

Runway Incursion Incidents in Europe - Safety Functions Maps analysis of 2013 - 2015 data sample

Executive summary

This document describes the process and the results of the analysis of a sample of European A and B severity runway incursions incidents that occurred in EUROCONTROL member states in the period 2013 - 2015. The analysis was carried by means of the Safety Functions Maps barrier model.

The purpose of this report is to support the review of the European Action Plan for the Prevention of Runway Incursions.

The analysis was performed using the approach applied by EUROCONTROL for the identification of the Network Manager Top 5 safety priorities. It is based on plotting the incident information onto the Safety Functions Map (SAFMAP) barrier structure that provides defence against runway collision accidents.

This incident analysis provides information about Safety-I (i.e. safety functions that failed) but also about Safety-II (i.e. safety functions that performed well). In particular, at barrier level, the resilience (Safety-II) is addressed by identifying the barrier that stopped the incident from propagating further, while Safety-I is addressed by analysing the previous barriers. With regard to Safety-I, the information regarding the barriers component's that failed is available in most cases. As regards Safety-II, incidents of lower severity level would need to be analysed in order to build a reliable picture of 'what worked well'.

The analysed sample includes 126 runway incursion incidents from a total of 270 A and B severity runway incursion incidents that occurred in 2013, 2015 and 2016 and were reported to EUROCONTROL. It can be concluded that the analysed sample of runway incursion incidents is sufficiently representative for the overall population of runway incursion incidents in Europe.

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1. INTRODUCTION

1.1 Incident sample

The study used a sample of European A and B severity runway incursions incidents that occurred in in EUROCONTROL member states in the years 2013, 2014 and 2015. The source of the data was 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 on 12 April 2016. The process, as approved, defined the data requirements based on the evolution of the NM Top 5 prioritisation process during the years of 2014, 2015 and 2016 and the respective data samples for 2013, 2014 and 2015. It is to be noted that the data sample for 2013 was only available in coded format while the samples for 2014 and 2015 description allowed the extended SAFMAP coding as provided in Annex 1.

The analysed sample, as presented on Figure 1, includes 126 runway incursion incidents, of which 27 were classified as severity A and 99 were classified as severity B incidents. The sample of runway incursions analysed constitutes 47% from all 270 A and B severity runway incursion incidents that occurred in the period 2013 -2015 and were reported to EUROCONTROL. It can be concluded that the analysed sample of runway incursion incidents is sufficiently representative for the overall population of runway incursion incidents in Europe.



Figure 1: Analysed incident sample

1.2 Approach

The sample of 126 incidents was analysed using the same approach applied by EUROCONTROL for the identification of Network Manager Top 5 safety priorities. It is based on plotting the incident information on the Safety Functions Map (SAFMAP) barrier structure providing defence against runway collision accidents. The used model version is “Safety Functions Map Configuration Description Model” of 18 November 2016.

The SAFMAPs are barrier models based on a 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 can impact 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 “Pilot/driver detection that RWY protected area entry will be incorrect” does not specify the actual means to implement this function such as stop-bars, runway guard lights or runway entry lights.

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 runway collision are presented on Figure 2.

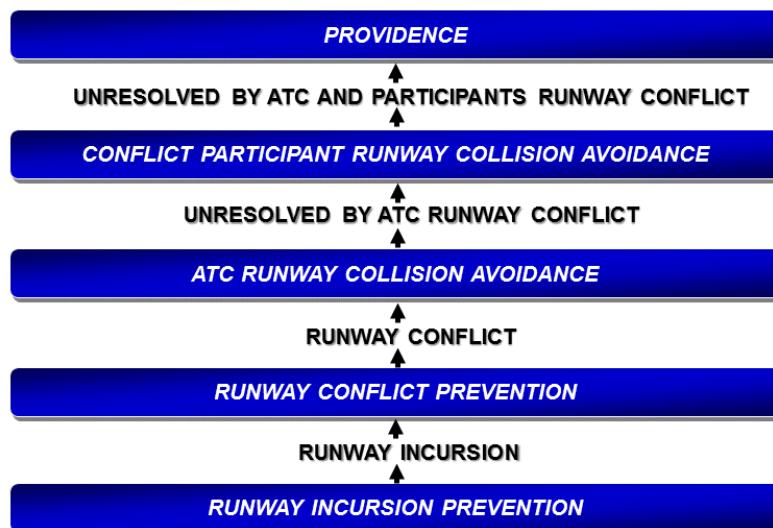


Figure 2: Basic barriers for runway collision prevention

2. GENERAL ANALYSIS OF BARRIERS' PERFORMANCE

2.1 Basic barriers' overall performance

The information presented by Figure 3 below provides an indication of the barrier strength, i.e. the basic barriers' ability to stop an event developing into a more severe outcome and ultimately into a runway collision. An exception is the barrier 'Runway incursion prevention' - all the events analyses with the help of the SAFMAP model have been classified as A and B severity events, hence it is obvious that the 'Runway incursion prevention' barrier has failed in the vast majority of the analysed cases. Information about the Runway incursion prevention' barrier strength could be obtained by analysis of safety occurrences of lower severity, i.e. reported cases when this barrier 'worked well'.

In the analysed sample the 'Runway conflict prevention' barrier was tested 122 times and worked 38 times, i.e. its recorded efficiency is 31 %.

The 'ATC runway collision avoidance' barrier has been tested 84 times and worked 38 times, i.e. its recorded efficiency is 45 %.

The 'Conflict participant runway collision avoidance' barrier has been tested 46 times and worked 40 times, i.e. its recorded efficiency is considerably higher reaching 87 %.

In 6 cases the conflict geometry (chance) helped avoid the collision, which means that the overall recorded efficiency of the runway conflict prevention and collision avoidance barriers is 95 %.

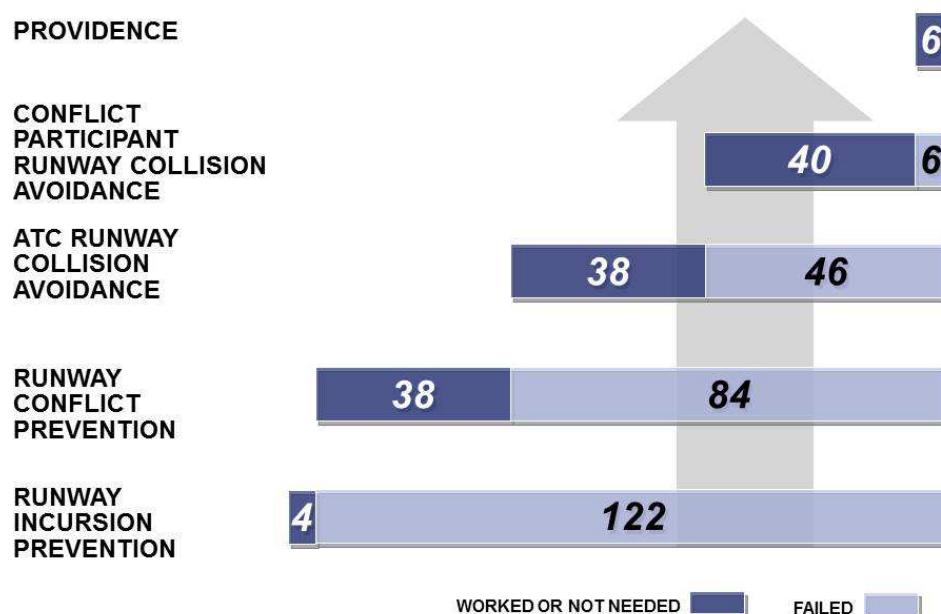


Figure 3: Basic barriers' performance

Figure 4 (next page) provides further insight into the barriers' strength. It identifies the number of incidents stopped by a barrier in terms of absolute number (shown to the left of the barrier bars) and percentage (shown to the right of the barrier bars) of all incidents analysed. It also identifies the number of times the next barrier was not challenged despite the failure of the previous one. For example, in 12 out of 122 cases (10%) there was no need for runway conflict prevention. Such events include infringement of ILS sensitive area by a mobile during Low Visibility Operations (LVO).

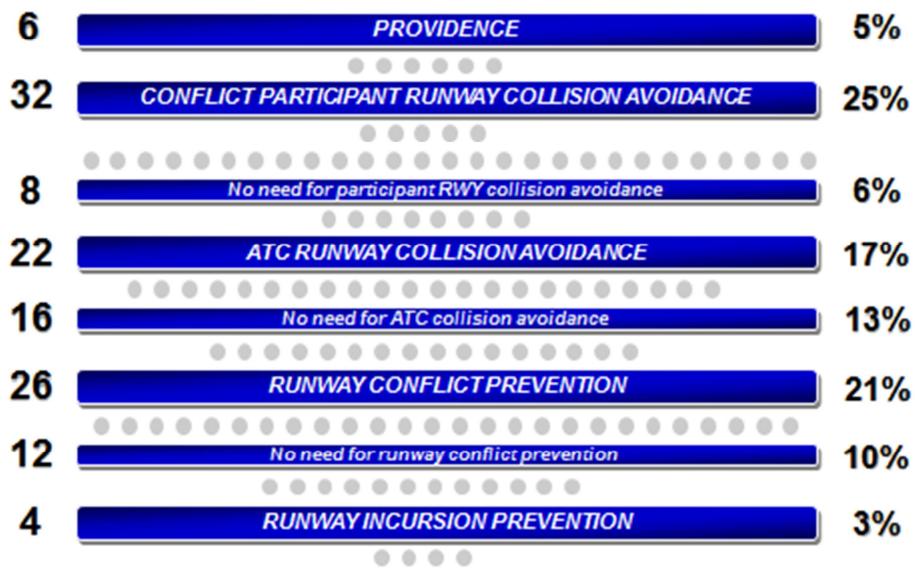
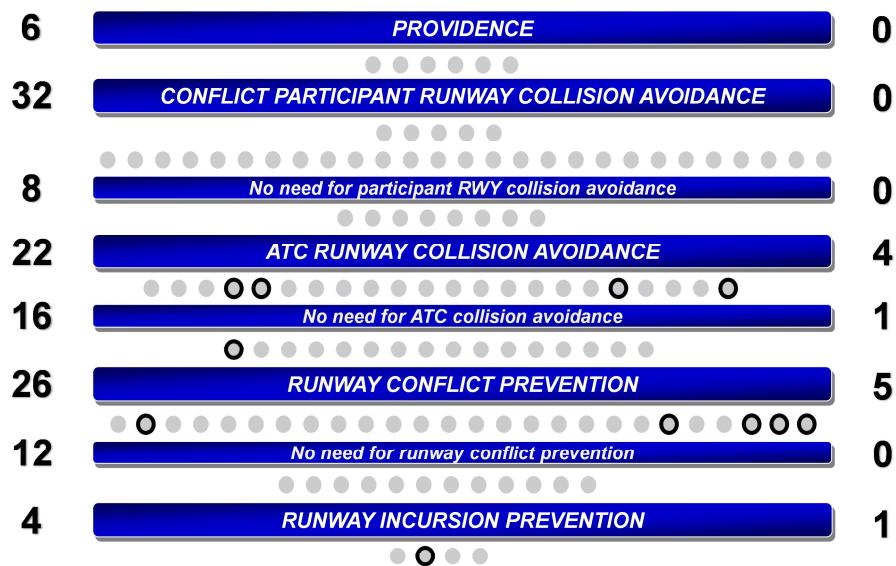


Figure 4: Number of incidents stopped by a barrier

Figure 5 below illustrates the events that were stopped (to develop into a runway collision) by one of the ATC barriers, but where only providence was left as a further barrier had the ATC barrier that stopped them failed.



○ Event stopped by ATC barriers but only providence left as an alternative barrier

Figure 5: Events with only providence left as alternative barrier

The number shown to the left of a barrier bar identifies the total number of incidents stopped by that barrier. The number shown to the right of a barrier bar identifies the number of incidents stopped by that barrier with only providence left as alternative barrier.

2.2 Barriers' resilience per initiator

The barriers' resilience per initiator is illustrated on Figure 6 below. The initiators are failures of one of the 6 sub-functions (sub-barriers) of the 'Runway Incursion Prevention' basic safety barrier:

- Prevention of ATC causing incorrect entry of a taxiing mobile into the RWY protected area.
- Prevention of taxiing mobile from incorrectly entering the RWY protected area
- Prevention of incorrect presence of a vacating mobile in the RWY protected area
- Prevention of incorrect presence of a departing aircraft in the RWY protected area
- Prevention of incorrect presence of landing aircraft
- Prevention of incorrect presence of people in the RWY protected area

In addition to the barrier resilience per initiator, Figure 6 illustrates the events that were stopped to develop into runway collision by one of the barriers, but where only providence was left as a further barrier had the barrier that stopped them failed. It is to be noted that such events have various originators; however, the majority is caused by incorrect presence of departing aircraft on the runway protected area and by landing without clearance.

