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Conflict Alerts in A-SMGCS

Different point of view on evaluating the conflict alert function

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Abstract—***This article focuses on issues regarding safety nets within A-SMGCS. A different point of view on evaluating the conflict alert function is presented. The given function is studied within the environment of continuation training of Air Traffic Controllers (ATCO) on 3D Tower simulator. During the exercises, the ATCOs are subjected to RWY incursion situations. The outcome is the proposal of methodology to be used to evaluate the performance of conflict alert function as well as the results of the evaluation itself. Conclusions regarding timing of alerts and performance of the conflict alert function as such are issued at the end.***

Keywords-Safety nets, A-SMGCS, RIMCAS, alert, LKPR, NOVA 9000, conflict, RWY incursion, TWR

I. Introduction

A significant number of accidents (including the fatal ones) related to runway (RWY) incursion occurred throughout the history of civil aviation. The possibility of conflict situation in the vicinity airports or directly on the movement area increases due to traffic growth, related airport capacity growth issues, increased layout complexity, Low Visibility Operations(LVO) and other factors.

Advanced Surface Movement Guidance and Control System (A-SMGCS) is one of the solutions to answer those problems. A-SMGCS is not only a tool intended to support the provision of aerodrome air traffic control; it is also a complex system with new functions enabling capacity increase even in low visibility conditions without compromising safety of the airport operations.

In this article, the focus is put on a safety net provided by A-SMGCS, the conflict alert function. It monitors aerodrome traffic primarily in areas associated to RWYs. The goal of this function is to detect conflict situations, mainly possible RWY incursions. Once a conflict situation is detected, the system provides audible and graphical alerts to the ATCOs to notify them about the unfolding events.

The objective of this study is to determine whether the conflict alerts are generated early enough to give the ATCO enough time to successfully solve the conflict situation. Overall, the performance of the conflict alert function is studied with focus on timing of alerts issued in reaction to a RWY incursion.

II. A-SMGCS

Procedures based on “see and be seen” principle have become inadequate to handle the growing demand (mainly during LVO) safely. As a result, a new concept was developed and implemented: the A-SMGCS. It is designed to benefit from the use of technology and automation and offers enhanced capacity and increased safety regardless of metrological conditions. [1]

There are four primary functions of the A-SMGCS [1]:

- Surveillance function
- Routing function
- Guidance function
- Control function

And four implementation levels of the A-SMGCS exist:

- Level 1 (Improved surveillance)
- Level 2 (Surveillance + Safety Nets)
- Level 3 (Conflict detection)
- Level 4 (Conflict resolution, Automatic planning and guidance)

III. Current Situation on Site

A. A-SMGCS at Praha Ruzyně airport

The research is performed on Park Air Systems NOVA 9000 A-SMCGS installed at Praha Ruzyně airport (LKPR); a system used by the Air Navigation Services of the Czech Republic (ANS CR). It is a Level 2 system with the safety nets implemented and used operationally. [2]

B. Controller Working Position

The output of the A-SMGCS is shown on Controller Working Position (CWP) which is the HMI for the ATCO. Targets with identification are superimposed on a 2D airport map. Through the CWP several tools and other functions are accessible.

C. RIMCAS

Runway Incursion Monitoring and Conflict Alert Subsystem (RIMCAS) is a NOVA 9000 subsystem responsible for detecting the conflicts on movement area and in the airspace in the vicinity of the airport.

1) Alert calculation

The algorithm uses geographically defined conflict alert areas and a set of configurable parameters. Several types of conflict alert areas exist. For purpose of this study, only two types are crucial: Arrival Area and Departure Area. Those areas comprise the RWY and encompassing area.

2) Alert levels

Alert is displayed in a graphical form on the CWP. There are two alert levels: Stage 1 (yellow) and Stage 2 (red). [3] Stage 1 is intended as a caution to a certain situation and Stage 2 as a warning prior to a critical situation. Figure 1 below shows Stage 2 alert displayed on the CWP.

