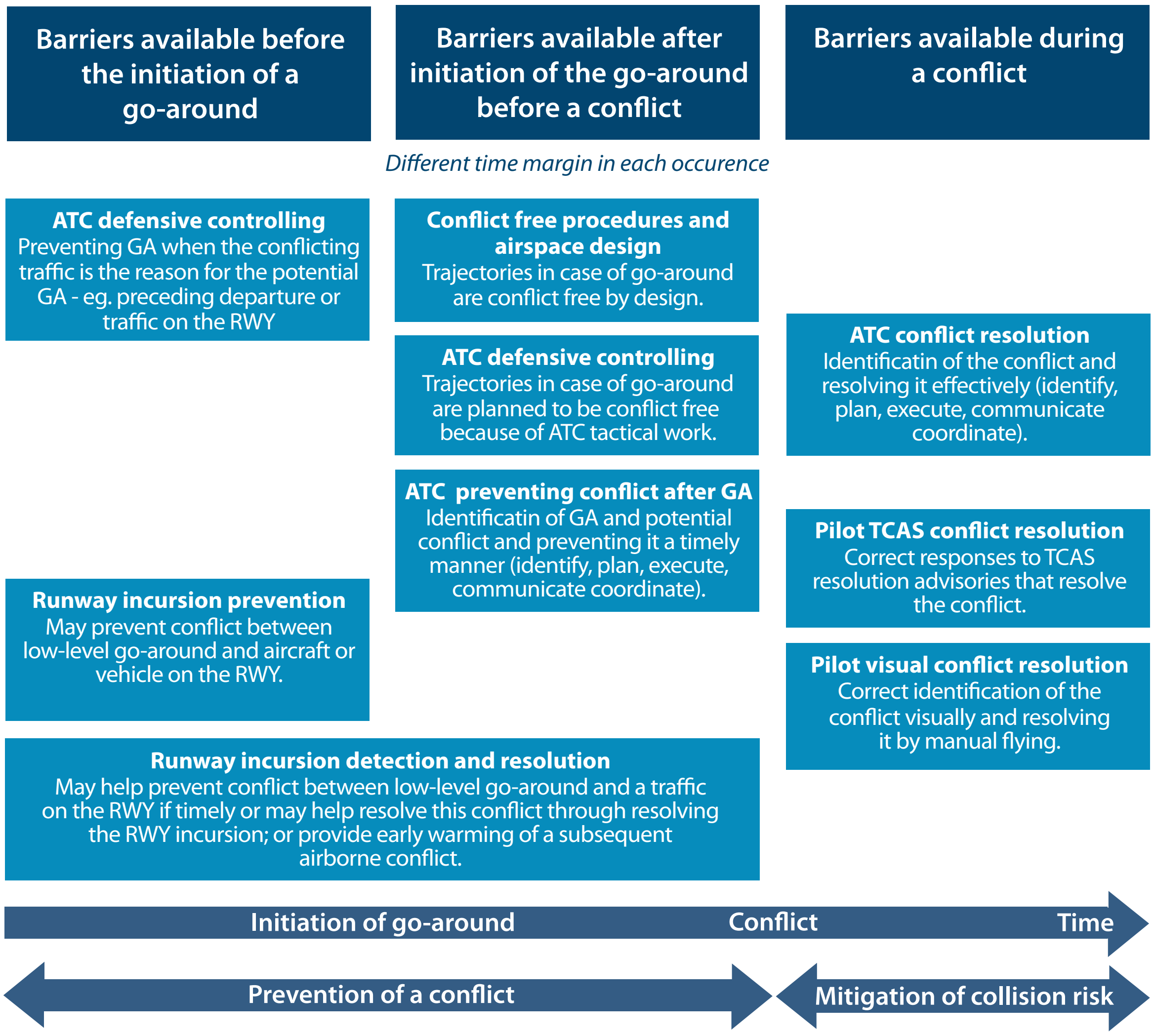

Figure 9

6.4 Removing the potential for conflict prior to the initiation of a go-around

Conflicts following a low-level go-around can be prevented by not having a low-level go-arounds in the first place. This can be achieved by effective planning, execution and communication by ATC and by flight crews. It can also be achieved by effective runway incursion prevention. Section 4.2.3 introduces the six possible scenario outcomes. Two of these six possible outcomes can be stopped by barriers at this early stage:

- Conflicts with departing aircraft from the same runway
- Conflicts with other traffic on the runway

Not all scenarios have precursors or warning flags which could have alerted users in a timely enough fashion to facilitate a successful approach and landing. No barrier will be effective in every case.

6.5 Prevention of go-arounds – barriers

ATC, flight deck and airport ground tools and procedures are detailed in the following publications:

- EUROCONTROL Network Manager Operational Safety Study: Controller Detection of Potential Runway and Manoeuvring Area Conflicts. Ed. 1.0 (2015)
- EUROCONTROL Network Manager Operational Safety Study: Sudden High-Energy Runway Conflicts, Ed. 1.0 (2017)
- EUROCONTROL Network Manager European Action Plan for the Prevention of Runway Incursions (EAPPRI), Version 3.0, Ed. 1.0 (2017)

It is not the intention of this study into low-level go-around conflicts to repeat all of the barriers, procedures and recommendations referred to in these extant documents. Network actors who undertake operational safety analysis and improvement activities regarding the risk relating to runway conflicts should refer to these documents.

For the purposes of this study, we will generalise pre-go-around barriers as:

- Airport design and runway lighting
- Airport safety nets and runway incursion prevention tools
- ATC defensive controlling
- Pilot defensive flying

These are shown and detailed in the tabulation as PB Pre-GA 1-4

6.6 Prevention of conflicts after a go-around has been initiated

Airspace design and ATC planned procedures can pre-tactically remove the risk of a conflict occurring in the event of a low-level go-around.

Conflict prevention after the initiation of a low-level go-around can also be effected by:

- ATC tactical prevention of the conflict through detection, planning, coordination/communication and effective execution;
- pilot prevention of the conflict by awareness of the potential conflict and flying in such a manner as to prevent safety margins being eroded.

These conflict-prevention barriers are shown as PB Post GA 5-7.

6.7 Chronological tabulation of barriers which have the potential to prevent conflicts on low-level go-arounds

PB Pre-GA 1	**Airport design and runway lighting** ■ Clear line-of-sight from ATC to all runway touchdown zones, including remote cameras ■ Angled or wide runway entry/exit points, promoting shorter runway occupancy, e.g. RETs ■ RETILs: Rapid exit taxiway indicator lights
PB Pre-GA 2	**Airport safety nets and runway incursion prevention tools** Various tools, both hardware and software, can help in preventing runway incursions. This in turn prevents the presence of the traffic on the same runway, and thus prevents the need for a go-around. ■ ATC clearance conformance monitoring alerts and confliction detection ■ 24-hour use of illuminated stop bars and procedures so that a lit stop bar is never crossed and ATC never clear an aircraft/vehicle to cross a lit stop bar ■ Runway entrance lights (RELs) ■ Airport moving maps for aircraft and vehicles ■ Transponders in vehicles and analogous ATC functionality
PB Pre-GA 3	**ATC defensive controlling** ATC defensive controlling is a range of ATC ways of working which can prevent low-level go-arounds primarily caused by less-than-optimum controlling. ■ Non-aggressive approach sequencing. Avoiding positioning aircraft too close, too fast, too high on the approach or too marginally behind preceding aircraft. This can be done in order to optimise runway utilisation or by prioritising "efficiency" over customer service. ■ Low-risk runway occupancy planning. Avoiding the creation of situations which are always going to be marginal, relying on everyone to expedite on and off the runway and no room for unexpected factors. This may involve attempting to get a departing aircraft airborne within the approach sequence or attempting to get two consecutive departures airborne, when there is really only comfortable time for one. ■ Requesting runway exit/entry positions in order to meet the plan. If the ATC plan relies on an aircraft vacating the runway at a particular exit point, the pilot should be advised well before action is required. If the pilot is unaware of its importance, there is a greater chance of a plan failing and of a subsequent go-around. ■ Constantly evaluating the progress of the plan and taking the best action available early if safety margins begin to erode. This entails not letting the situation run and hoping that things will work. ■ Communicating with pilots/drivers on a level team basis when necessary in order to enhance their situational awareness and increase the likelihood of avoiding a go-around. ■ Airport moving maps for aircraft and vehicles ■ Transponders in vehicles and analogous ATC functionality

PB Pre-GA 4	**Pilot defensive flying** Pilot defensive flying comprises a range of proactive cockpit ways of thinking and acting. It involves taking a share of responsibility for runway safety. ■ Reacting quickly and decisively to arising situations. Just like ATC, this involves not letting the situation run and hoping that things will work. ■ Informing ATC of the likelihood of a go-around, thus providing an early warning and time for ATC to plan a conflict-free path. ■ Informing ATC of inability to vacate or depart expeditiously, thus providing ATC with additional time to re-plan.
PB Post-GA 5	**Conflict-free procedures** Procedures may exist which provide sufficient separation between a go-around aircraft and other traffic such that safety margins are maintained. These may be procedures and flight profiles and may be published in the AIC or local ATC procedures. ■ Missed approach procedures and other departure/arrival routings provide procedural separation ■ ATC standard procedures in the event of a go-around, providing conflict free routings
PB Post-GA 6	**ATC prevention of conflict** ATC prevention of conflict involves a range of actions by one or more controllers to maintain safety margins on or following a low-level go-around. ■ Advanced coordination between ATCOs in control of other runways or approach control ■ Tactical prevention of post-go-around conflicts by individual ATCOs
PB Post-GA 7	**Pilot prevention of conflict** ■ Awareness of potential conflicts and taking independent action in such a manner as to prevent safety margins being eroded

6.8 Barriers mitigating the risk of collision in a conflict which has been initiated on or after a low-level go-around

Once normal safety margins have begun to be eroded, i.e. once a conflict is in progress, there are four principle means of reducing the severity of the outcome.

- ATC ad-hoc resolution without system support
- ATC ad-hoc resolution with system support
- ATC best practice actions.
- Pilot resolution by visual avoidance or by independent action (non-visual)
- Pilot resolution with TCAS assistance

These are shown and detailed in the tabulation as MB 1-5.