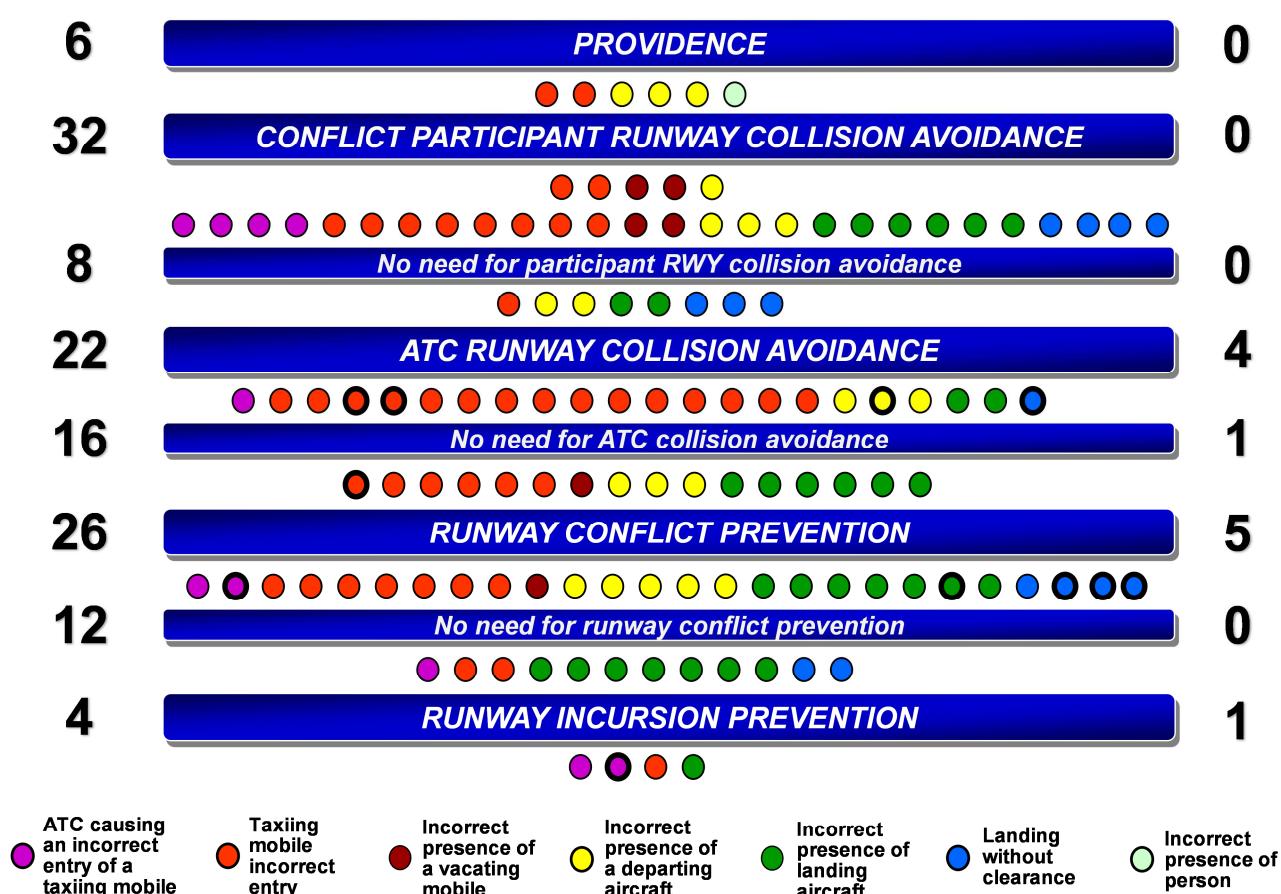


Figure 6: Barriers' resilience per initiator

The number shown to the left of a barrier bar identifies the total number of incidents stopped by that barrier. The number shown to the right of a barrier bar identifies the number of incidents stopped by that barrier with only providence left as alternative barrier.

Figure 7 below presents the share of the various initiators in the overall sample of events analysed. The incorrect entry of a taxiing mobile into the runway protected area is a clearly outstanding initiator (35 % of events analysed).

The share of events of incorrect presence of landing aircraft is also considerable - 25 % of all events analysed. Often, the cause is insufficient spacing of aircraft on final approach.

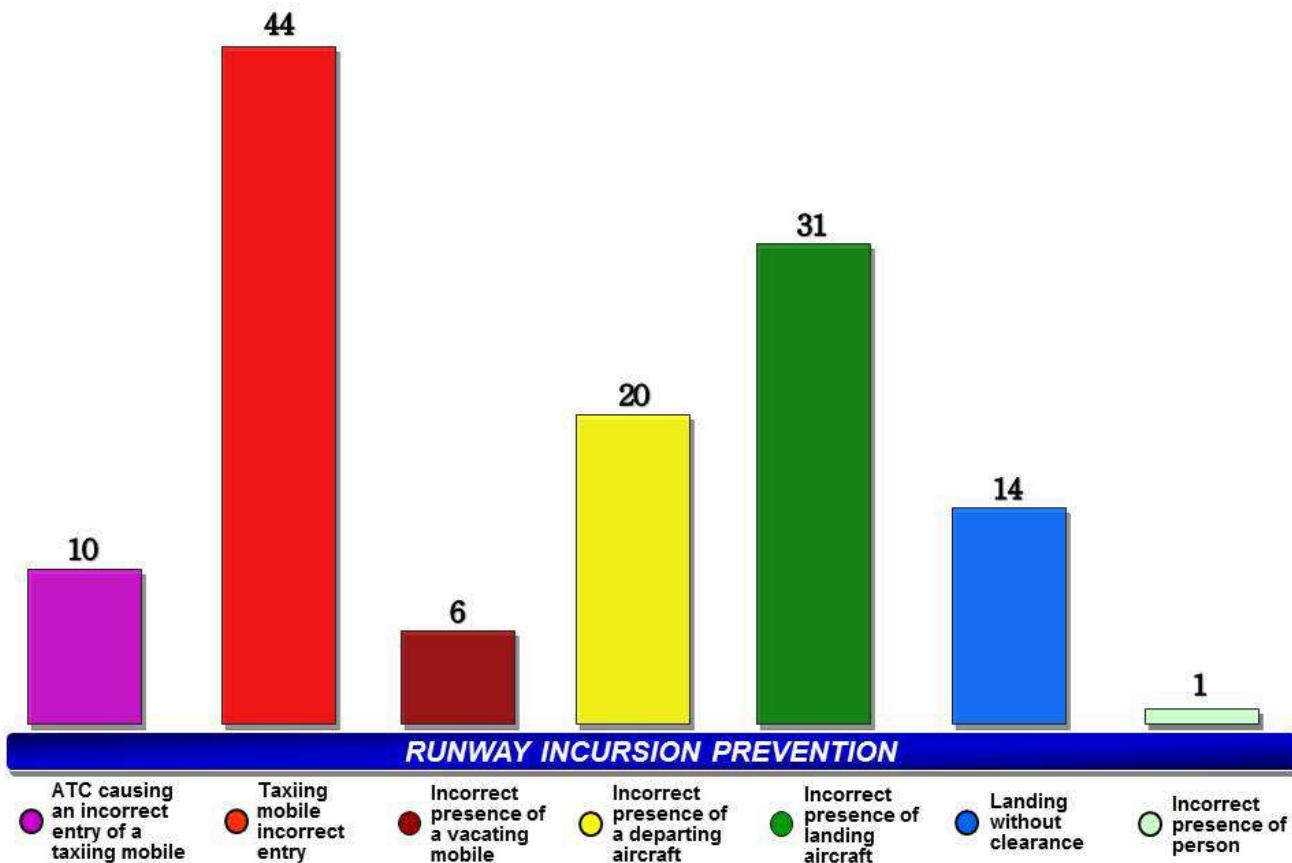


Figure 7: Distribution of events per initiator

3. ANALYSIS OF EVENTS WITH SPECIFIC CONTEXT

3.1 Sudden High Energy Runway Conflict

Figure 8 below illustrates the barrier efficiency in mitigating risk of Sudden High Energy Runway Conflicts (SHERCs), as well as the SHERC events that were stopped by one of the barriers, but where only providence was left as a further barrier had the barrier that stopped them failed. SHERC events account for 10 % of the analysed sample.

The main initiator of the SHERC events in the analysed sample is incorrect entry of a taxiing mobile into the runway protected area. This initiator is one of the most safety critical initiators as it initiated the 2 SHERC events stopped by the 'providence' barrier and the 2 SHERC events saved by ATC with only providence left as alternative barrier.

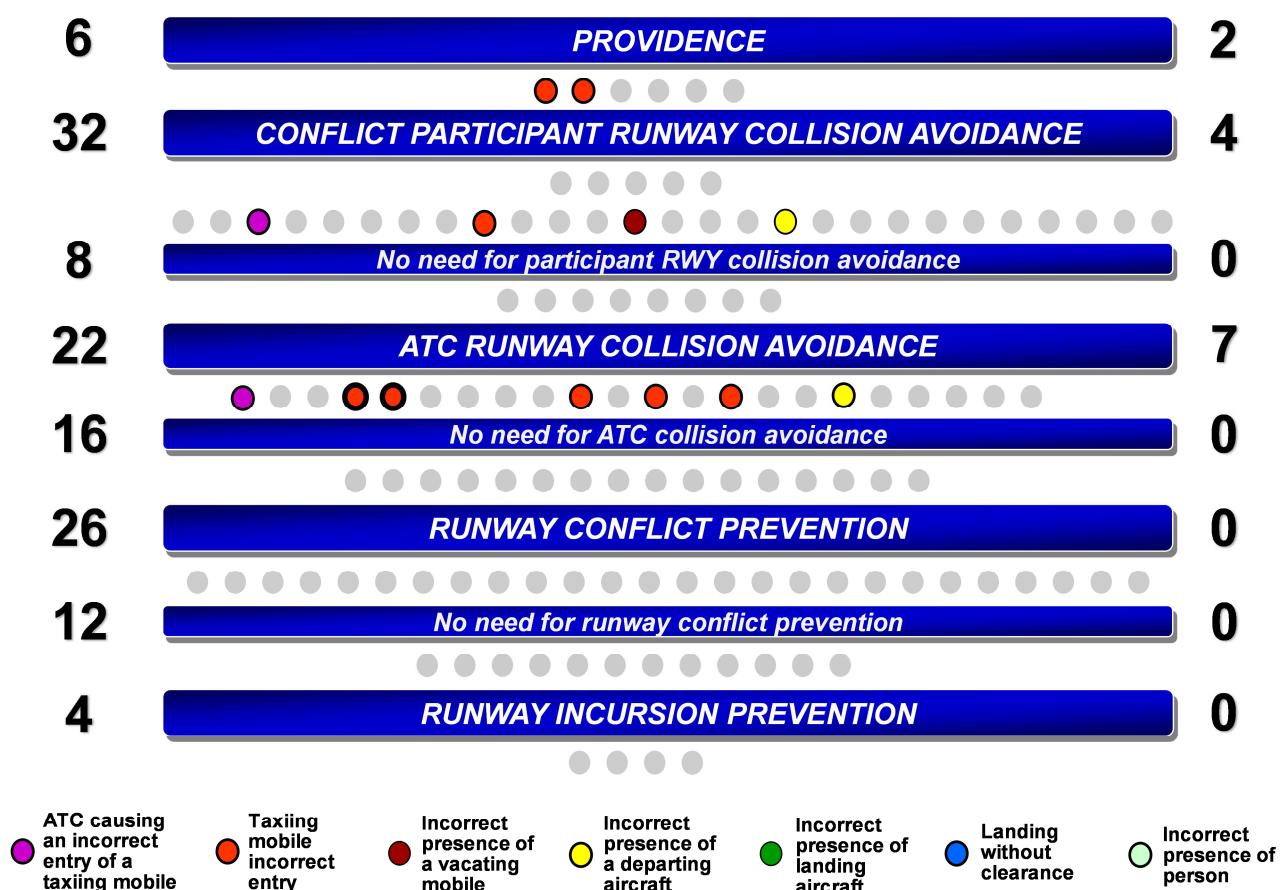


Figure 8: Sudden High Energy Runway Conflict

The number shown to the left of a barrier bar identifies the total number of incidents stopped by that barrier. The number shown to the right of a barrier bar identifies the number of SHERC incidents stopped by that barrier.

3.2 ATC not identifying occupied runway

The ATC (Tower controller) did not identify that the runway is occupied when issuing a runway use clearance in 33 events, i.e. in 26 % of the analysed cases. As illustrated on Figure 9 more than the half these incidents crossed the ATC prevention barriers and were stopped at the top of the barrier model.