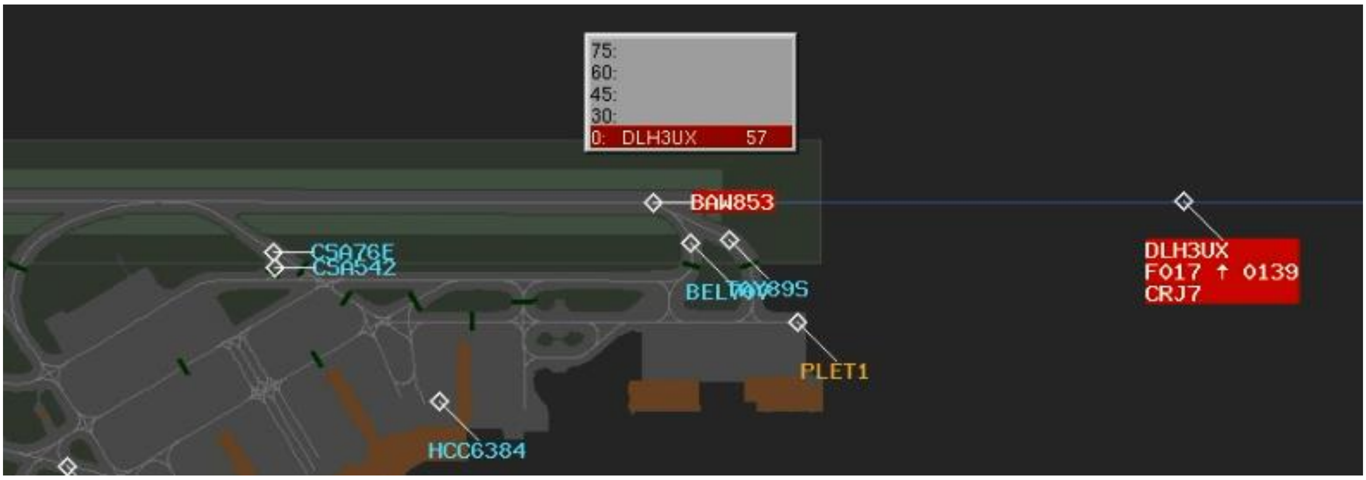

Figure 1. Alert stage 2 presented on CWP

3) Monitoring of Approaching/Landing Aircraft

The key parameters for calculation of alerts for arrivals are:

- *Time-to-Threshold (TTT) limit*
- *Closest Point of Approach (CPA) limit*
- *Time to Closest Point of Approach (TCPA) limit*

In fact, an alert is issued once the aircraft is on final approach, another target is in or enters the conflict alert area and the limits mentioned above are breached. After the aircraft reaches the threshold, the TTT is not applicable and only a part of the conflict area ahead of the aircraft is searched for intrusion. The limits differ for stage 1 or stage 2 alerts. During LVO, TCPA and CPA calculations are not used

4) Monitoring of Departing Aircraft

Alert stage 1 is issued once there are two and more targets in the departure conflict area. Once the lead target moves faster than *Stage 1 speed limit,* the alert is suppressed.

If a target on departure moves faster than *Stage ½ speed sel* only a part of departure conflict alert area in front of the aircraft is searched for intruders. Stage 2 alert is raised once the intruder is detected. There is an exception for targets accelerating away – the *TCPA* value is negative. During LVO, TCPA check is not preformed.

D. Current approach to evaluation of the conflict alert function

Currently, the conflict alert function of the A-SMGCS at LKPR is evaluated after a report of an ATCO or after a log analysis. It is the analysis of alerts already issued done in order to retrospectively determine whether the alert should have been generated or not in each particular situation. Then alerts are classified as follows: nuisance, false or correct (needed).

IV. DIFFERENT POINT OF VIEW ON EVALUATING THE CONFLICT ALERT FUNCTION

This article brings a different approach to evaluating the conflict alert function. The response of the function to simulated RWY incursion situation is studied within continuation training of TWR ATCOs on a 3D TWR simulator. The study evaluates timing of alerts and whether they were useful and the conflict situation has been successfully solved.