MB1	**ATC ad-hoc conflict resolution** ATC ad-hoc conflict resolution is impromptu last-minute action, once safety margins have already been eroded, by one or more controllers in order to remove the risk of collision and achieve as big a safety margin as practical. ■ A single ATCO issues an ad-hoc collision avoidance instruction. ■ ATC is coordinated and implements ad-hoc collision avoidance instructions.
MB2	**ATC conflict resolution with system support** This provides ATC with an alert that an aircraft is carrying out a go-around which was previously unknown, perhaps because of poor visibility, line of sight, focus elsewhere, e.g. Go-Around Detection System (GARDS). An ATCO is thus able to take early action to mitigate the outcome of an immediate conflict.
MB3	**ATC best practice** ATC actions and consequent flight profiles for each appropriate scenario on each runway are documented, understood and practised among ATCOs. This may provide faster more effective conflict resolution.
MB4	**Pilot provides own conflict resolution** ■ Pilot flies own tactical trajectory to increase distance horizontally and/or vertically between aircraft. ■ Pilot/s obtain visual acquisition of conflicting traffic and take visual avoidance manoeuvres.
MB5	**Pilot follows TCAS conflict resolution** ■ Correct response to TCAS resolution advisories. This is limited by functionality inhibiting RAs below 1000 ft AGL.

6.9 Barrier assumptions and dependencies

The following assumptions and dependencies apply for the analysis of barrier effectiveness:

- All barriers are deemed operationally available and operated correctly within their design limits.
- It is assumed that controllers and pilots will react correctly to all aural and visual safety nets.
- All barriers are limited by the responsiveness of the players to the signals.
- Deliberate non-conformance is excluded from the analysis.

For each scenario, consideration is given to how the available barriers could, if deployed and operated correctly, have a significant impact by preventing or mitigating the collision risk.

The high-level assessment considers the various operational scenarios and is based on expert judgment. This judgment includes the likelihood, given the available time, that the barrier could have a substantive effect.

No single barrier is effective in all situations, as each scenario outcome can have a variety of initiators, as shown in 4.2.1.

7. ANALYSIS: LOW-LEVEL GO-AROUND CONFLICT SCENARIOS

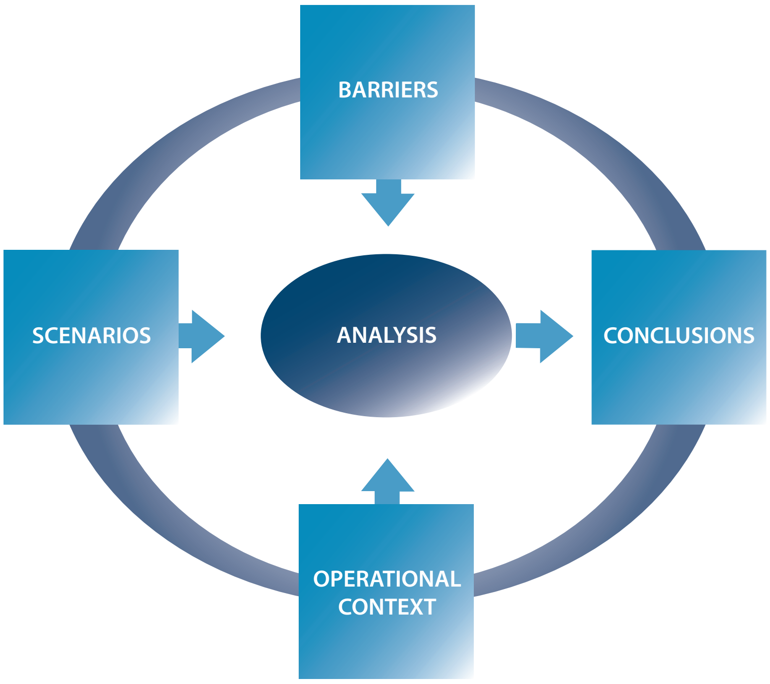

Figure 10

It was shown in 4.6. that within the defined context there are six major scenario outcomes associated with go-around safety:

1. Conflict with departing aircraft from the same runway
2. Conflict with other traffic on the same runway
3. Conflict with departing aircraft from another parallel runway
4. Conflict with departing aircraft from another crossing runway
5. Conflict with other aircraft in the vicinity of the aerodrome, such as crossing or arriving traffic
6. Conflict with other go-around traffic

An example of each of the scenario outcomes is described and analysed below. They are either in the public domain or have been supplied with the permission of the relevant authorities.

In order to disidentify all stakeholders whilst maintaining the safety lessons, the following editorial actions have been taken:

- No airport, aircraft operator or ANSP is specified.
- The aircraft involved in each event are denoted solely by the aircraft type.
- Controller working positions have been generalised to two terms: TWR meaning the controller in control of the runway, and GMC meaning the controller in charge of the manoeuvring area excluding the active runway (unless otherwise specified).
- Unless necessary to describe the event, no runway or holding point designators are mentioned. In cases where it is necessary, e.g. interacting runways, the runway designators have been changed whilst maintaining a general relationship.

7.1 Conflict with departing aircraft from the same runway

Section 4.6. shows that for each of the six scenario outcomes there are three scenario mechanisms.

In this case:

1A	Conflict with departing aircraft from the same runway after a go-whilst around following the MAP
1B	Conflict with departing aircraft from the same runway after a go-around whilst following an ATC instructed trajectory
1C	Conflict with departing aircraft from the same runway after a go-around, pilot deviating to follow own trajectory

The storyline below illustrates this scenario. In this case, it is an example of 1B: conflict with departing aircraft from the same runway after a go-around following the ATC instructed trajectory.

The subsequent analysis of the potential barriers, however, covers the whole range of **conflict with departing aircraft from the same runway scenarios**, not the illustrative example.

Example:

Weather conditions: Night, visibility 2500 m, cloud ceiling 500 ft.

An A320 checked in on the TWR frequency on the ILS, at a distance of 6 NM. There was a business jet ahead on the approach and the TWR controller had planned to depart a B737 aircraft in between the two landing aircraft.

The TWR controller was aware that the bizjet was intending to park at the Business Aviation Centre to the right of the runway (the main terminal being to the left). He anticipated that it would vacate the runway at the first available exit (Y), which was 1700 m down the runway from the threshold. There is a second exit (Z) a further 800 m down the runway. After landing, the bizjet rolled past the first exit. ATC had not given the crew any instructions regarding which exit taxiway to take. The first exit is difficult to locate after landing at night. It is not well lit and its narrowness and its intersection with runway at 90° requires the aircraft to almost completely stop before it can enter. The bizjet pilot later advised that the poor weather meant that they had been "heads down" longer than normal and had landed long. They had braked strongly but passed taxiway Y and continued to roll at low speed to the Z exit taxiway.

After the bizjet had landed, a B737 at the holding point for runway 23 was instructed to line up and wait. As it lined up, ATC informed the B737 to be ready for immediate departure when cleared, so as to vacate the runway as there was landing traffic at 2 miles. The captain of the B737 was worried. The captains of the bizjet and the A320 had no awareness that there was a situation building.

The TWR controller's heart rate was rising. He instructed the bizjet to expedite, hoping that it might just work.

When ATC saw the bizjet turning at the exit, they cleared the B737 for immediate take-off. The captain did his best and the B737 started to roll. The A320 was at 1 mile. The captain of the A320 was now worried.

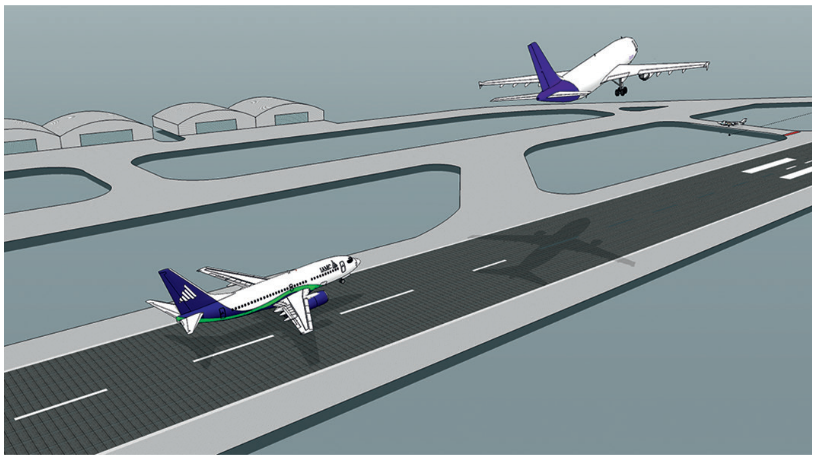

Figure 11

ATC finally decided that it was not going to work and instructed B737 to “stop” and by using the “break” in the same transmission instructed the A320 to go around. The captain of the B737 did not hear the instruction to “stop” as the crew was “cross-checking speeds” and focused on helping ATC by getting airborne as soon as possible. ATC again instructed the B737 to “stop”. This instruction was heard but the captain decided at over 100 kn to continue the take-off. He did not inform ATC.

In the go-around, the crew of the A320 quickly lost sight of the departing B737, but heard the instruction for it to stop and so believed that it was still on the runway.

The missed approach procedure is to climb on the runway heading to 2000 ft and then turn right 60° climbing to 3000 ft. The crew of the A320 re-confirmed their joint understanding of the procedure. However, on passing 400 ft, ATC instructed the A320 to “start the right turn now, climb to 3000 ft”. This differed from the published procedure and began at a low altitude height and at night in IMC conditions. This placed the crew in a heavy workload situation.

Shortly after the A320 passed 1000 ft, the crew were surprised and alarmed to receive a TCAS RA to climb. The B737 received a TCAS TA as ATC instructed them to “continue straight ahead, maintain 2000 ft on reaching”. The FO of the B737 saw the A320 briefly between the clouds and they made a small turn to the left without informing ATC.

The minimum distances between the two aircraft were 1 NM and 300 ft.

Barriers which, if deployed and employed correctly, could be effective in preventing a conflict with departing aircraft from the same runway, and the limitations of each barrier for this conflict scenario:

PB Pre-GA 1	Airport design and runway lighting
Limitations	Airports can be designed or modified to ensure the ability of ATC to observe the threshold and touchdown zone of the runway and make use of remote cameras. Angled runway entry/exits and RETILs can reduce runway occupancy time but are only in play when the situation is already marginal. Airport design and runway lighting will not have an impact on less-than-optimum ATC or unexpected pilot action.

PB Pre-GA 3	ATC defensive controlling
Limitations	ATC defensive controlling involves a range of ATC ways of working which can prevent low-level go-arounds primarily caused by less-than-optimum controlling. ATC defensive controlling will not prevent events initiated by pilot action or runway incursions.

PB Pre-GA 4	Pilot defensive flying
Limitations	Pilot defensive flying comprises a range of proactive cockpit ways of thinking and acting. It involves taking a share of responsibility for runway safety. Pilot defensive flying will not prevent events initiated by ATC.