The biggest initiator of incidents in which ATC did not identify that the runway is occupied is the incorrect presence of a departing aircraft. In the majority of these events the TWR controller issued a clearance for take-off not identifying or forgetting the presence of a mobile on the runway.

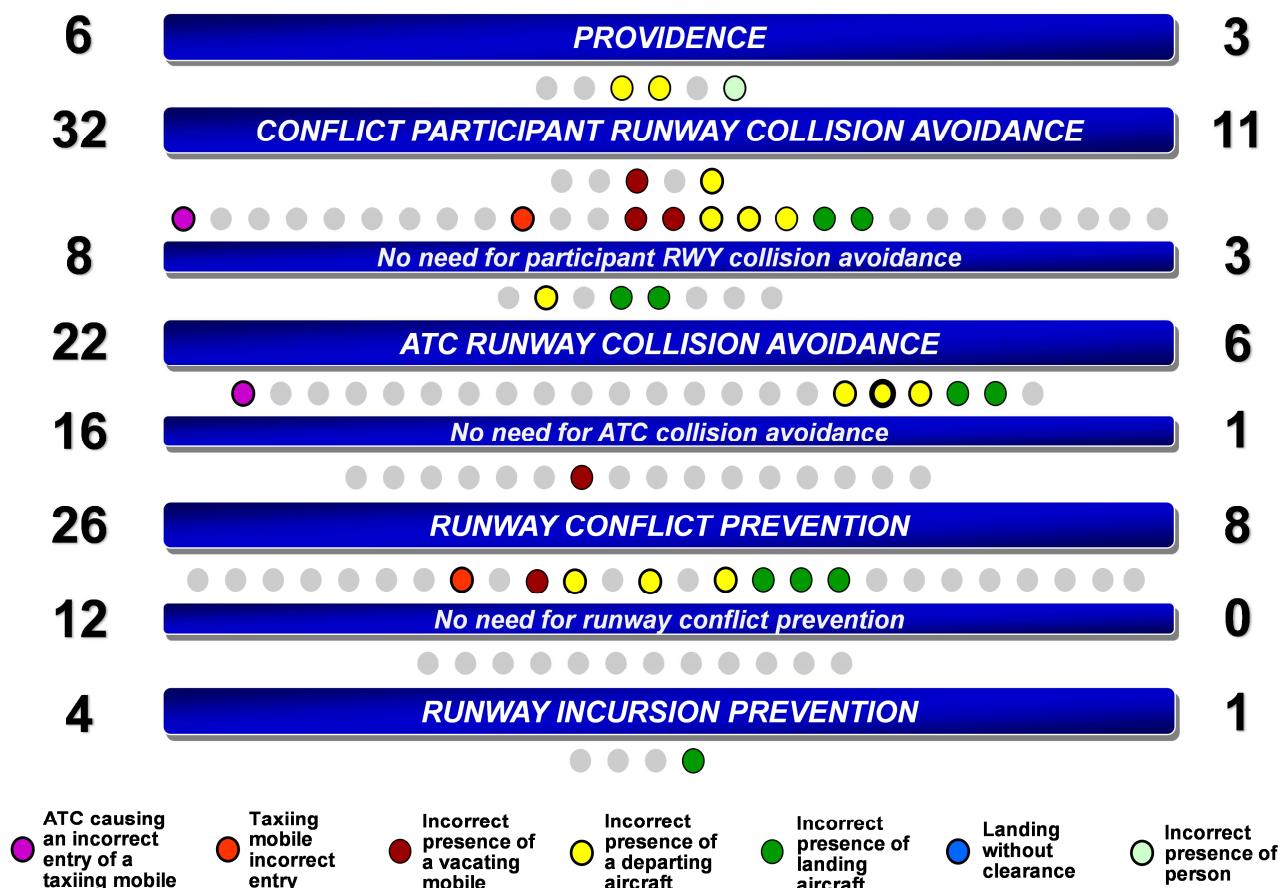


Figure 9: ATC not identifying occupied runway

The number shown to the left of a barrier bar identifies the total number of incidents stopped by that barrier. The number shown to the right of a barrier bar identifies the number of incidents stopped by that barrier in which the TWR controller did not identify that the runway was already occupied when issuing a runway use clearance.,

3.3 Vehicles participating in the event

The runway incursion events involving the presence of vehicles on the runway protected area represent 25 % of the analysed sample of events. It is to be noted that the ATC conflict prevention and collision avoidance barrier are not particularly efficient in stopping these events – 60% of the events passed through these basic barriers.

It appears that the combination of vehicles participating in the event scenario and the presence of a departing aircraft accounts for a considerable part of the most critical events, i.e. those that were stopped by the top barriers of the model.

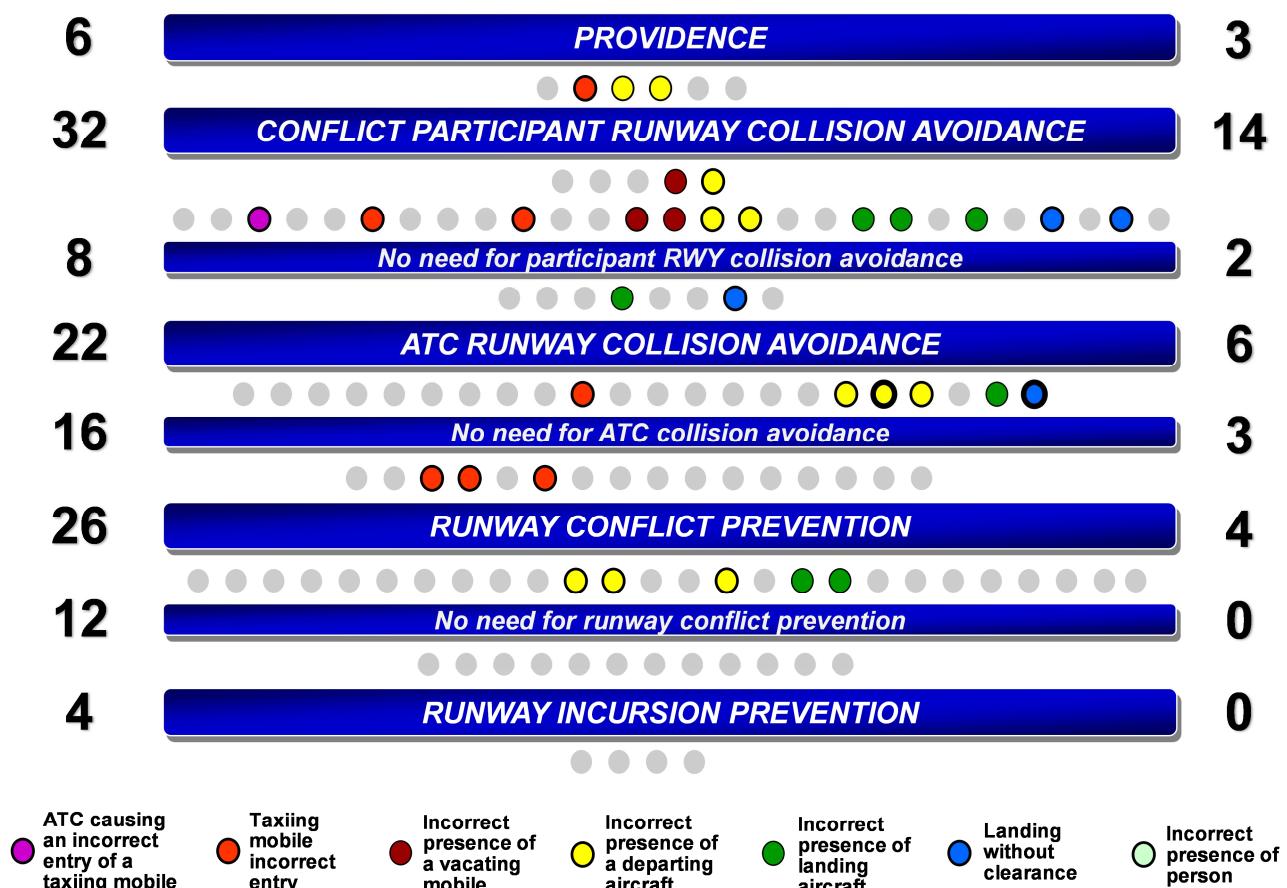


Figure 10: Runway incursions involving vehicles

The number shown to the left of a barrier bar identifies the total number of incidents stopped by that barrier. The number shown to the right of a barrier bar identifies the number of incidents with vehicle participation stopped by that barrier.

3.4 Hand-over & take-over of ATC operational positions

In the analysed sample the TWR position hand-over and take-over is an initiating factor with a quite limited impact – 6 out of 7 events were stopped by the ATC conflict prevention and collision avoidance barriers.

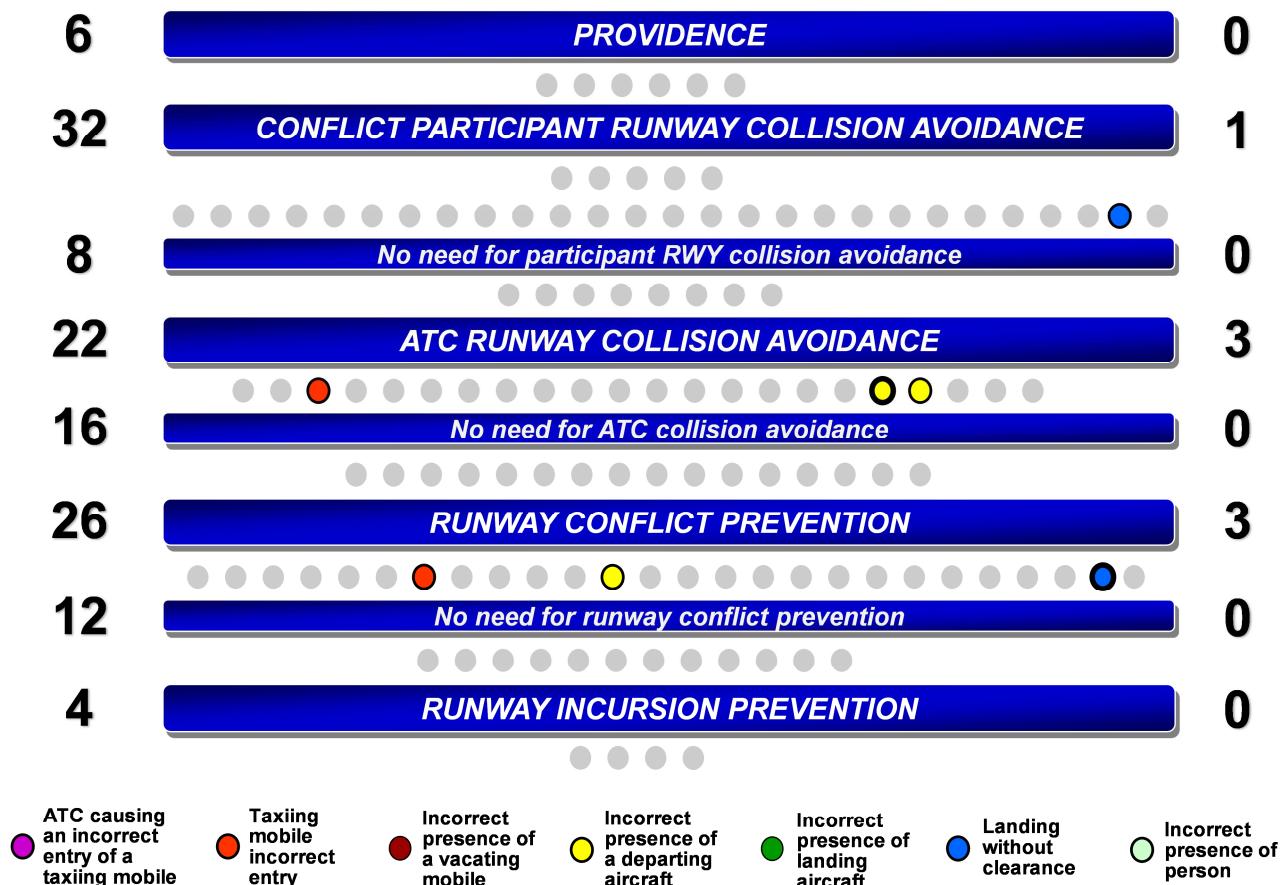


Figure 11: Hand-over & take-over of operational positions

The number shown to the left of a barrier bar identifies the total number of incidents stopped by that barrier. The number shown to the right of a barrier bar identifies the number of incidents stopped by that barrier in which hand-over / take-over was a factor.