A. Continuation Training

Continuation training for ATCOs of TWR Praha took place at 3D TWR simulator in the premises of ANS CR. The simulator is configured in the same way as the real TWR Praha and features the same systems.

The traffic is simulated by pseudopilots (PP) who command and control all mobiles in the training exercises according to the procedures and exercise scenario. The PPs are responsible for communication with the ATCOs as well. Each day of the training concerned 4 ATCOs who performed 4 exercise runs interchanging the roles.

B. The Methodology

The following methodology is proposed:

- Design a RWY incursion situation

- Implement the situation to the ATCO training exercise on 3D TWR simulator
- Set up recording and select data sources
- Collect data during the exercise runs
- Evaluate the conflict alert function

C. *Modelling the RWY incursion situation*

After an analysis of the traffic at LKPR, twelve different incursion situations were initially proposed. It was decided to implement two of them into the training exercises.

In exercise EMG_1, there is a conflict situation between arrival and departure traffic on RWY 24. When Aircraft 1 (DLH3UX) is 1.5NM from the threshold, Aircraft 2 infringes the clearance, overruns CAT I holding point (HP) at TWY A and enters RWY 24. There are multiple aircraft waiting at HPs on TWY Z, A and B.

In exercise EMG_2, a conflict is modelled between a departing aircraft (CSA9301) from RWY 12 and a vehicle (GAMMA1) crossing RWY12/30 without clearance.

Figure 4 at the end of the article shows ICAO Aerodrome chart with highlighted RWY 24 and TWYs A and B.

Details about the conflict situations are described in the supporting documentation for the exercises, e.g. instructor log, log for PP. Before the training, the timing of events in the exercises was verified in dry-runs.

V. DATA GATHERING AND ANALYSIS

A. *Preparation*

First, it was necessary to determine how a general conflict situation evolves in time, what are the main events, how to track them, which data to collect, what could be the data sources. Figure 2 below shows a general conflict situation.

The reaction time of the system to the infringement of the clearance can be measured (*System reaction*).

The conflict situation needs a certain time window for solving. This time period (*Time to solve the conflict*) is measured from the time the alert was issued by the system. This time period includes the reaction time of the controller (ATCO reaction), duration of the ATCO's RTF transmission, the reaction time of the crew and possibly a part of read back from the crew. The conflict situation ends when the trend of movement of the aircraft changes (Change in trend of movement, e.g. in case of a go-around, when the aircraft starts to climb).

From the log of the system a calculated value of *Time to Closest Point of Approach* can be obtained. This value calculated at the time when the alert was issued provides the maximum time space during which the conflict needs to be solved. However, to make sure there is enough time to solve the conflict a *Buffer* must be added as a safety margin.

Conflict alert is generated on time if:

$$Time\ to\ Closest\ Point\ of\ Approach \geq Time\ to\ solve\ the\ conflict + Buffer$$

The conflict situation is not fully described just by the values mentioned above. For the analysis of the conflict situation further data must be gathered and processed, e.g. call signs, sequence of the alerts issued, calculated values and defined parameters, phraseology and opinions of the ATCOs.

B. *Data Sources*

1) *Audio*

The 3D simulator platform is equipped with a Voice Communications System (VCS) which enables recording of the RTF communication in internal format and export to *.wav for further processing.