PB Post-GA 6	ATC prevention of conflict
Limitations	ATC prevention of conflict involves a range of actions by one or more controllers to maintain safety margins on or following a low-level go-around. ATC prevention of conflict may be limited by the ability to maintain visual contact with aircraft or by the use of air traffic monitors. ATC prevention of conflict may also be limited by early knowledge of the go-around.

PB Post-GA 7	Pilot prevention of conflict
Limitations	Pilot prevention of conflict involves good situational awareness and the willingness to act independently. Safety margins are maintained. Pilot prevention of conflict is generally limited to VMC flight conditions in order to allow sufficient visual contact with the potentially conflicting traffic to be acquired and maintained.

Barriers which, if deployed and employed correctly, could be effective in mitigating a conflict with departing aircraft from the same runway, and the limitations of each barrier for this conflict scenario:

MB1	ATC ad-hoc conflict resolution
Limitations	ATC ad-hoc conflict resolution involves impromptu last-minute action, once safety margins have already been eroded, by one or more controllers in order to remove the risk of collision and achieve as great a safety margin as practical. ATC ad-hoc action may be limited by the ability to maintain visual contact or by the use of air traffic monitors. It may also be limited by RTF frequency commonality. ATC ad-hoc action may be superseded by pilots providing their own separation.

MB2	ATC conflict resolution with system support
Limitations	ATC ad-hoc conflict resolution with system support involves impromptu last-minute action, initiated after an alert signals a go-around in progress, e.g. Go Around Detection System (GARDS). Such alerts may draw the controller's/s to a conflict and mitigation action may be taken earlier. ATC action may be limited, as described in MB1.

MB3	ATC conflict resolution with system support
Limitations	ATC conflict resolution actions may mitigate the reduction in safety margins more quickly if such actions and consequent flight profiles on each runway are documented, understood and practiced among ATCOs. The effectiveness of any ATC action is limited, as described in MB1. Best practice can only be identified for the most common situations, which are not complex.

MB4	Pilot provides own conflict resolution
Limitations	Pilots can deviate from any ATC clearance to provide their own collision avoidance manoeuvre from other conflicting traffic. Pilot collision avoidance is generally limited to VMC flight conditions in order to allow them to acquire and maintain visual contact with the conflicting traffic.

MB5	Pilot follows TCAS conflict resolution
Limitations	Pilots should follow TCAS resolution advisories received, which should ensure collision avoidance. TCAS-driven collision avoidance is limited by the functionality which inhibits RAs below 1000 ft AGL. TCAS-driven collision avoidance may also be limited by the level of TCAS fitted to conflicting traffic in the aerodrome control environment.

7.2 Conflict with other traffic on the same runway

Section 4.6. shows that for each of the six scenario outcomes there are three scenario mechanisms.

In this case:

2A	Conflict with other traffic on the same runway, on or after a go-around whilst following the MAP
2B	Conflict with other traffic on the same runway, on or after a go-around whilst following an ATC instructed trajectory
2C	Conflict with other traffic on the same runway, on or after a go-around, pilot deviating to follow own trajectory

The storyline below illustrates this scenario. In this case, it is an example of 2A: conflict with other traffic on the same runway, on or after a go-around whilst following the MAP.

The subsequent analysis of the potential barriers, however, covers the whole range of **conflict with other traffic on the same runway scenarios**, not just the illustrative example.

Example:

A DH8C Dash 8 was on final for runway 21. An airside tug had requested to cross runway 21 with an Embraer 195 attached to move it from the remote stands to the main apron.

GMC instructed the tug driver "proceed stand 45 via Delta to holding Juliet Two, runway 21."

The read-back was "Roger, via Delta, Juliet Two, Runway 21". GMC passed the "runway crosser" data to AIR and then instructed the tug to change frequency to the AIR controller.

The tug driver had difficulty getting his radio equipment to change to the AIR control frequency. A second hand-held radio for the airport services frequency was very active and he thought that he might be called. Before he knew it, he was crossing the holding point "head down" fiddling with both radios.

The Dash 8 PNF saw the aircraft under tow coming up to the holding point but was not immediately concerned.

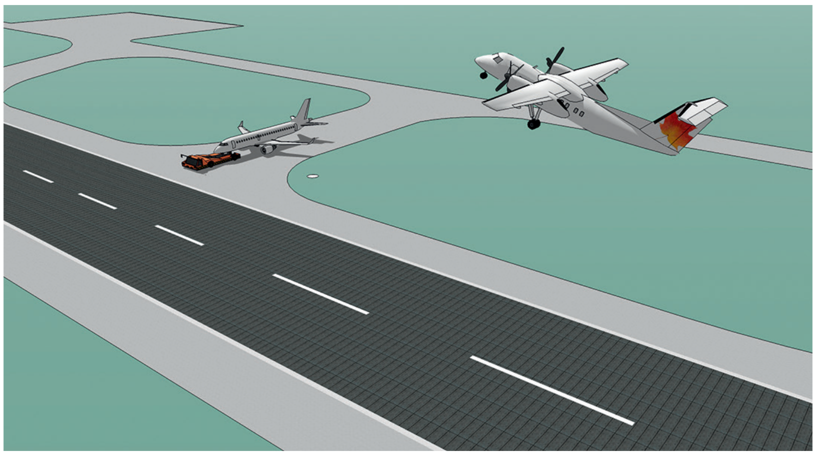

Figure 12

The GMC controller passed the details on the tug to the AIR controller. The AIR controller was busy trying to attract the attention of the supervisor, as he needed a comfort break and quickly put the flight data into his runway pending bay. He did not check the position of the tug visually.

Meanwhile, the tug driver looked up and braked sharply a few metres short of the runway. The Dash 8 PNF shouted to the PF "go around, go around". The PF did not question the command as it was delivered with urgency.

The AIR controller returned his attention to the runway and was dumbstruck to see the Dash 8 going around, and then saw the tug and E195 past the holding point.

The Dash 8 crew carried out their go-around drill and cleaned up the aircraft, with a high nose attitude.

The story of the event is continued in 7.5.

Barriers which, if deployed and employed correctly, could be effective in preventing a conflict with other traffic on the same runway, and the limitations of each barrier for this conflict scenario:

PB Pre-GA 1	Airport design and runway lighting
Limitations	Airports can be designed or modified to ensure the ability of ATC to observe the threshold and touchdown zone of the runway and to make use of remote cameras. Airport design and runway lighting will not have an impact on less-than-optimum ATC or unexpected pilot action.

PB Pre-GA 2	Airport safety nets and runway incursion tools
Limitations	Various tools, both hardware and software, can help in preventing runway incursions. This in turn prevents the presence of the traffic on the same runway, and thus prevents the need for a go-around. Airport safety nets will not affect movement which follows an incorrect or unwise clearance. Airport safety nets will not have an impact on long-term but forgotten clearances. Airport safety nets will not affect runway vacation requests or go-around requests which are not immediately acted upon.

PB Pre-GA 3	ATC defensive controlling
Limitations	ATC defensive controlling involves a range of ATC ways of working which can prevent low-level go-arounds primarily caused by less-than-optimum controlling. ATC defensive controlling will not prevent events initiated by pilot action or runway incursions.

PB Pre-GA 4	Pilot Defensive flying
Limitations	Pilot defensive flying comprises a range of proactive cockpit ways of thinking and acting. It involves taking a share of responsibility for runway safety. Pilot defensive flying is limited tor events initiated by ATC or runway incursions. The pilot would need to observe a potential conflict and take independent action which maintains safety margins.

Barriers which, if deployed and employed correctly, could be effective in mitigating a conflict with other traffic on the same runway, and the limitations of each barrier for this conflict scenario:

MB1	ATC ad-hoc conflict resolution
Limitations	ATC ad-hoc conflict resolution involves impromptu lastminute action, once safety margins have already been eroded, by one or more controllers in order to remove the risk of collision and achieve as great a safety margin as practical. ATC ad-hoc action may be limited by the ability to maintain visual contact. It may also be limited by RTF frequency commonality. Pilots providing their own ad-hoc separation may supersede ATC.

MB4	Pilot provides own conflict resolution
Limitations	Pilots can perform their own manoeuvres to avoid collisions with other conflicting traffic. Pilot collision avoidance is generally limited by the time available once the pilot becomes aware of the conflict. Pilot collision avoidance is also dependent on speed, height and aircraft performance capabilities.

7.3 Conflict with departing aircraft from another parallel runway

Section 4.6. shows that for each of the six scenario outcomes there are three scenario mechanisms.

In this case:

3A	Conflict with departing aircraft from another parallel runway after a go-around whilst following the MAP
3B	Conflict with departing aircraft from another parallel runway after a go-around whilst following an ATC instructed trajectory
3C	Conflict with departing aircraft from another parallel runway after a go-around, pilot deviating to follow own trajectory

The storyline below illustrates this scenario. In this case, it is an example of 3B: conflict with departing aircraft from another parallel runway after a go-around whilst following an ATC instructed trajectory

The subsequent analysis of the potential barriers, however, covers the whole range of conflict with departing aircraft from another parallel runway scenarios, not just the illustrative example.

Example:

The airport has parallel left and right runways aligned east/west. Operations at the time involved the runways in a westerly configuration with the left runway being used for landings and the right runway being used for departures. A previous aircraft landing on the left runway was observed to have smoke coming from its main undercarriage, possibly due to a burst tyre on landing. The left arrivals Controller considered that there might be FOD on the runway and instructed the following aircraft on approach, an A300, to go around. The go-around instruction was followed by a further instruction to climb on the runway heading to 1500 ft. This is the missed approach procedure for both runways, with further instructions to be agreed between the two aerodrome controllers in conjunction with the appropriate radar controller/s.

The right departures controller (responsible for the parallel right runway) was very busy. At the time when the A300 carried out its missed approach, two aircraft were lined up, one at a runway intersection and the other on the threshold. A B744, waiting at the holding point, had previously been cleared to line up and to be ready for take-off once the second of these had commenced its take-off run. The arrivals controller informed the departures controller of the go-around and the likelihood that the departure runway would be needed for a few arrivals. After the second aircraft had begun its take-off run, the B744 moved forward before the departure controller could secure the runway. He cleared the B744 for take-off. After it had departed, the B744 was instructed to maintain the runway heading.

The arrivals controller advised the A300 which was carrying out the missed approach that it was now clear to climb straight ahead to 3000 ft. The left arrivals controller's coordination with approach radar was delayed, as he was busy initiating the ground emergency call to the airfield fire service concerning the aircraft with the burst tyre and had given runway entry clearances to ground vehicles. He had also coordinated with the airfield unit responsible for checking the condition of the runway and advised a further aircraft, which by this time was 4 miles from touchdown that it was to continue its approach, as he anticipated that the runway would be available in time for it to land.