3.5 Incidents during LVO

The ATC conflict prevention and collision avoidance barriers are quite efficient for stopping RI events associated with Low Visibility Operations (LVO). One particular scenario (applicable in 4 events) is the infringement of the ILS protected (sensitive) area, i.e. there is no actual runway conflict.

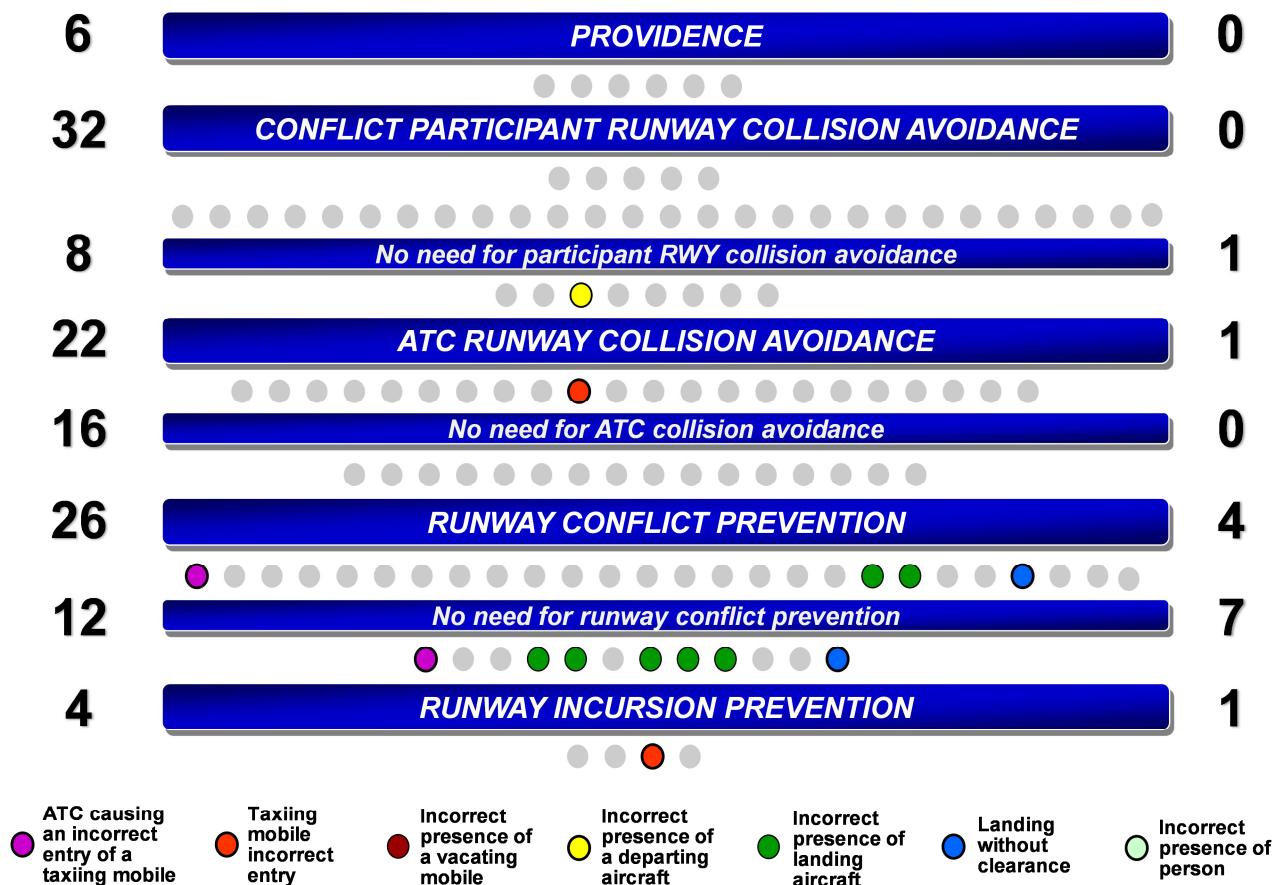


Figure 12: Incidents during low visibility operations

The number shown to the left of a barrier bar identifies the total number of incidents stopped by that barrier. The number shown to the right of a barrier bar identifies the number of incidents that occurred during LVO and were stopped by that barrier.

3.6 Crossing lit stop bars

The events involving crossing of lit red stop bar by the conflict participant represent 6 % of the analysed sample, i.e. crossing lit red stop bar is a rather rare event. It is to be noted that the ATC conflict prevention and collision avoidance barriers worked in all cases. In one of these cases the ATC collision avoidance barrier was identified as the last available barrier before 'providence'.

The initiator of all events was the incorrect entry of a taxiing mobile into the runway protected area.

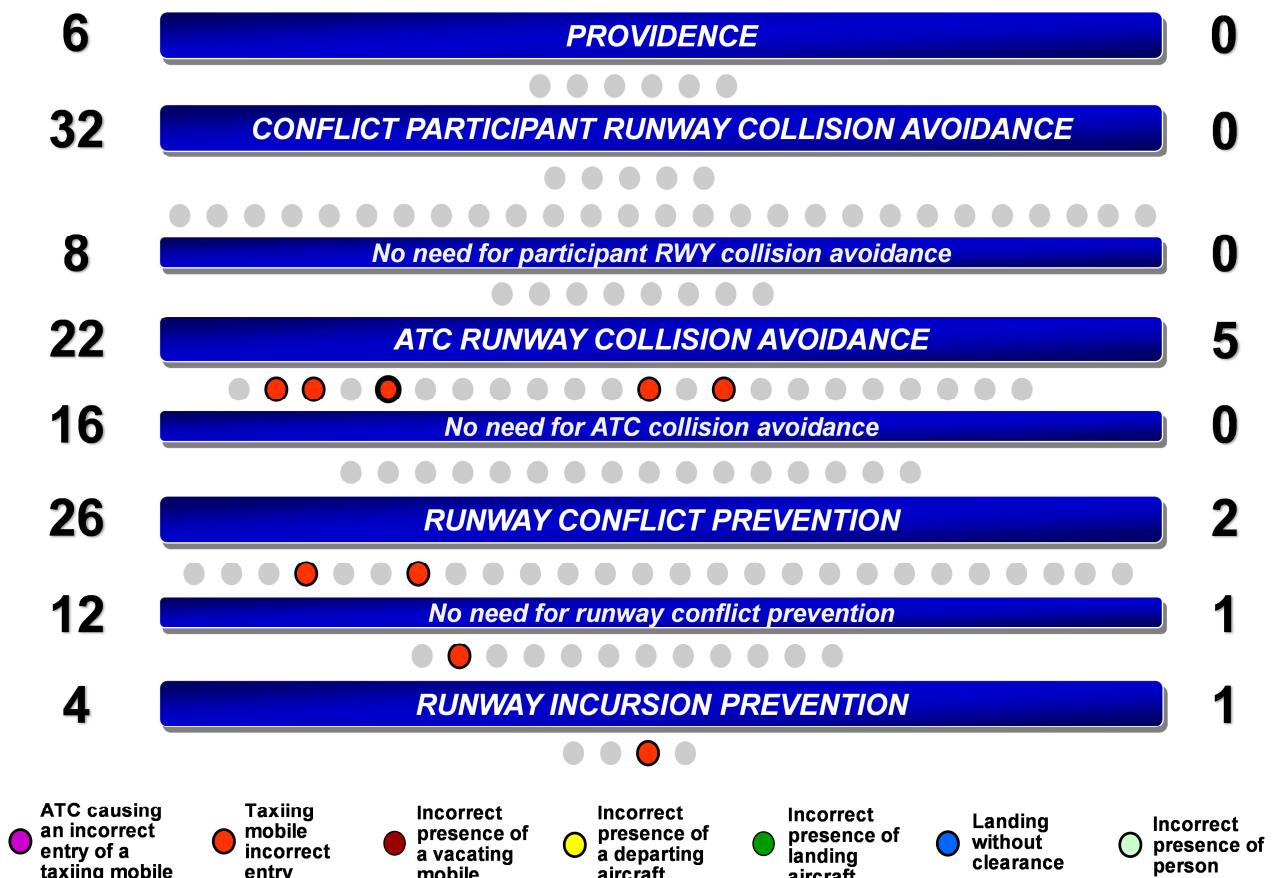


Figure 13: Incidents involving crossed red lit stop bars

The number shown to the left of a barrier bar identifies the total number of incidents stopped by that barrier. The number shown to the right of a barrier bar identifies the number of incidents stopped by that barrier in which a red lit stop bar was crossed by a mobile.

In order to better assess the potential of the red stop bars as a RI prevention barrier an additional analysis of the events involving incorrect entry of a taxiing mobile into the runway protected area was done. This analysis is based on the premise that if stop bars existed, the ATCO would have switched them on correctly and the pilot/driver would have stopped upon observing the red light.

Out of the 10 events triggered by "ATC causing an incorrect entry of taxiing mobile" there are 4 cases where there is a reasonable expectation that stop bars could have prevented the runway incursion. Out of the 44 events triggered by "Taxiing mobile incorrect entry" there are 25 events where there is a reasonable expectation that stop bars could have prevented the incursion.

The cases where it was considered that stop bars could have been inefficient to prevent the incursion are two major groups: (1) those involving conditional clearance and (2) those involving a mobile entry not via the designated taxiways.

3.7 Use of conditional clearances

Although the share of events involving use of conditional clearance is relatively low in the analysed sample (8%) the potential for a high severity outcome is considerable. A considerable number of the events (40 %) the events were stopped by the last 2 barriers – collision avoidance by the conflict participant and providence. Another 30 % of the events were stopped by the ATC collision avoidance barrier.

In all but one events the initiator was the incorrect entry of a taxiing mobile into the runway protected area. It should be noted that the conditional clearance in this scenario is not necessarily the cause of the runway incursion.

In five of the analysed cases the incorrect entry into the runway protected area was triggered by an inadequate air-ground communication, in particular inadequate application of read-back/ hear-back procedure.

In three of the analysed cases the incorrect entry into the runway protected area was triggered by an incorrect execution of otherwise correctly read-back conditional clearance. In all of these cases the pilot/driver misunderstood the clearance and entered the runway before the traffic constituting the condition.

In one of the analysed cases the incorrect entry into the runway protected area was triggered after a conditional clearance issued to the second traffic using the runway.

In one of the analysed cases the incorrect entry into the runway protected area was triggered by the insufficient spacing between the departure aircraft and the landing aircraft. It took more time than expected by ATCO for the take-off run to take place.

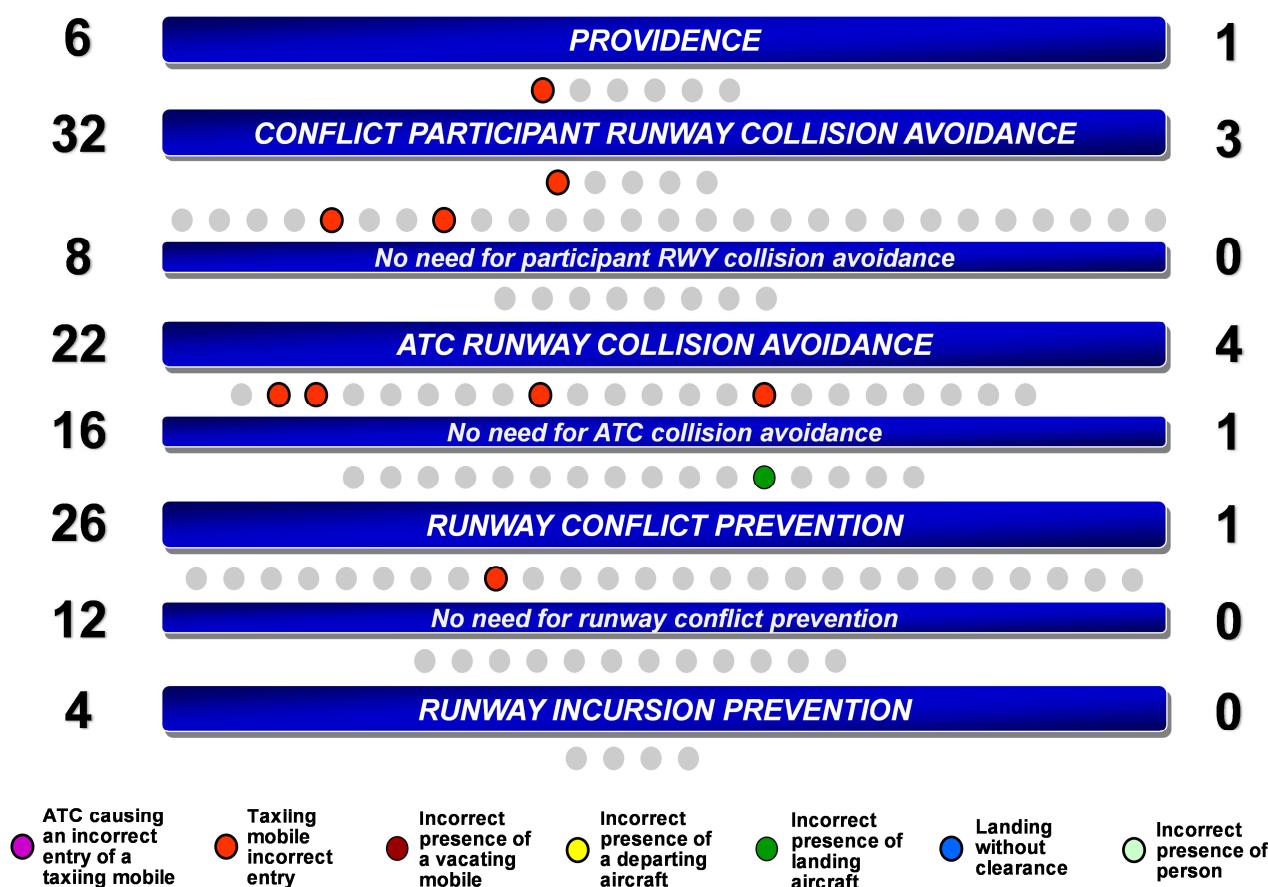


Figure 14 – Incidents involving conditional clearances

The number shown to the left of a barrier bar identifies the total number of incidents stopped by that barrier. The number shown to the right of a barrier bar identifies the number of incidents stopped by that barrier in which the use of conditional clearance was a factor.

4. PERFORMANCE OF THE RUNWAY INCURSION PREVENTION BASIC BARRIER

4.1 Incorrect entry of taxiing mobile into RWY protected area

The incorrect entry of a taxiing mobile into the RWY protected area is the strongest initiator in the analysed sample of RI events. It accounts for 35 % of the sample events. The factors with the highest contribution to the incorrect entry are communication issues (misunderstanding) and incorrect execution of ATC clearance (non-compliance).

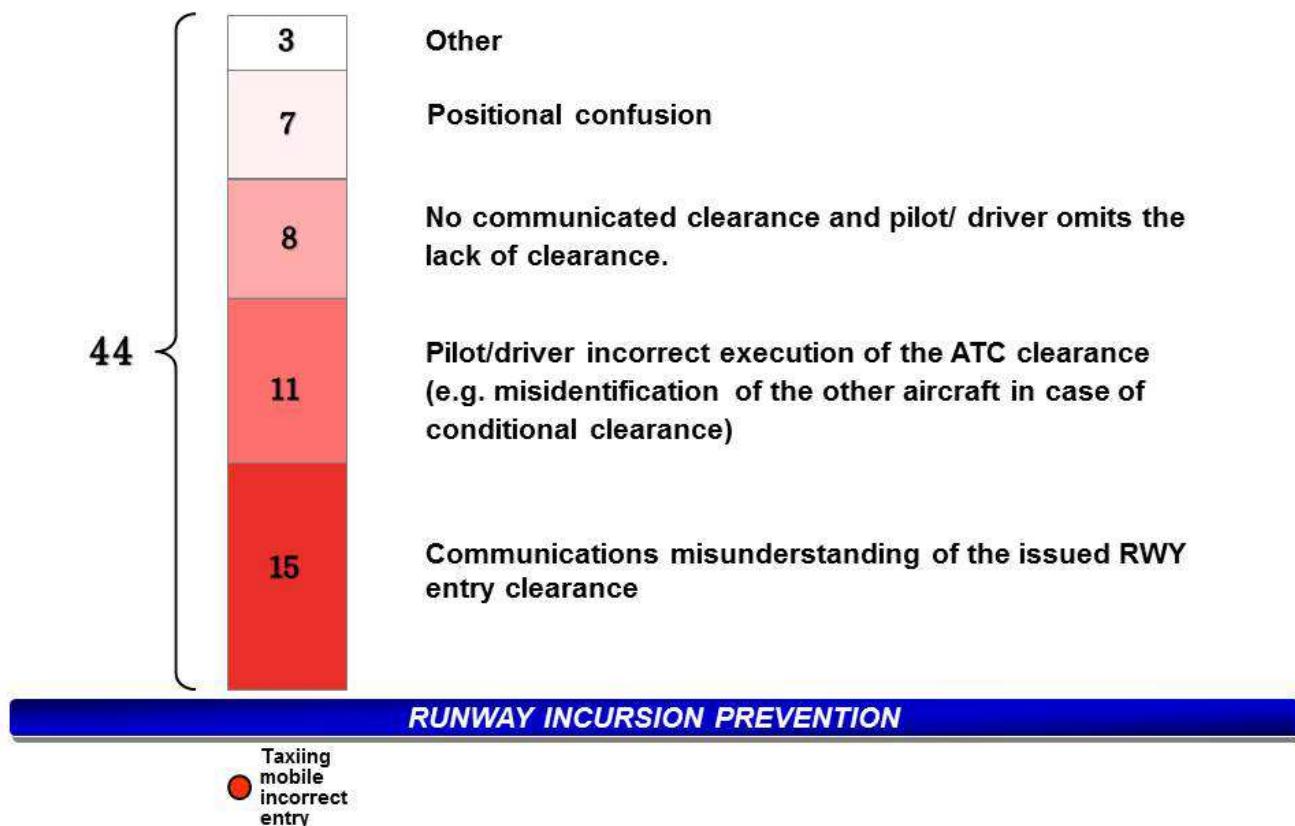


Figure 15:
Incorrect entry of a taxiing mobile into the RWY protected area – factors

Incorrect entry due to communication misunderstanding has the potential to pass through the ATC barriers - 40 % of these events were stopped by the conflict participant barrier and the providence.

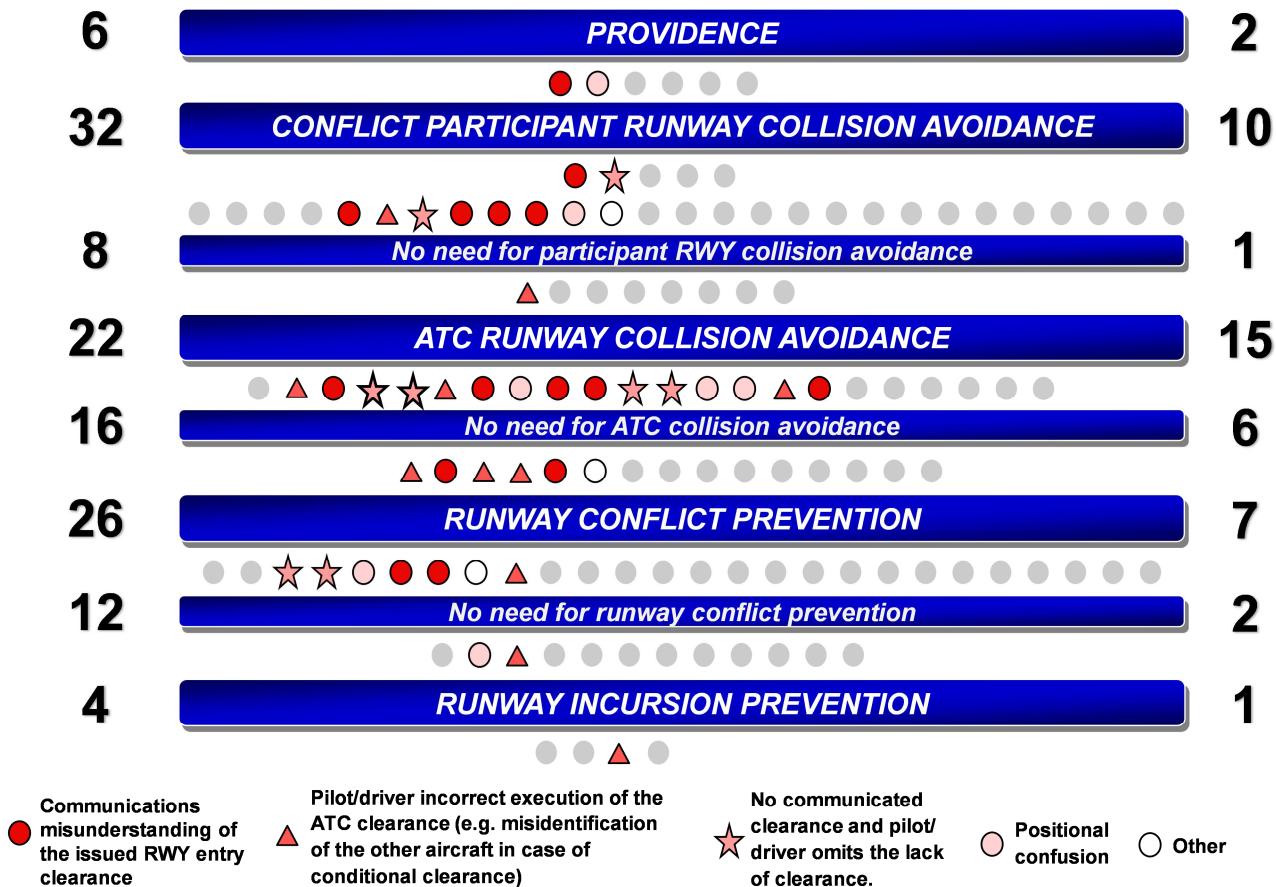


Figure 16:
Incorrect entry of a taxiing mobile into the RWY protected area – barriers' resilience

The number shown to the left of a barrier bar identifies the total number of incidents stopped by that barrier. The number shown to the right of a barrier bar identifies the number of incidents initiated by an incorrect entry of a taxiing mobile into the runway protected area and stopped by that barrier.

4.2 Incorrect presence of landing aircraft

Incorrect presence of landing aircraft is the second largest initiator for runway incursions in the sample. The 31 events account for 25% of the analysed sample of reported incidents. There were two major groups of factors for the incorrect presence of landing aircraft.

The first group, accounting for 74% (23 incidents) of the incorrect presence of landing aircraft events involved ATC not providing a correct and timely landing clearance, leading to the landing aircraft incorrectly passing beyond the specified spacing limits or entering the RWY protected area.

The second group, accounting for 26% (8 incidents) of the incorrect presence of landing aircraft events involved insufficient spacing between landing aircraft and between landing and departing aircraft that caused landing aircraft to incorrectly pass beyond the specified spacing limits.

Note: The spacing limits are locally defined and may vary, for example 4NM, RWY threshold, distance from RWY threshold when the clearance to land is issued, etc.

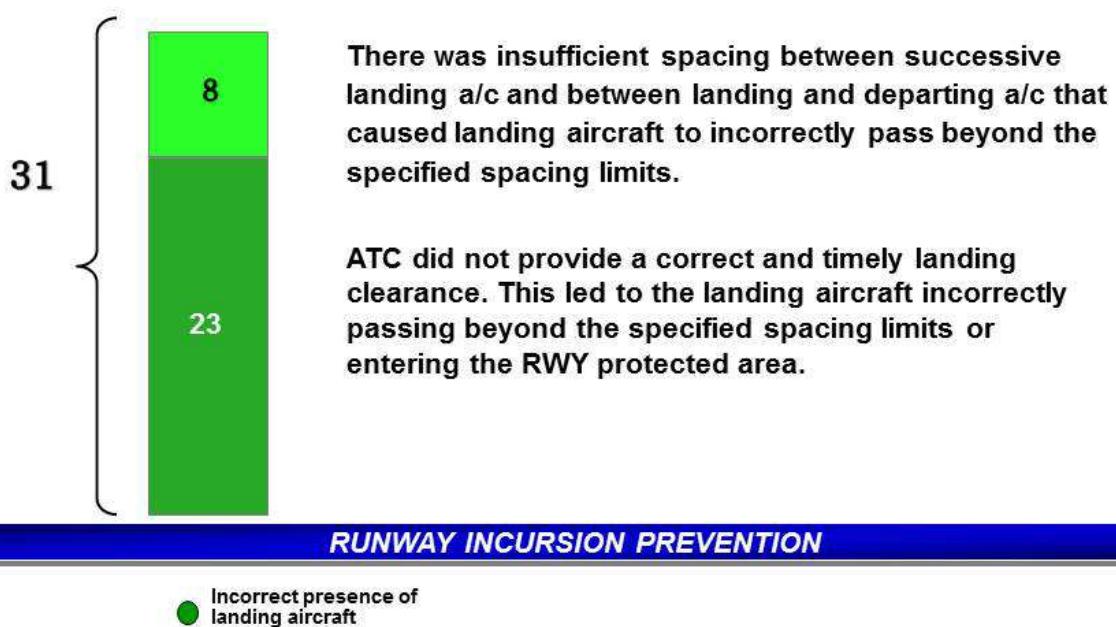


Figure 17: Incorrect presence of landing aircraft – factors

Landing without clearance can be classified as a particular kind of incorrect presence of landing aircraft but it is analysed separately and illustrated on Figure 18 below to provide additional insights.