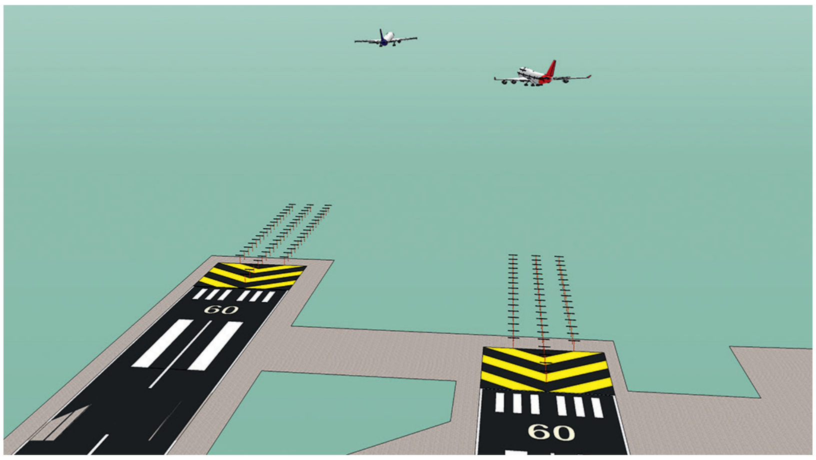

Figure 13

When contact was finally established with approach radar, the left arrivals controller was told that the A300 was to be cleared onto a heading of 130 climbing to 3000 ft and to be transferred to a specified frequency. Since he had already cleared the A300 to climb to 3000 ft, the approach controller instructed it to turn onto heading 130. His workload was now exacerbated by the aircraft on short finals for his runway (left) which was too close to switch to the right runway. A missed approach was initiated for this aircraft and speaking to the runway-checking unit once again, he finally advised the A300 crew to change frequency.

Meanwhile, twenty seconds before this frequency change, the departures controller had instructed the B744 "cancel the straight ahead restriction, continue on the SID routing". The departures controller forgot that whilst this flight would normally turn north on an SID to the east, today's flight was to turn left on the SID going south-east, owing to flow management restrictions. The B744, now IMC, commenced the left turn on the SID (across the left runway's centreline) and was instructed to change radio frequency to the ACC departure frequency for an aircraft turning right. No further coordination regarding the A300 and the B744 took place between the two aerodrome controllers.

The B744 and the A300 checked in on their respective frequencies. They were at this stage on converging tracks 1·39 NM apart, with the A300 at 3000 ft and the B744 700 ft below it. As soon as radio contact was established, the A300 was instructed to climb to 4000 ft and to turn further left onto a heading of 090. The B744 was instructed to stop climbing immediately, given traffic information concerning the conflicting aircraft. The B744 was then instructed to stop its turn.

The B744 crew received a TCAS TA. This was followed by an RA to reduce the climb rate, which coincided with the similar instruction from ATC. The A300 aircraft received a TCAS RA instructing the crew to «monitor vertical speed".

Apart from the traffic information passed on to the B744 concurrently with the TCAS alerts, neither crew were aware of the presence of the other. They were using different radio frequencies at all times and were not informed of each other's position by their respective controllers. Both crews followed their RAs and the conflict was resolved.

The minimum separation was recorded as 600 ft and 0.7 NM.

Barriers which, if deployed and employed correctly, could be effective in preventing a conflict with departing aircraft from another parallel runway, and the limitations of each barrier for this conflict scenario:

PB Pre-GA 3	ATC defensive controlling
Limitations	ATC defensive controlling involves a range of ATC ways of working which can prevent low-level go-arounds primarily caused by less-than-optimum controlling. ATC defensive controlling can also prevent conflicts before the initiation of a go-around through proactive coordination and or action, acting on the perception that an aircraft may go around. ATC defensive controlling will not prevent events initiated by pilot action or runway incursions.

PB Post-GA 5	Conflict-free procedures
Limitations	Procedures may exist which provide sufficient separation between a departure and a go-around on different runways, such that safety margins are maintained. These may be procedures and flight profiles and may be published in the AIC or local ATC procedures.

PB Post-GA 6	ATC prevention of conflict
Limitations	ATC prevention of Conflict involves a range of actions by one or more controllers to maintain safety margins on or following a low-level go-around. ATC prevention of conflict may be limited by the ability to maintain visual contact with aircraft or by the use of air traffic monitors. ATC prevention of conflict may also be limited by early knowledge of the go-around.

PB Post-GA 7	Pilot prevention of conflict
Limitations	Pilot prevention of conflict involves good situational awareness and the willingness to act independently. Safety margins are maintained. Pilot prevention of conflict is generally limited to VMC flight conditions in order to allow sufficient visual contact with the potentially conflicting traffic to be acquired and maintained.

Barriers which, if deployed and employed correctly, could be effective in mitigating a conflict with departing aircraft from another parallel runway, and the limitations of each barrier for this conflict scenario:

MB1	ATC ad-hoc conflict resolution
Limitations	ATC ad-hoc conflict resolution involves impromptu lastminute action, once safety margins have already been eroded, by one or more controllers in order to remove the risk of collision and achieve as great a safety margin as practical. ATC ad-hoc action may be limited by the ability to maintain visual contact or by the use of air traffic monitors. It may also be limited by RTF frequency commonality. Pilots providing their own ad-hoc separation may supersede ATC.

MB2	ATC conflict resolution with system support
Limitations	ATC ad-hoc conflict resolution with system support involves impromptu last-minute action, initiated after an alert signals a go-around in progress, e.g. Go Around Detection System (GARDS). Such alerts may draw the controller's/s' attention to a conflict and mitigation action may be earlier. * ATC action may be limited, as described in MB1.

MB3	ATC best practice
Limitations	ATC conflict resolution actions may mitigate the reduction in safety margins more quickly if such actions and consequent flight profiles on each runway are documented, understood and practised among the ATCOs. * The effectiveness of any ATC action is limited, as described in MB1. * Best practice actions can only be identified for the most common situations, which are not complex.

MB4	Pilot provides own conflict resolution
Limitations	Pilots can deviate from any ATC clearance to perform their own manoeuvres to avoid collisions with other conflicting traffic. Pilot collision avoidance is generally limited to VMC flight conditions in order to allow visual contact with the conflicting traffic to be acquired and maintained.

MB5	Pilot follows TCAS conflict resolution
Limitations	Pilots should follow TCAS resolution advisories received, which should ensure collision avoidance. TCAS- driven collision avoidance is limited by the functionality which inhibits RAs below 1000 ft AGL. TCAS-driven collision avoidance may also be limited by the level of TCAS fitted to conflicting traffic in the aerodrome control environment.

7.4 Conflict with departing aircraft from another crossing runway

Section 4.6. shows that for each of the six scenario outcomes there are three scenario mechanisms.

In this case:

4A	Conflict with departing aircraft from another crossing runway after a go-around whilst following the MAP
4B	Conflict with departing aircraft from another crossing runway after a go-around whilst following an ATC instructed trajectory
4C	Conflict with departing aircraft from another crossing runway after a go-around, pilot deviating to follow own trajectory

The storyline below illustrates this scenario. In this case, it is an example of 4C: conflict with departing aircraft from another crossing runway after a go-around, pilot deviating to follow own trajectory.

The subsequent analysis of the potential barriers, however, covers the whole range of **conflict with departing aircraft from another crossing runway scenarios**, not just the illustrative example.

Example:

An Airbus A330 was making an approach to runway 02. As it did so, immediately before landing it encountered turbulence caused by the north-easterly wind, resulting in an unstabilised final approach. The captain instructed a go-around shortly before touching the runway. Then, there was a conflict with an A319 which was taking off from the runway 34. The surfaces of the runways do not cross, but their extended airborne centrelines do.

When the A330 was 7 NM from the threshold of runway 02, ATC gave it landing clearance together with current ground wind information. At 2 NM from touchdown, ATC gave a further wind check of 030/05 kn. The captain replied "up here it is 050 at 20".

When the A330 was a little over 0.6 NM from the threshold of runway 02 and approximately 200cft above ground, ATC cleared the A319 for take-off on 34. This was contrary to ATC instructions, which state "once an aircraft has flown over the threshold of runway 02 it can be assumed that the aircraft is landing, then a take-off from runway 34 can be cleared." Passing the threshold of runway 02 was primarily established visually.

A relatively inexperienced FO was flying the Airbus A330. The aircraft had not been established to the level expected by the captain, who was giving instruction to the FO (PF) from 200 ft. At about 10 ft above ground, the aircraft's synthetic voice stated "retard". However, the aircraft was floating and drifting left of the centreline. A go-around was initiated and the commander took over the function of pilot flying.

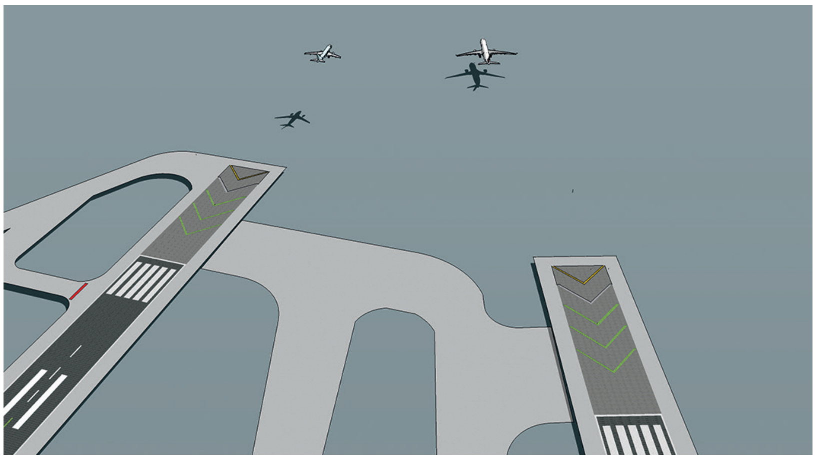

Figure 14

ATC did not immediately see the go-around by the A330. When ATC became aware of the go-around, the A319 was instructed to reject its take-off in order to avoid convergence of the two aircraft on their extended runway centrelines. The A319, however, continued the take-off. The captain of the A319 stated that at the time of receiving the call from ATC to stop the take-off, the aircraft had just passed V1 and he decided to continue the take-off.

The A330 reported its go-around, following the published missed approach procedure for runway 02, and was already about 1200 m beyond the threshold of the runway. The A319 passed 0.2 NM behind the A330 and 300 ft below it.