The major factor leading to landing without clearance was communications misunderstanding, followed by deliberate landing without clearance and landing without clearance after loss of communications.

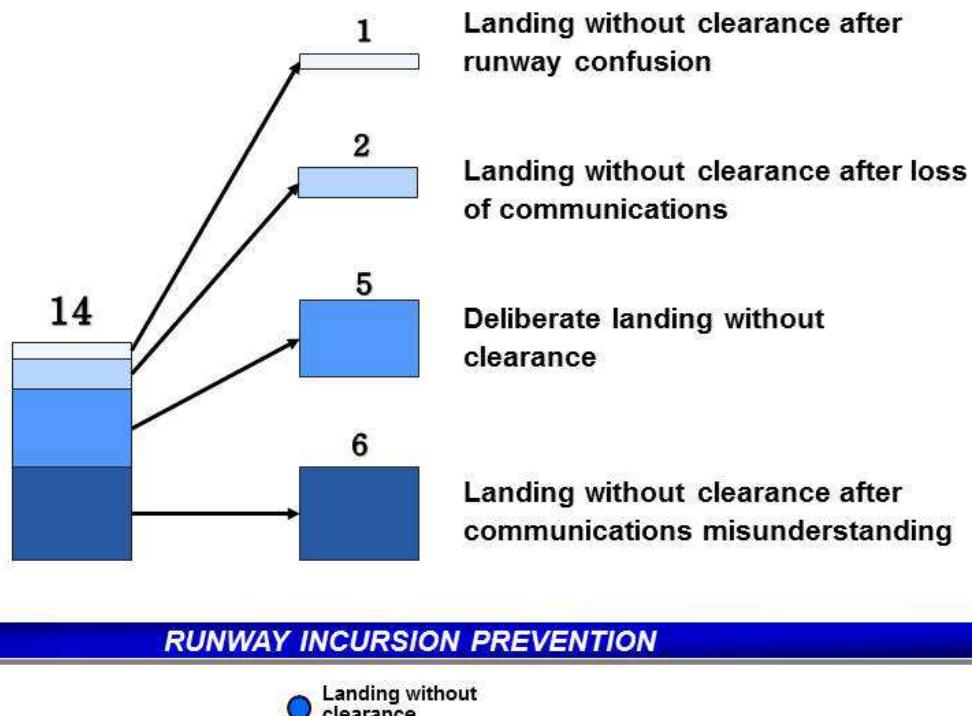


Figure 18 : Landing without clearance - factors

The resilience of the basic safety barriers to the initiators “Incorrect presence of landing aircraft” and “Landing without clearance” is shown on Figure 19.

In all but one events initiated by insufficient spacing between successive landing and between landing aircraft and departing there was no need of collision avoidance.

More than one third of the events involving ATC not providing correct and timely landing clearance required collision avoidance either by ATC or the conflict participant.

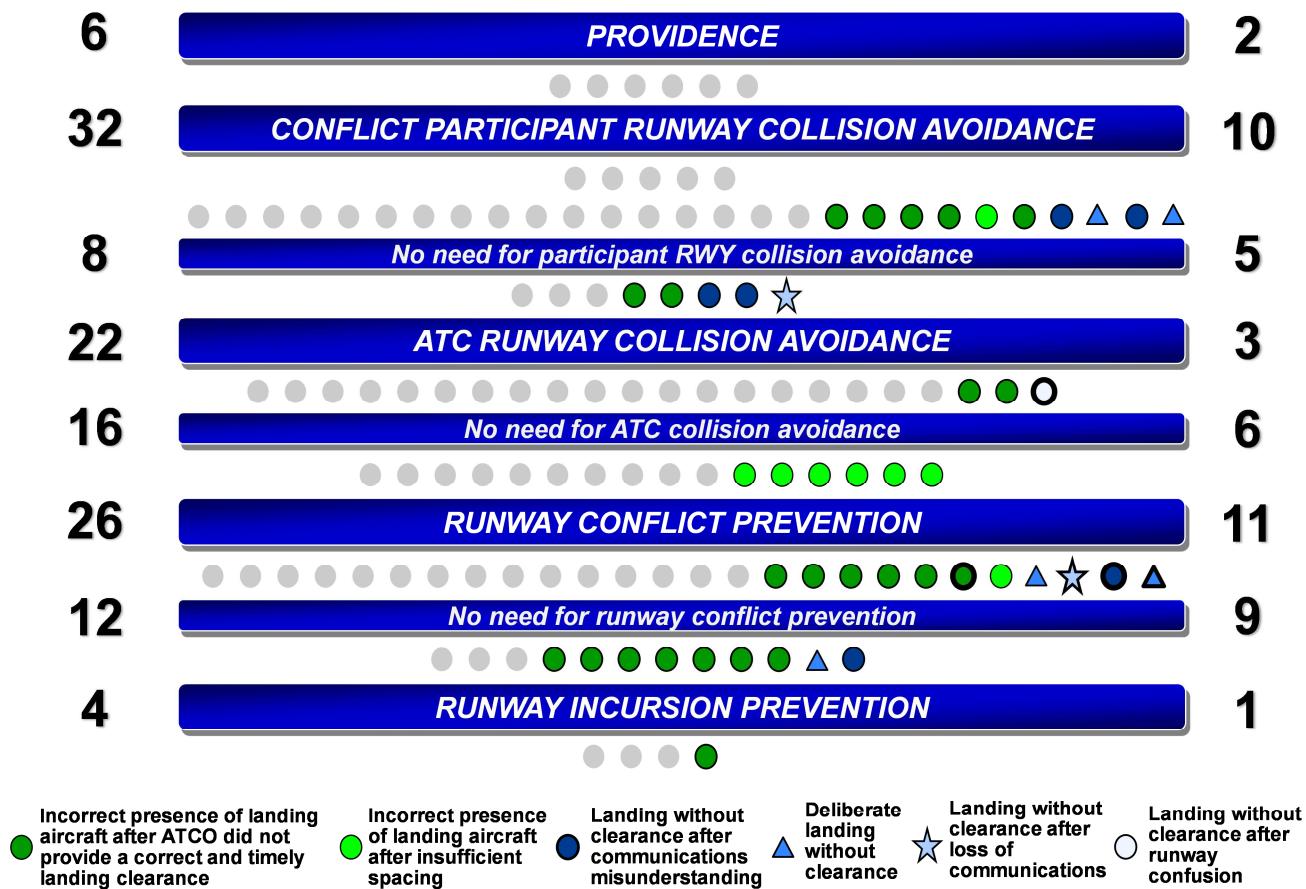
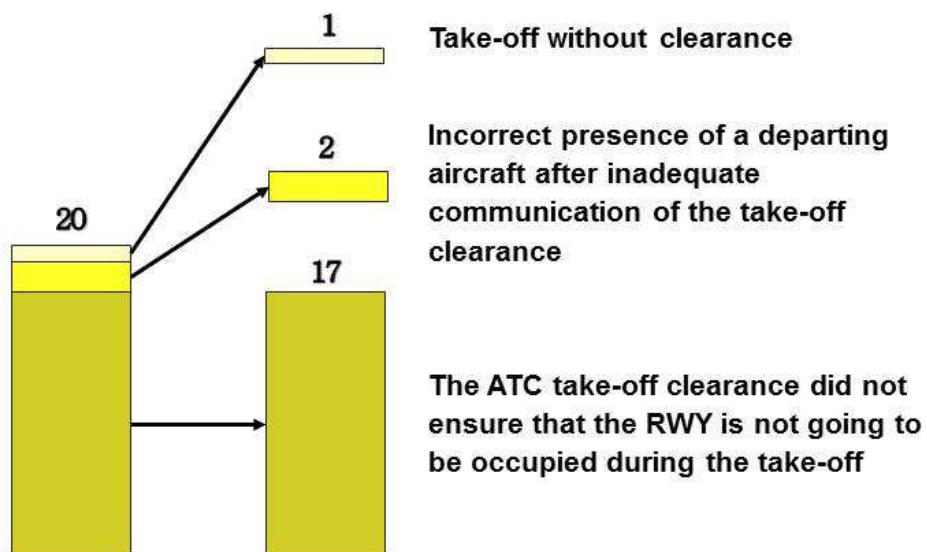


Figure 19:
Incorrect presence of landing aircraft (including landing without clearance) – barriers’ resilience

The number shown to the left of a barrier bar identifies the total number of incidents stopped by that barrier. The number shown to the right of a barrier bar identifies the number of incidents initiated by incorrect presence of landing aircraft and stopped by that barrier.

4.3 Incorrect presence of a departing aircraft

As in the events involving incorrect presence of landing aircraft, ATC is the main causal factor of this group of events. In 85% of the cases (17 events) involving incorrect presence of a departing aircraft ATC did not ensure that the runway was not going to be occupied during the take-off. This failure could have been corrected by the presence of adequate flight data, visual traffic monitoring, surveillance information, position reports and RWY status information and detection and resolution of clearance non-conformity (e.g. with the help system support) of route deviations, high speed taxiing towards the Holding Point, etc.



RUNWAY INCURSION PREVENTION

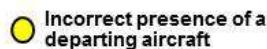


Figure 20: Incorrect presence of a departing aircraft – factors

The resilience of the basic safety barriers to the initiator “Incorrect presence of a departing aircraft” is shown on Figure 21.

About half of the events involving incorrect presence of departing aircraft required collision avoidance either by ATC or the conflict participant. In all but one of these events the initiator was ATC who did not ensure that runway is clear during the take-off.

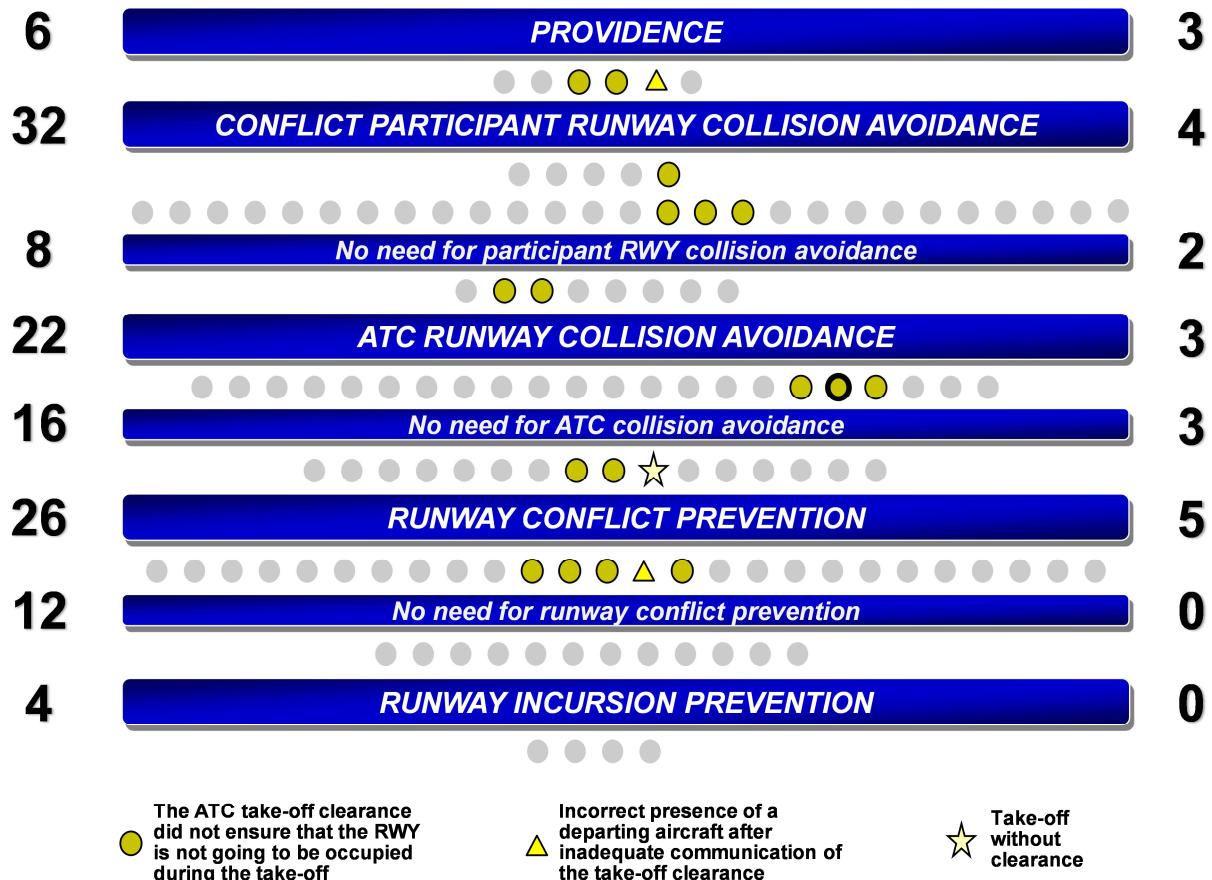
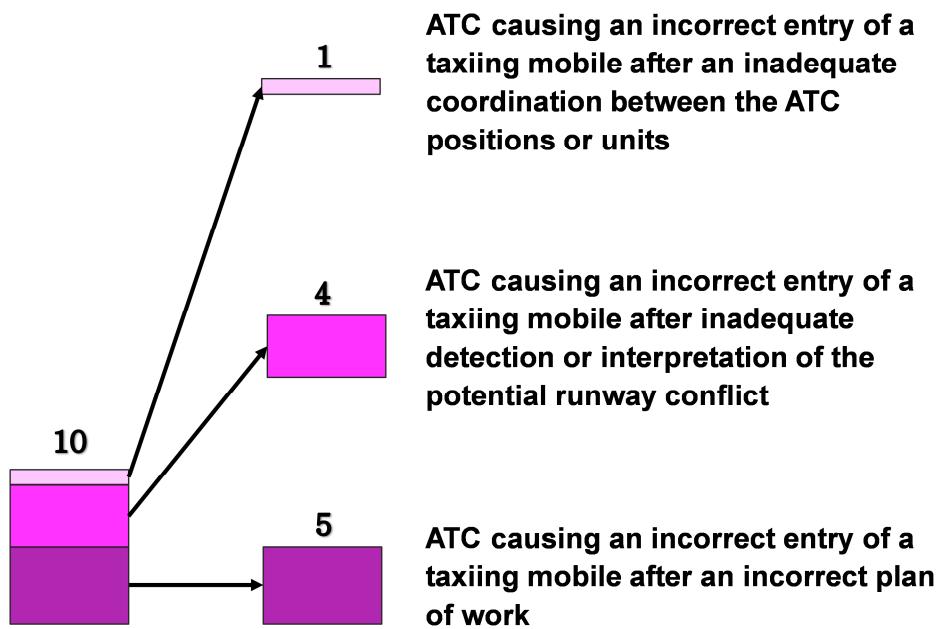


Figure 21: Incorrect presence of a departing aircraft – barriers’ resilience

The number shown to the left of a barrier bar identifies the total number of incidents stopped by that barrier. The number shown to the right of a barrier bar identifies the number of incidents initiated by incorrect presence of departing aircraft and stopped by that barrier.

4.4 ATC causing an incorrect entry of a taxiing mobile

The two main causes of the 10 events when ATC caused incorrect entry of a taxiing mobile into the runway protected area are incorrect plan of work (5 events) and inadequate detection or interpretation of the potential runway conflict.



RUNWAY INCURSION PREVENTION

● ATC causing an incorrect entry of a taxiing mobile

Figure 22:

ATC causing incorrect presence of a taxiing mobile – factors

With the caveat that the number of events involving ATC causing an incorrect entry of a taxiing mobile in the analysed sample, it is to be noted that those events involving inadequate detection or interpretation of the potential runway conflict by ATC required collision avoidance.

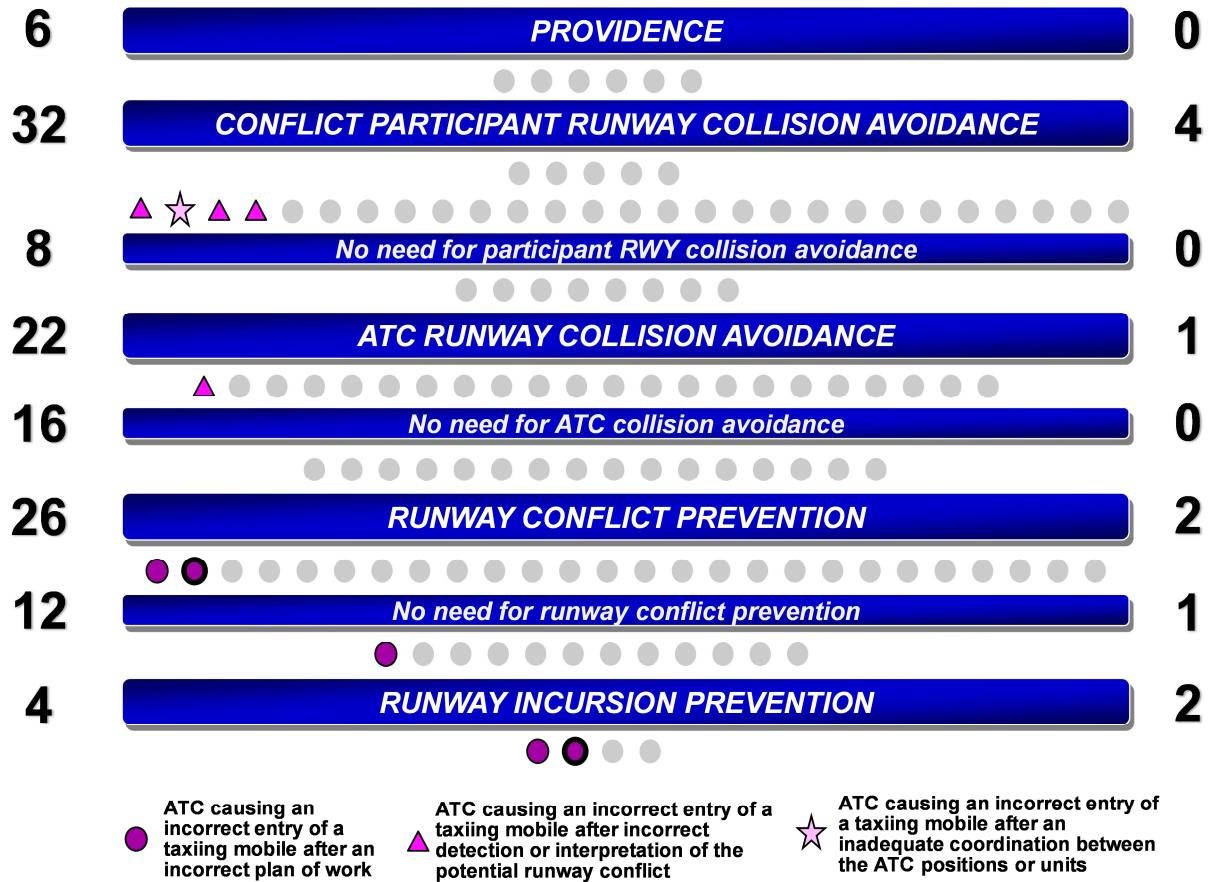


Figure 23:
ATC causing incorrect presence of a taxiing mobile – barriers' resilience

The number shown to the left of a barrier bar identifies the total number of incidents stopped by that barrier. The number shown to the right of a barrier bar identifies the number of incidents initiated by incorrect presence of a taxiing mobile caused by ATC and stopped by that barrier.

5. PERFORMANCE OF THE RUNWAY CONFLICT PREVENTION BASIC BARRIER

5.1 Runway incursions that turned into runway conflicts

The second basic safety barrier 'Runway Conflict Prevention' was challenged 122 times, prevented the runway conflict in 38 of these events (31 % efficiency) and failed 84 times (69% failure rate). In 65 of the cases when the barrier failed the clearance for the intended RWY use has already been given prior to the incorrect entry into the RWY protected area and there was no opportunity for ATC to prevent it.

ATCO conflict prevention barrier was challenged 32 times. When challenged (runway incursion leading to potential conflict), it worked once and failed 31 times. In 18 out of the 31 cases when conflict prevention by the ATCO failed the other conflict participants also failed to identify and prevent the runway conflict.

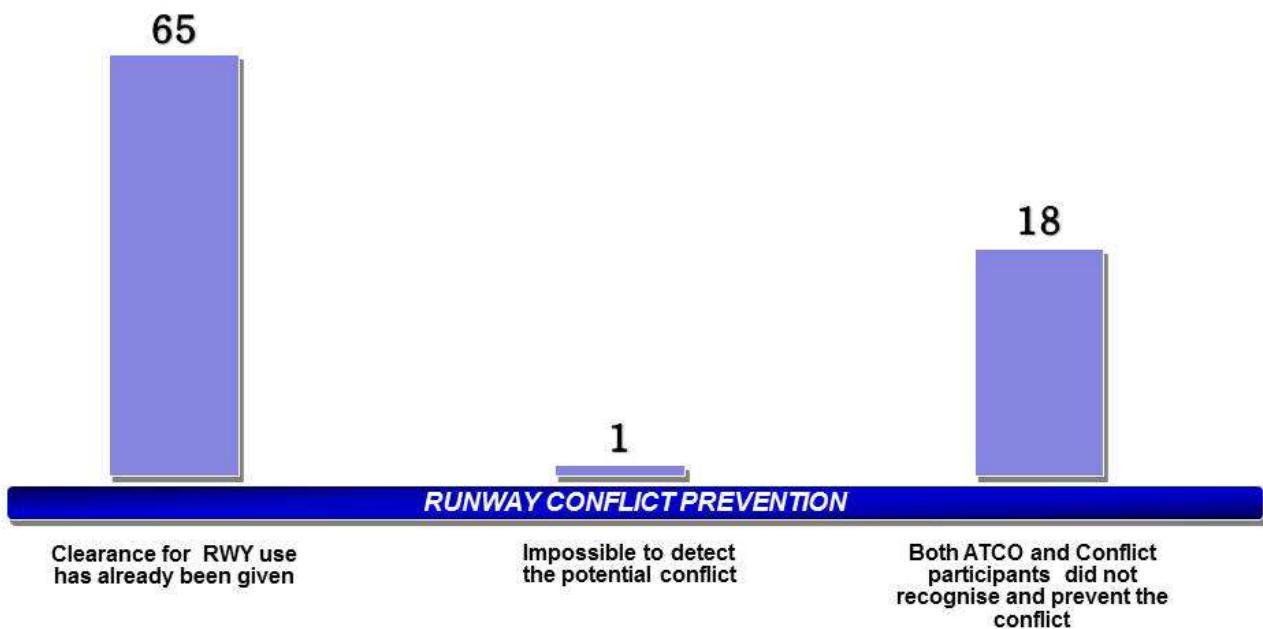


Figure 24: Runway incursions that turned into runway conflicts - causes

5.2 Initiators of scenarios involving clearance for RWY use already given

The “zoom” into the 65 events that involved clearance for RWY use already given (to the other conflicting mobile) shows that the distribution of the initiators in the overall sample of runway incursion events (shown on Figure 7, section 2.2) is very similar to the distribution of the initiators of the runway incursion events that occurred when runway use clearance was already issued to other mobile.