The A319 crew observed the A330 crossing left to right and flattened their climb rate a little. Whilst a collision was not going to happen, they were concerned about wake turbulence. The air was, however, already "bumpy" and the aircraft rolled both left and right but within normal limits.

The A330 crew were unaware of the A319, as the captain was concentrating on flying the aircraft.

The risk lies in the fact that the flight paths cross immediately after the end of the runway. The topographical conditions on the runway 02 approach may lead to turbulence, which in turn means an increased risk of a go-around. This circumstance requires the ATCO to have direct sight of the last phase of the final approach and landing of aircraft on runway 02 in order to observe the attitude of these aircraft. In actual fact, however, the relevant visibility options for runway 02 are restricted by the presence of part of the terminal building.

Barriers which, if deployed and employed correctly, could be effective in preventing a conflict with departing aircraft from another crossing runway, and the limitations of each barrier for this conflict scenario:

PB Post-GA 6	ATC prevention of conflict
Limitations	ATC prevention of conflict involves a range of actions by one or more controllers to maintain safety margins on or following a low-level go-around. ATC prevention of conflict may be limited by the ability to maintain visual contact with aircraft or by the use of air traffic monitors. ATC prevention of conflict may also be limited by the time a go-around is detected.

Barriers which, if deployed and employed correctly, could be effective in mitigating a conflict with departing aircraft from another crossing runway, and the limitations of each barrier for this conflict scenario:

MB1	**ATC ad-hoc conflict resolution**
Limitations	ATC ad-hoc conflict resolution involves impromptu lastminute action, once safety margins have already been eroded, by one or more controllers in order to remove the risk of collision and achieve as great a safety margin as practical. ATC ad-hoc action may be limited by the ability to maintain visual contact or by the use of air traffic monitors. It may also be limited by RTF frequency commonality. Pilots providing their own ad-hoc separation may supersede ATC.

MB3	**ATC best practice**
Limitations	ATC conflict resolution actions may mitigate the reduction in safety margins more quickly if such actions and consequent flight profiles on each runway are documented, understood and practised among the ATCOs. The effectiveness of any ATC action is limited, as described in MB1. Best practice actions can only be identified for the most common situations, which are not complex.

MB4	**Pilot provides own conflict resolution**
Limitations	Pilots can deviate from any ATC clearance to perform their own manoeuvres to avoid collisions with other conflicting traffic. Pilot collision avoidance is generally limited to VMC flight conditions in order to allow visual contact with the conflicting traffic to be acquired and maintained.

7.5 Conflict with other traffic in the vicinity of the aerodrome, such as crossing or arriving traffic

Section 4.6. shows that for each of the six scenario outcomes there are three scenario mechanisms.

In this case:

5A	Conflict with other aircraft in the vicinity of the aerodrome, such as crossing or arriving traffic after a go-around whilst following the MAP
5B	Conflict with other aircraft in the vicinity of the aerodrome, such as crossing or arriving traffic after a go-around whilst following an ATC instructed trajectory
5C	Conflict with other aircraft in the vicinity of the aerodrome, such as crossing or arriving traffic after a go-around, pilot deviating to follow own trajectory

The storyline below illustrates this scenario. In this case, it is an example of 4C: conflict with departing aircraft from another crossing runway after a go-around, pilot deviating to follow own trajectory.

The subsequent analysis of the potential barriers, however, covers the whole range of conflict with other traffic in the vicinity of the aerodrome, such as crossing or arriving traffic scenarios, not just the illustrative example.

This example follows directly on from the runway incursion event described in 7.2.

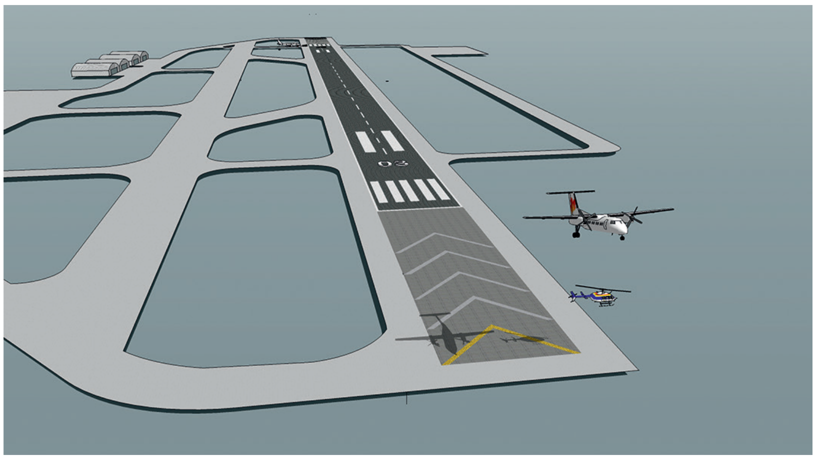

Figure 15

A helicopter was cleared to transit the area northbound, following the coastline at "not above 1000 ft VFR". The upwind end of runway 21 is 1.5 NM from the coast. The Dash 8 was cleared to land. The helicopter was given traffic information on the Dash 8. The helicopter briefly glanced to his right and saw the Dash 8 just about to touch down. He then resumed his story to his passengers about a shipwreck which was just offshore.

The Dash 8 announced that it was going around. The controller responded "Roger, Standard Missed Approach" (which was runway heading to 2000 ft, turn left to YYY climbing to 3000 ft, level by YYY). The controller had been taught to keep R/T instructions to a minimum during a go-around, so he addressed the helicopter pilot next: "Dash 8 traffic in the go-around on your right-hand side". The helicopter was just crossing the extended centreline. The helicopter pilot saw the Dash 8 and immediately pushed down.

The controller then gave traffic Information to the Dash 8 crew "Helicopter traffic in your 12 o'clock right to left, which was at 1000 ft but now descending.

The Dash 8 crew never saw the helicopter. The Dash 8 passed directly over the helicopter by 300 ft.

Barriers which, if deployed and employed correctly, could be effective in preventing a conflict with other traffic in the vicinity of an aerodrome, such as crossing or arriving traffic, and the limitations of each barrier for this conflict scenario:

PB Post-GA 5	Conflict-free procedures
Limitations	Procedures may exist which provide sufficient separation between a go-around and other aerodrome traffic, e.g. visual reference points, such that safety margins are maintained. These may be procedures and flight profiles and may be published in the AIC or local ATC procedures.

PB Post-GA 6	ATC prevention of conflict
Limitations	ATC prevention of conflict involves a range of actions by one or more controllers to maintain safety margins on or following a low-level go-around. * ATC prevention of conflict may be limited by the ability to maintain visual contact with aircraft or by the use of air traffic monitors. * ATC prevention of conflict may also be limited by the time a go-around is detected.

Barriers which, if deployed and employed correctly, could be effective in mitigating a conflict with other traffic in the vicinity of an aerodrome, such as crossing or arriving traffic, and the limitations of each barrier for this conflict scenario:

MB1	ATC ad-hoc conflict resolution
Limitations	ATC ad-hoc conflict resolution involves impromptu lastminute action, once safety margins have already been eroded, by one or more controllers in order to remove the risk of collision and achieve as great a safety margin as practical. ATC ad-hoc action may be limited by the ability to maintain visual contact or by the use of air traffic monitors. It may also be limited by RTF frequency commonality. Pilots providing their own ad-hoc separation may supersede ATC.

MB3	ATC best practice
Limitations	ATC conflict resolution actions may mitigate the reduction in safety margins more quickly if such actions and consequent flight profiles of transiting/arriving aircraft are documented, understood and practised among the ATCOs. The effectiveness of any ATC action is limited, as described in MB1. Best practice actions can only be identified for the most common situations, which are not complex.

MB4	Pilot provides own conflict resolution
Limitations	Pilots can deviate from any ATC clearance to perform their own manoeuvres to avoid collisions with other conflicting traffic. Pilot collision avoidance is generally limited to VMC flight conditions in order to allow visual contact with the conflicting traffic to be acquired and maintained.

MB5	Pilot follows TCAS conflict resolution
Limitations	Pilots should follow TCAS resolution advisories received, which should ensure collision avoidance. TCAS-driven collision avoidance is limited by the functionality which inhibits RAs below 1000 ft AGL. TCAS-driven collision avoidance may also be limited by the level of TCAS fitted to conflicting traffic in the aerodrome control environment.

7.6 Conflict with aircraft going around from another runway

Section 4.2.2 shows that for each of the six scenario outcomes there are three scenario mechanisms. Combining the mechanisms with the outcomes (4.2.3) provides the operational scenarios (4.3).

In this case:

6A	Conflict with other go-around traffic after a go-around whilst following the MAP
6B	Conflict with other go-around traffic after a go-around whilst following an ATC instructed trajectory
6C	Conflict with other go-around traffic after a go-around, pilot deviating to follow own trajectory

The storyline below illustrates this scenario. In this case, it is an example of 6C: conflict with other go-around traffic after a go-around, pilot deviating to follow own trajectory.

The subsequent analysis of the potential barriers, however, covers the whole range of **conflict with aircraft going around from another runway scenario**, not just the illustrative example.

Example:

The airport has parallel runways 24L and 24R. Runway 24R was briefly the single runway in use as a Beech 200 on a special flight permit was carrying out a photographic run of the approach lighting on 24L and the reciprocal 06R.

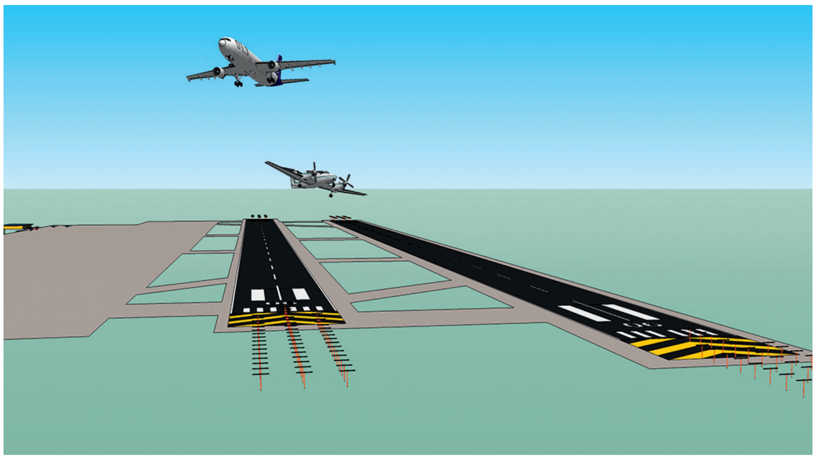

Figure 16

An Airbus 321 was on final approach to 24R as the Beech 200 was doing its run down the 24L approach lighting. Traffic was light, so the Beech 200 had been cleared to overfly 24L and carry out a visual dumb-bell onto the 06R approach.

The A321 was cleared to land on 24R, when at 2 miles the SCO notified the crew that the cabin was not secured. The captain informed his FO and the SCO that decision had to be made in 30 seconds. At that time, the SCO said "no sir" and the captain initiated a go-around from 300 ft, informing ATC immediately.

At that moment, the BE200 was passing the upwind end of 24L and banked to the right, in order to complete the transition onto the 06R approach.

ATC initially just acknowledged the go-around report from the A321 with "Roger, standard Missed Approach" as the reason for the go-around was not obvious.

The controller then heard a shout behind him to "watch the King Air". The BE200 was crossing the extended centreline of 24R and starting to turn left again at around 500 ft climbing. The controller instructed the King Air to "tighten the left turn and level off, traffic going around behind you".

The crew of the A321 heard this transmission and saw the BE200 in the turn directly ahead and just below. The PF turned the A321 right to avoid the BE200, thus keeping it in sight.

Barriers which, if deployed and employed correctly, could be effective in preventing a conflict with aircraft going around from another runway, and the limitations of each barrier for this conflict scenario:

PB Pre-GA 3	ATC defensive controlling
Limitations	ATC defensive controlling involves a range of ATC ways of working which can prevent low-level go-arounds primarily caused by less-than-optimum controlling. ATC defensive controlling can also prevent conflicts before the initiation of a go-around by proactive coordination and or action, acting on the perception that an aircraft may go around. If one of the go-arounds is planned, its consequent routing could be made conflict-free. ATC defensive controlling will not prevent events initiated by pilot action or runway incursions.

PB Post-GA 6	ATC prevention of conflict
Limitations	ATC prevention of conflict involves a range of actions by one or more controllers to maintain safety margins on or following a low-level go-around. ATC prevention of conflict may be limited by the ability to maintain visual contact with aircraft or by the use of air traffic monitors. ATC prevention of conflict may also be limited by the time a go-around is detected.

Barriers which, if deployed and employed correctly, could be effective in preventing a conflict with aircraft going around from another runway, and the limitations of each barrier for this conflict scenario:

MB1	ATC ad-hoc conflict resolution
Limitations	ATC ad-hoc conflict resolution involves impromptu lastminute action, once safety margins have already been eroded, by one or more controllers in order to remove the risk of collision and achieve as great a safety margin as practical. ATC ad-hoc action may be limited by the ability to maintain visual contact or by the use of air traffic monitors. It may also be limited by RTF frequency commonality. Pilots providing their own ad-hoc separation may supersede ATC.

MB4	Pilot provides own conflict resolution
Limitations	Pilots can deviate from any ATC clearance to perform their own manoeuvres to avoid collisions with other conflicting traffic. Pilot collision avoidance is generally limited to VMC flight conditions in order to allow visual contact with the conflicting traffic to be acquired and maintained.

MB5	Pilot follows TCAS conflict resolution
Limitations	Pilots should follow TCAS resolution advisories received, which should ensue collision avoidance. TCAS-driven collision avoidance is limited by the functionality which inhibits RAs below 1000 ft AGL. TCAS-driven collision avoidance may also be limited by the level of TCAS fitted to conflicting traffic in the aerodrome control environment.

8. ANALYSIS: SUMMARY

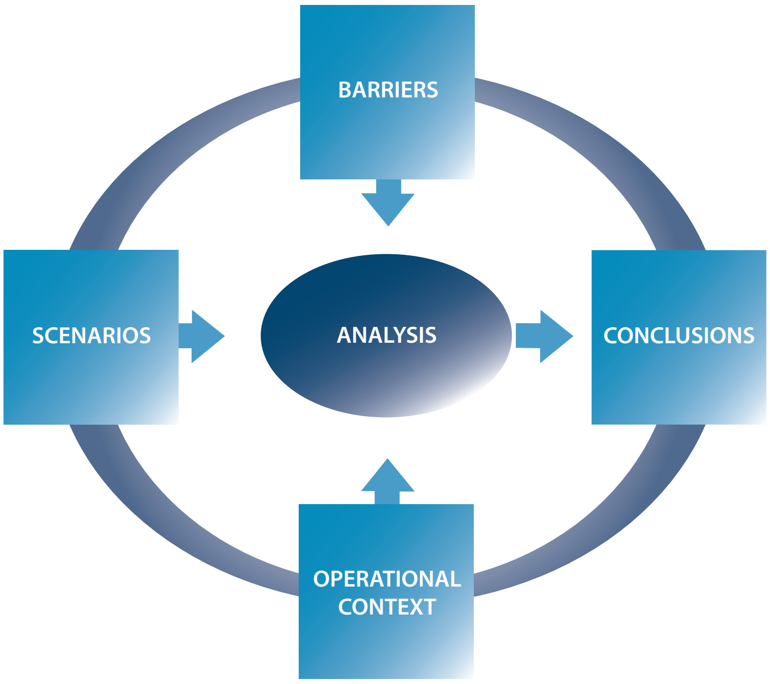

Figure 17

8.1 Prevention barrier assessment

The first step of the analysis consists in assessing the potential availability of the prevention barriers for each operational scenario. The high-level assessment considers the various operational scenarios and is based on expert judgment.

The barriers are assessed individually. The initial analysis does not consider the interactions or the results of more than one barrier acting in combination.

Scenario outcomes	Pre-GA 1	Pre-GA 2	Pre-GA 3	Pre-GA 4	Post-GA 5	Post-GA 6	Post-GA 7
Conflict with departing aircraft from the same runway	✓		✓	✓		✓	✓
Conflict with other traffic on the same runway	✓	✓	✓	✓			
Conflict with departing aircraft from another parallel runway			✓		✓	✓	✓
Conflict with departing aircraft from another crossing runway						✓	
Conflict with other aircraft in in the vicinity of the aerodrome, such as crossing or arriving traffic					✓	✓	
Conflict with other go-around traffic			✓				

As can be seen from the above table, the following two prevention barriers have the widest spread of scenarios in which they may prevent conflict on or following low-level go-arounds:

- PB3 ATC defensive controlling
- PB6 ATC prevention of conflict

8.2 Mitigation barrier assessment

The first step of the analysis consists in assessing the potential availability of the prevention barriers for each operational scenario. The high-level assessment considers the various operational scenarios and is based on expert judgment.

The barriers are assessed individually. The initial analysis does not consider the interactions or the results of more than one barrier acting in combination.

Scenario outcomes	MB 1	MB 2	MB 3	MB 4	MB 5
Conflict with departing aircraft from the same runway	✓	✓	✓	✓	✓
Conflict with other traffic on the same runway	✓			✓	
Conflict with departing aircraft from another parallel runway	✓	✓	✓	✓	✓
Conflict with departing aircraft from another crossing runway	✓		✓	✓	
Conflict with other aircraft in in the vicinity of the aerodrome, such as crossing or arriving traffic	✓		✓	✓	✓
Conflict with other go-around traffic	✓			✓	✓

As can be seen from the above table, the following two mitigation barriers have the widest spread of scenarios in which they may prevent collision and reduce the severity of conflict on or following low-level go-arounds:

- MB1 ATC ad-hoc conflict resolution
- MB4 Pilot provides own conflict resolution

This study does not, however, promote any particular barrier or course of action as being a panacea across all types of aerodrome operation. Each airport and ATC unit has different levels of exposure to the go-around scenarios.

The following chapter suggests how each stakeholder might address their own situation.

9. ASSESSING BARRIER SELECTION FOR SAFETY IMPROVEMENT AT INDIVIDUAL AIRPORTS AND ATC UNITS

9.1 Each airport and ATC unit has different risk levels of exposure

Each airport and ATC unit will have different risk levels of exposure to the six scenario outcomes leading to a conflict on or after low-level go-around.

For instance, an airport with a single runway does not need to consider conflicts involving parallel or crossing runways.

Airports with a broad traffic mix of IFR/VFR traffic may wish to consider the risk level of conflict with other aircraft in the vicinity of the airport to be high.

Airports with a complex multi-runway operation may wish to consider the risk level involving more than one runway to be of significance.

It is suggested that airports, ATC units and, at a higher level, airport operators and ANSPs could decide on their own levels of exposure to each of the six scenario outcomes and apply their own weighting to the relevance of each scenario and thus to an overall view of the efficacy of each possible preventive and mitigation barrier.

9.2 Weighting the relevance of each scenario at any airport/ATC unit

Each airport authority and ANSP can decide on its own method of weighting the efficacy of each possible preventive and mitigation barrier, according to the type of operation.

The methodology outlined here is an example of how such a weighting might be applied.

9.3 Airports with a multi-runway operation

An airport with a multi-runway operation may weight the severity/repeatability of each scenario outcome something like this:

Scenario outcome	Weighting
Conflict with departing aircraft from the same runway	10
Conflict with departing aircraft from the same runway	8
Conflict with departing aircraft from another crossing runway	6
Conflict with departing aircraft from another parallel runway	4
Conflict with other aircraft in the vicinity of the aerodrome, such as crossing or arriving traffic	2
Conflict with other go-around traffic	1

9.4 Airports with a single runway operation

An airport with a single runway operation may weight the severity/repeatability of each scenario outcome something like this:

Scenario outcome	Weighting
Conflict with other traffic on the same runway	5
Conflict with departing aircraft from the same runway	4
Conflict with other aircraft in the vicinity of the aerodrome, such as crossing or arriving traffic	2
Conflict with departing aircraft from another crossing runway	0
Conflict with departing aircraft from another parallel runway	0
Conflict with other go-around traffic	0

9.5 Airport with a high level of IFR/VFR traffic

An airport with a high-level mix of IFR/VFR traffic may weight the severity/repeatability of each scenario outcome something like this:

Scenario outcome	Weighting
Conflict with other aircraft in the vicinity of the aerodrome, such as crossing or arriving traffic	5
Conflict with other traffic on the same runway	3
Conflict with departing aircraft from the same runway	2
Conflict with departing aircraft from another crossing runway	0
Conflict with departing aircraft from another parallel runway	0
Conflict with other go-around traffic	0

All of these examples are solely to illustrate how individual airports and ATC units could carry out their own study of the severity/repeatability of conflicts on/after lowlevel go-arounds and use a method such as this to consider what might be the most effective barriers available to them.

When carrying out such a study, users may find the lists of operational contextual factors in Chapter 5 to be helpful.