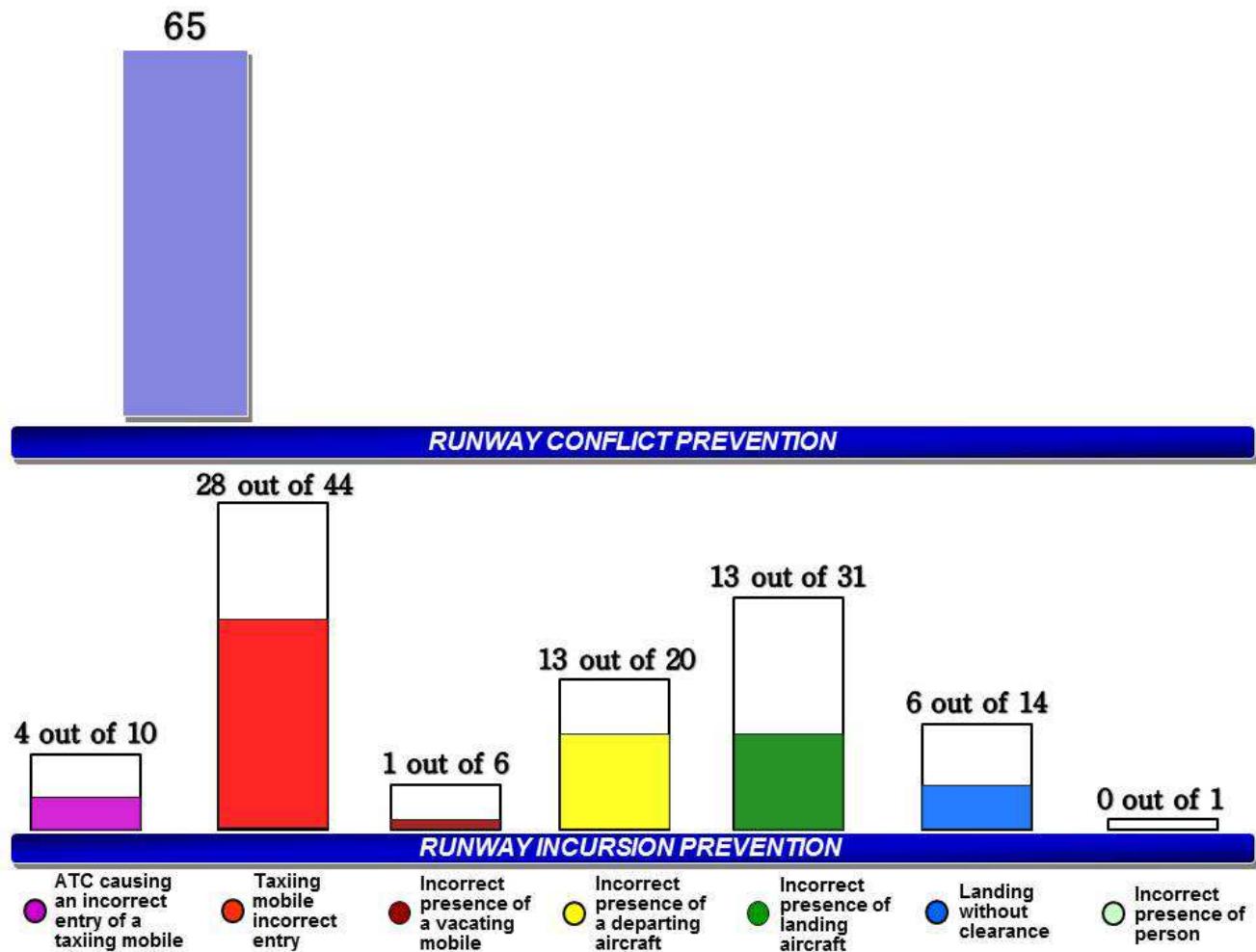


Figure 25:
Initiators of scenarios involving ‘clearance for RWY use already given’

5.3 Initiators of scenarios involving ATCO not recognising and preventing the conflict

ATCO conflict prevention barrier was challenged 32 times. When challenged (runway incursion leading to potential conflict), it worked once and failed 31 times.

Same initiators can be seen as in the scenarios when runway use clearance was already issued to another mobile.

It should be noted that the performance of the 'ATCO barrier' in runway conflict prevention is rather weak when the initiating factor is a vacating mobile. This may be explained with the limited opportunities for visual acquisition of vehicles due to the combination of environmental factors such as vehicle size, colour, distance from ATC tower, obstructed line of sight, etc.

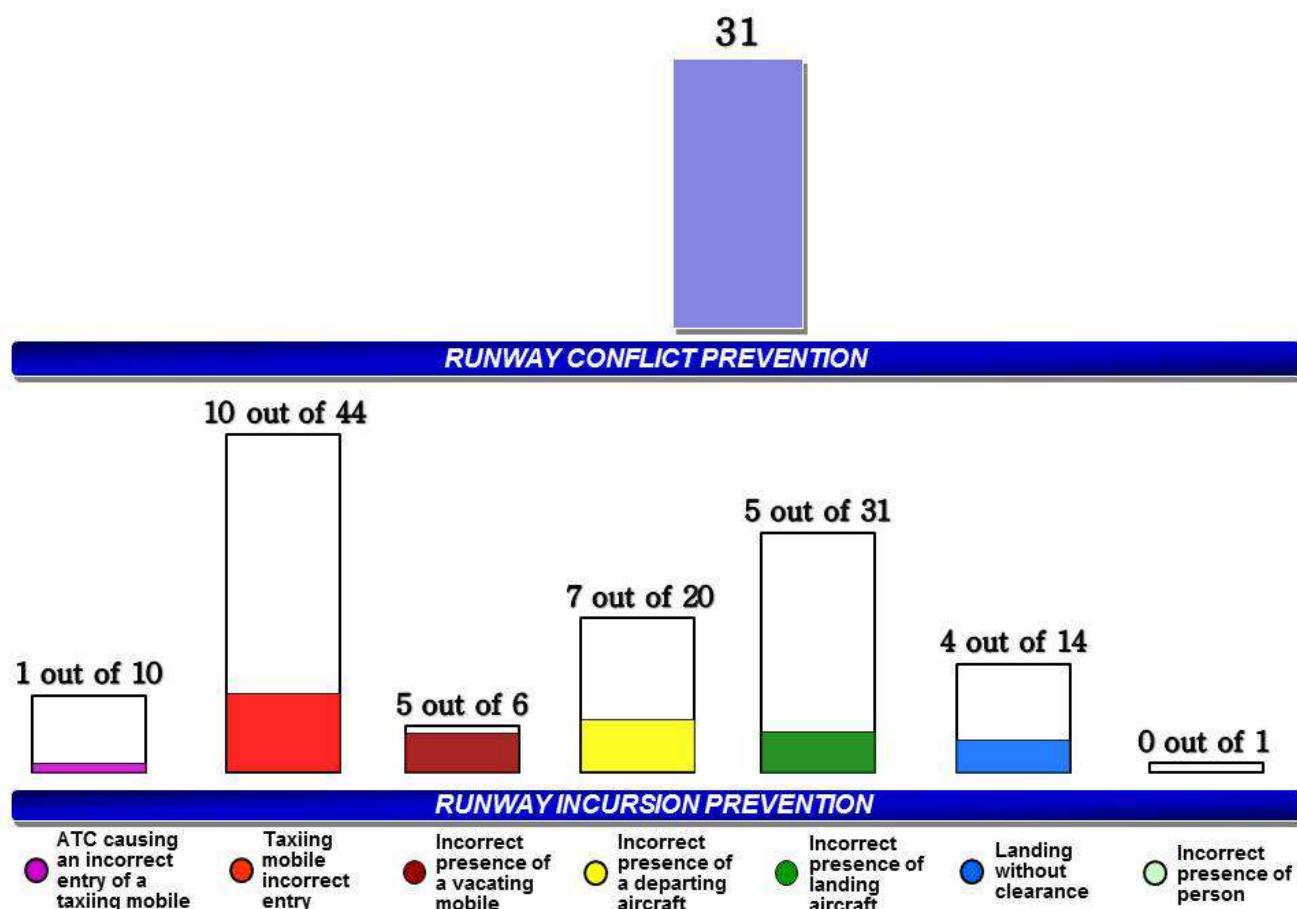


Figure 26:

Initiators of scenarios involving 'ATCO not recognising and preventing the conflict'

6. PERFORMANCE OF THE ATC RUNWAY COLLISION AVOIDANCE BASIC BARRIER

6.1 Conflicts not resolved by ATC runway collision avoidance

It should be noted that in the majority of cases when the ATC runway collision avoidance barrier failed to stop the events (67%), ATCO did not detect or did not interpret correctly the runway conflict. In order to improve the overall performance of this barrier means and measures to improve conflict detection by ATCO could be considered.

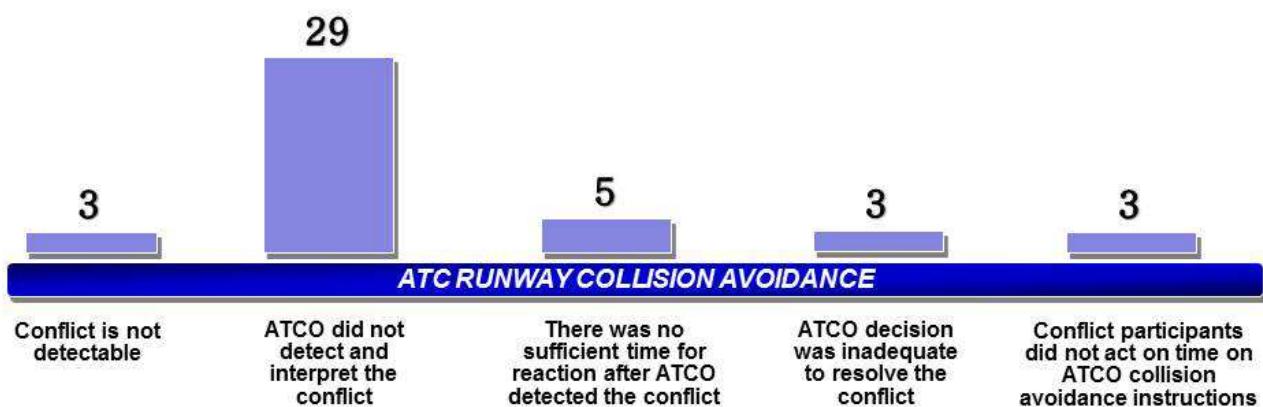


Figure 27:
Runway conflicts not resolved by ATC runway collision avoidance - causes

6.2 Initiators of scenarios involving inadequate conflict detection and interpretation by ATCO

All types of initiators (except unauthorised presence of person on the RWY protected area) contribute to the scenarios whereupon ATCO failed to detect and/or interpret correctly the runway conflict. The majority of the scenarios are linked to 2 initiators: incorrect entry of a taxiing mobile into, and incorrect presence of departing aircraft on, the RWY protected area.

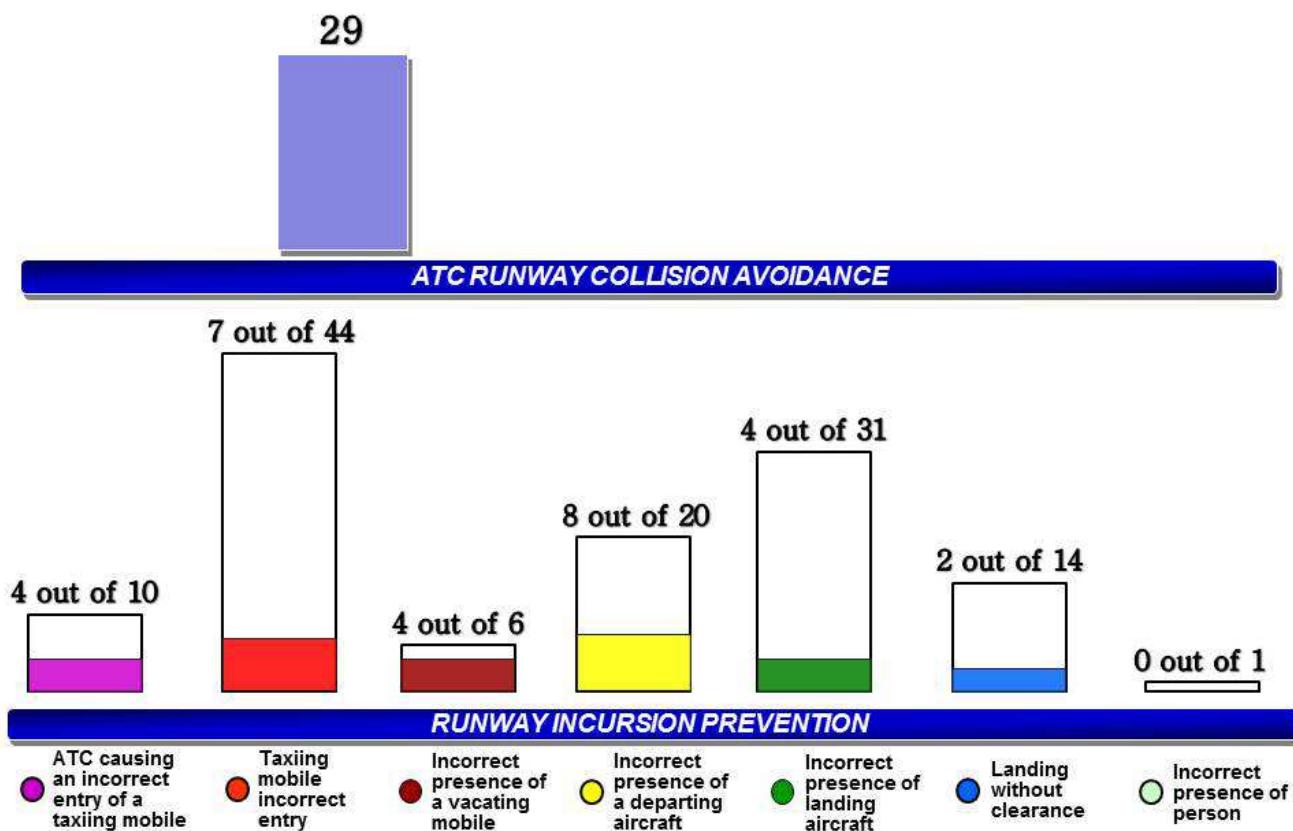


Figure 28:

Initiators of scenarios involving inadequate conflict detection and interpretation by ATCO