10. DISCUSSION OF SOME RELEVANT BARRIERS

10.1 Advanced surface movement guidance and control systems (A-SMGCS)

A-SMGCS covers applications and systems for air traffic controllers, vehicle drivers and aircraft pilots. Operationally available systems offer:

- controller surveillance display,
- runway incursion alerts for the controller,
- selective switching of taxiway lights, stop and hold bars;
- routing guidance functions, and
- runway protected area penetration alerts and runway occupied alerts for vehicle drivers.

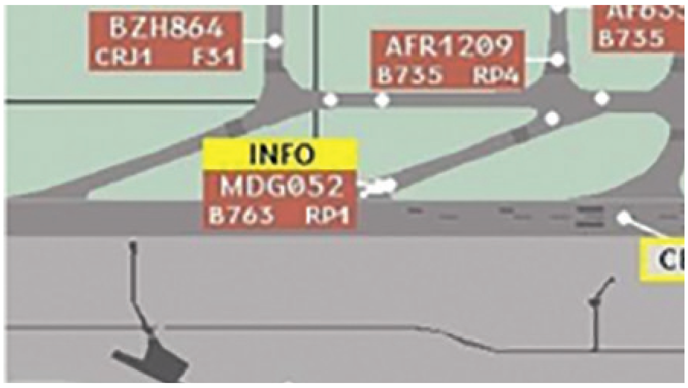

Figure 18: A-SMGCS display when an aircraft is on the runway strip and a car is on the runway

The most common level of implementation of A-SMGCS across Europe is a surface movement radar together with a Mode S multilateration system and a runway incursion alerting system (RIM) in the air traffic control tower. A-SMGCS technologies can help prevent runway incursions and mitigate the impact of runway incursions, thus reducing conflicts between aircraft and vehicles on the runway.

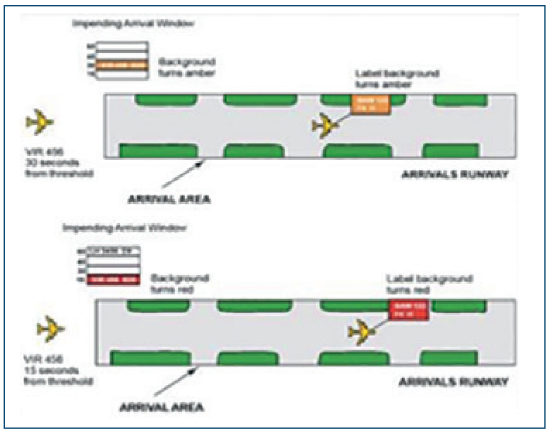

Figure 19: Example of A-SMGCS level II warning and alert in an approach scenario

The predictive runway incursion monitor (RIM) function generates two-stage alerts at times determined by whether low-visibility procedures (LVPs) are in force.

A-SMGCS is therefore capable of alerting controllers 30-45 seconds before a low-level go-around may be necessary. This can provide a safety net against traffic on the same runway. It can also provide an early warning of a potential low-level go-around, giving time to plan de-confliction with any other traffic.

RIM alert	Stage One Amber	Stage Two Red
Non-LVP	30 seconds	15 seconds
LVP	45 seconds	30 seconds

10.2 Go-around Detection System (GARDS)

Based on surveillance data, the GARDS algorithm determines whether an aircraft is approaching a runway and detects non-nominal parameters of the landing. GARDS monitors the flight path of the aircraft during final approach and simultaneously checks the speed of the aircraft on the runway. If the flight path (including speeds during roll-out) deviates from the nominal trajectory, the system provides a visual and aural alert to the runway controller in the control tower.

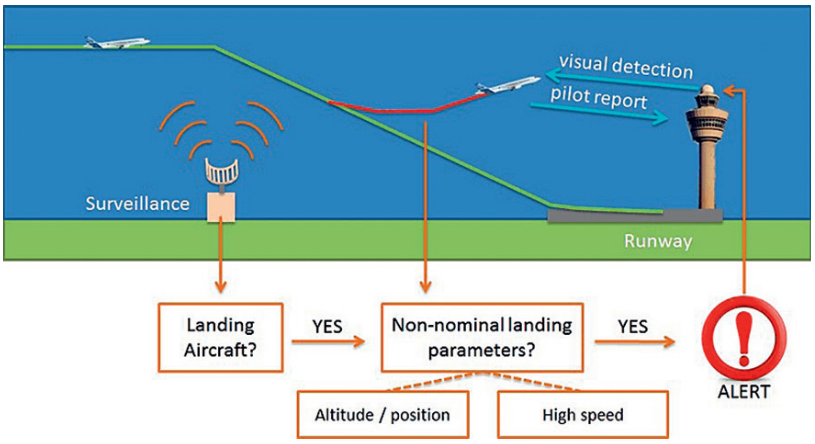

Figure 20: GARDS alert process

In addition to the position of the aircraft, the speed of the aircraft is analysed on the runway during touchdown and roll-out. The reason for this is that, for late go-arounds (i.e. after the runway threshold), the speed of the aircraft is an earlier indication of a possible go-around than the position of the aircraft. Usually, aircraft going around do not slow down in a timely manner and may even increase speed before they start to increase altitude. Including speed in the detection algorithm therefore reduces detection times.

Such a system has been operational at Amsterdam Schiphol Airport since 2015.

10.3 Conformance monitoring alerts and conflict detection

The introduction of electronic flight strips in many control towers means that instructions given by a controller are available electronically and can be integrated with other data such as flight plans, surveillance, routing and published rules and procedures. The integration of this data allows the system to monitor the information and alert the controller when inconsistencies are detected. This solution highlights potential conflicts much sooner than the current practice of relying on surveillance data to trigger an alarm.

This solution is due for deployment across Europe in accordance with the Pilot Common Project.

This system, currently under development by SESAR, detects when two clearances are considered to be not safe or not allowed.

Any combination of:

- Landing clearance
- Take-off clearance
- RWY crossing clearance
- RWY entry clearance

Any combination considered as not safe or not allowed will trigger a conflicting ATC clearance alert.

Below are some examples of the information and alert messages which are generated in the concept. The list is illustrative and only those which may affect the frequency and potential severity of low-level go-arounds are included here.

10.4 Incorrect ATC clearance

In this example, the ATCO has input “cleared to land” on LGL8011 and a pop-up window appears asking the ATCO if he really wants to accept the condition.

Figure 21: Pop-up window in centre asks for confirmation of apparent conflicting clearances

10.5 No landing clearance

Figure 22: Red highlight appears in alert window at top of display and red highlight on ATM element and arrivals elements for aircraft with no landing clearance within 1 mile

This alert is generated when an aircraft is within 1 NM of a runway threshold without a landing clearance, thus highlighting the possibility of a low-level go-around to the controller.

10.6 No line-up Clearance (NO LUP CLR)

Figure 23: Red highlight appears in alert window at top of display and red highlight in holding point bay and runway entry point for an aircraft which is entering the runway without a clearance

This alert is generated when an aircraft is lining up the runway without a runway entry clearance.

10.7 Runway incursion tools

EAPPRI (2017)[2] Recommendation 1.2.12 states:

New aerodrome infrastructure and changes to existing infrastructure should be designed to reduce the likelihood of runway incursions.

EAPPRI (2017) Recommendation 1.2.14 states:

Regularly assess the operational use of aerodrome ground lighting, e.g. stop bars, to ensure a robust policy to protect the runway from the incorrect presence of traffic.

Airport ground safety nets therefore assist in the prevention of runway incursions, however caused, and in turn assist in the prevention of low-level go-arounds leading to a conflict.

10.8 Autonomous runway incursion warning system (ARIWS)

The operation of an ARIWS is based on a surveillance system which monitors the actual situation on a runway and automatically returns this information to warning lights at the runway (take-off) thresholds and entrances. When an aircraft is departing from a runway (rolling) or arriving at a runway (short final), red warning lights at the entrances will illuminate, indicating that it is unsafe to enter or cross the runway. When an aircraft is aligned on the runway for take-off and another aircraft or vehicle enters or crosses the runway, red warning lights will illuminate at the threshold area, indicating that it is unsafe to start the take-off roll.

In practice, not every entrance or threshold needs to be equipped with warning lights. Each aerodrome will assess its needs individually depending on the characteristics of the aerodrome. There are several systems developed offering the same or similar functionalities.

[2] European Action Plan for the Prevention of Runway Incursions. EUROCONTROL, November 2017

Pilots are presented with a globally consistent signal which means "STOP IMMEDIATELY" and must be taught to react accordingly. Likewise, pilots receiving an ATS clearance to take-off or cross a runway, and seeing the red light array, must stop and advise ATS that they aborted/stopped because of the red lights. Again, the criticality of the timeline involved is so marginal that there is no room for misinterpretation of the signal. It is of utmost importance that the visual signal be consistent around the world.

10.9 Runway status lights (RWSL)

Runway status lights (RWSL) are a type of autonomous runway incursion warning system (ARIWS).

The two basic visual components of RWSL are runway entrance lights (RELs) and take-off hold lights (THLs). Either may be installed independently, but the two components are designed to be complementary.

It is the prevention of runway incursions which is of interest in this study. Consequently, only runway entrance lights are detailed.

RELs are installed at taxiway/runway intersections to provide an indication when it is unsafe to enter the runway. The first light in the pattern is installed 2 ft prior to the runway holding point marking. They continue to a penultimate light pair 2 ft before the runway edge marking, with the last light then sited 2 ft before the runway centreline lights.

The RWSL safety logic process accepts fused surveillance from three sources: 1) Primary radar returns from the airport surface detection equipment, 2) the time difference of arrival multilateration utilising interrogation and replies from transponder-equipped aircraft and vehicles, and 3) the terminal radars used for air traffic control. The fused logic determines the operational state of the track (e.g. stopped, taxiing, landing, or departing), predicts likely future behaviour on the basis of the current state, and determines when and which lights should be illuminated. The location of traffic and their dynamic state drive the decision-making process for lighting illumination.

10.10 Stop bars

Safety studies have demonstrated that the use of H24 stop bars can be an effective runway incursion prevention barrier. Aerodrome operators, together with ANSPs, should therefore consider the implementation of H24 stop bars at all runway holding points.

Stop bars and runway guard lights which protect the runway should be ICAO compliant. Aerodrome operators should consider using stop bars and runway guard lights at all runway holding positions under all weather conditions (24 hours a day) to help prevent runway incursions. These lights should be visible to approaching aircraft up to the stop bar position.

Aerodrome operators should consider installing extra lights, uniformly, to enhance the conspicuousness of an existing stop bar.

Aerodrome operators should consider adding a pair of elevated lights to each end of the stop bar:

- to enhance their conspicuousness to pilots and manoeuvring area drivers when needed;
- where the in-pavement stop bar lights might be obscured from a pilot's view, for example by snow or rain;
- where a pilot may be required to stop the aircraft in a position so close to the lights that they are blocked from view by the structure of the aircraft.

When planning to implement stop bars, it is important to acknowledge the potential cost. Consequently:

- stop bars located across entrance taxiways are selectively switchable;
- stop bars located across taxiways intended to be used only as exit taxiways are switchable selectively or in groups;
- stop bars should be interlocked with the first 90 metres of taxiway centreline lights beyond the stop bar so that when the centreline lights beyond the stop bar are illuminated the stop bar is extinguished and vice versa.
- The electrical system for the lights should be designed so that all lights of a stop bar will not fail at the same time.

If stop bars fail in the illuminated state, appropriate contingency procedures are required. For example:

- When an alternative suitable taxiway is equipped with a functioning stop bar, and is available, close the taxiway where the failure happened and use the taxiway with the functioning stop bar.
- Instruct aircraft to cross/enter the runway taxiing behind a follow-me car, if available, with RTF confirmation to cross/enter the runway.
- Instruct aircraft to cross/enter the runway with a specific clearance given by ATC to cross an illuminated stop bar owing to a malfunction of the system.

All access to a runway (even if inactive) requires a specific ATC clearance to enter or cross the runway, regardless of whether the runway is active or not. An extinguished stop bar, or any other red light, is NOT a clearance to enter or cross a runway.

10.11 Rapid exit taxiway indicator lights (RETILs)

The purpose of RETILs is to provide pilots with distance-to-go information to the nearest rapid exit taxiway on the runway, to enhance situational awareness in lowvisibility conditions, and to enable pilots to apply a braking action for more efficient roll-out and runway exit speeds.

RETILs are located on the runway on the same side of the runway centreline as the associated rapid exit taxiway. The lights are located 2 m apart, and the light nearest to the runway centreline should be displaced 2 m from the runway centreline.

Where more than one rapid exit taxiway exists on a runway, the set of RETILs for each exit should not overlap when displayed.

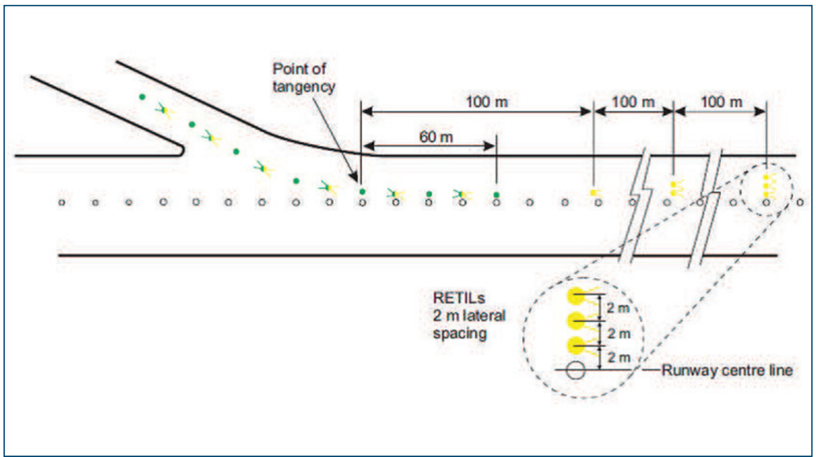

Figure 24: Rapid exit taxiway indicator lights (RETILs)

RETILs are fixed lights and comprise a set of yellow unidirectional lights installed in the runway adjacent to the centreline. The lights are positioned in a 3-2-1 sequence at 100-m intervals prior to the point of tangency of the rapid exit taxiway centreline.

Following a landing, the runway occupancy time has a significant effect on the achievable runway capacity. Rapid exit taxiway indicator lights allow pilots to maintain a good roll-out speed until it is necessary to decelerate to an appropriate speed for the turn into a rapid exit turn-off. A roll-out speed of 60 kn until the first RETIL (three-light barrette) is reached is seen as the optimum.

10.12 TCAS

TCAS resolution advisories have a limited use in resolving conflicts following a low-level go-around.

This is because (assuming both aircraft have functioning transponders and TCAS equipage) the display and annunciation of RAs are inhibited close to the ground. The figure below shows where varying stages of TCAS activation are available.

It can be seen that for departing aircraft and aircraft which are going around, i.e. climbing aircraft (blue), TCAS RAs are not available until they pass 1000 ft AGL, thus any conflict which has a closest point of approach below 1000 ft will not benefit from the availability of TCAS.

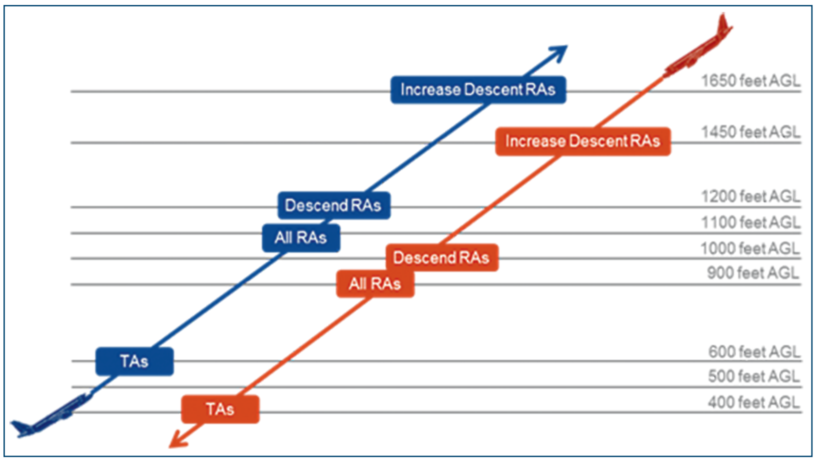

Figure 25: Heights above ground level which govern the inhibition of resolution advisories

10.13 Airport moving maps

Airport moving maps provide pilots and airside vehicle drivers with enhanced situational awareness.

They:

- help them to know their position on the manoeuvring area and avoid runway incursions;
- give them an immediate view of approaching runway exits and taxiways on roll-out.

10.14 Airport 3D moving map

Figure 26: 3D airport moving map on flight deck primary flight display

This 3D system is placed on the primary flight display. It looks similar to a car GPS. It uses the perspective of a position above and behind the subject aircraft. On turning onto a runway however, the display changes to a conventional view ahead from the flight deck. At present, the 3D version does not show traffic. This is a growth item for the future.

There is also a 2D version available which does include position of other traffic and vehicles.

11. CONCLUSIONS AND RECOMMENDATIONS

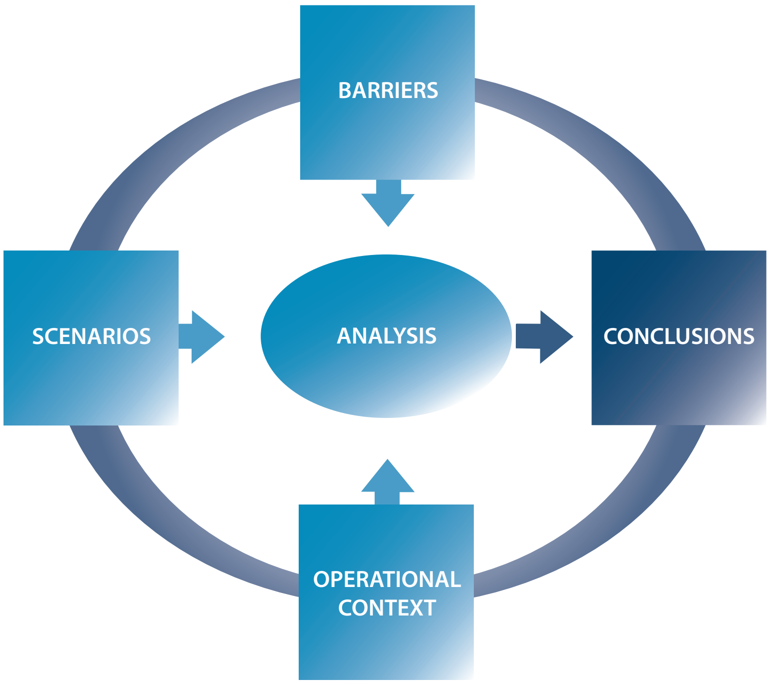

Figure 27

11.1 Conclusions

The study arrives at the following conclusions.

Conclusion 1

This study identified six different scenario outcomes which could result in a conflicts on or following low-level go-arounds. The study concluded that each airport and ATC unit has different levels of risk exposure to these scenarios and therefore no "one-size-fits-all" recommendations are made.

Conclusion 2

This study identified seven available barriers which, if deployed and used correctly, could prevent a conflict occurring by either preventing a low-level go-around or taking action immediately following a low-level go-around. ATC defensive controlling prior to go-arounds and subsequent ATC prevention of conflicts were the barriers with the highest spread of applicability.

Conclusion 3

The study identified five available barriers which, if deployed and used correctly, might mitigate the collision risk of a conflict occurring during a low-level go-around. ATC ad-hoc conflict resolution and independent pilot conflict resolution were the barriers with the highest spread of applicability.

Conclusion 4

This study identified and suggests a method of weighting the potential effectiveness of each barrier, depending on the prevalent types of runway configuration and traffic mix at individual aerodromes.

11.2 Recommendations

On the basis of the conclusions, the following recommendations are made.

Recommendation 1

European airport authorities and ANSPs should review the identified potential barriers and the conclusions if they undertake operational safety analysis and improvement activities for conflicts on or following low-level go-arounds events.

Recommendation 2

European airport authorities, ANSPs and the EUROCONTROL Safety Improvement Sub-Group (SISG) should monitor occurrences involving conflicts on or following low-level go-arounds to determine changes in frequency and severity.

Recommendation 3

European airport authorities and ANSPs should note that no "one- sizefits-all" recommendations are made, and that a method of weighting the potential effectiveness of each barrier could be considered which takes account of the prevalent types of runway configuration and traffic mix at individual aerodromes.

Recommendation 4

ANSPs and aircraft operators should note that ATC defensive controlling and the subsequent ad-hoc resolution actions by both controllers and pilots are currently the most effective barriers. It is therefore recommended that ab-initio and continuation training be reviewed and enhanced where appropriate in order to heighten awareness of best practice.

Recommendation 5

All European aviation stakeholders should note that the current most effective methods of reducing the frequency and severity of such events rely on human performance. It is therefore recommended that all European aviation stakeholders support the development of tools and procedures which increase resilience and reduce the level of reliance on human performance.

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