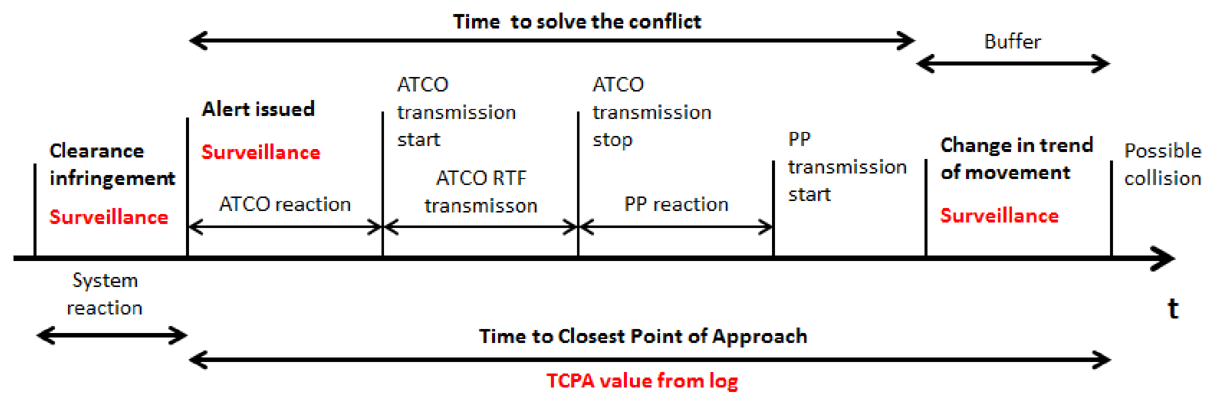

Figure 2. General conflict situation evolving in time

During the process of the conflict situation several key events happen. The conflict starts when the clearance issued by the ATCO is infringed (*Clearance infringement*). Moments later, the system reacts and issues a conflict alert (*Alert issued*).

2) *Video*

No tool to remotely record the video of the A-SMGCS CWP was available on site. It was necessary to develop a new solution in order to get the needed data. A dedicated workstation was created at first.

VNC freeware was used to remotely access and control one CWP and CamStudio Recorder freeware provided a tool to record the video output. Thus, video files in *.avi format are available for further analysis.

3) Log

The system provides a log file about conflict alerts generated by the RIMCAS.

4) Questionnaire

A simple questionnaire was designed and distributed to capture the opinions and comments of the ATCOs about the conflict alert function.

C. Audiovisual file creation

For each exercise, an audiovisual file was created using video editing software enabling combining the audio and video tracks. The necessary data were then extracted from this file during multiple replay sessions using Media Player Classic. The software enabled a frame by frames replay so the accuracy is limited only by the system time precision of 1 second.

VI. EVALUATION

Microsoft Excel spreadsheets were used for data entry and evaluation. The first spreadsheet was created to evaluate the conflict situations, every exercise had a dedicated line, and the columns defined the values. The second spreadsheet was used to evaluate data from the questionnaire and to derive charts.

A. The conflict situation dynamics

Even though just one specific RWY incursion was implemented in each exercise, the geometry of the conflict differed from run to run due to:

- Different manners of control applied by ATCOs
- PP wanted to keep the situation regardless the dynamics of the exercise
- The instructors changed some aspects ad-hoc

In EMG_1 following sub scenarios happened:

- The aircraft in conflict entered the RWY from HP on TWY A
- The aircraft in conflict entered the RWY from HP on TWY B

In EMG_2 following sub scenarios happened:

- The aircraft in conflict started the take-off run using full length of the RWY
- The aircraft in conflict started the take-off run from intersection F
- The aircraft in conflict started the take-off run from intersection G

Those differences in geometry of the conflicts prevent exact comparison of the system behaviour and personnel behaviour with respect to given exercise scenario. On the other hand, the system behaviour on multiple sub-types of conflict could be studied.

B. Main values

1) Sequence of alerts issued

This value tracks which type of alert was generated and how the sequence looked like. See Table I below.

TABLE I. SEQUENCE OF ALLERTS ISSUED IN RELATION TO THE EXERCISE SCENARIO

EMG_1	**8**
RWY entered from HP on TWY A	**6**
stage_1 stage_2 end	6
RWY entered from HP on TWY B	**2**
stage_2 end	2
EMG_2	**7**
Take-off run using full length of the RWY	**1**
stage_1 stage_2 stage_1 end	1
Take-off run from intersection F	**1**
stage_1 end	1
Take-off run from intersection G	**5**
stage_1 stage_2 end	1
stage_1 stage_2 stage_1 end	1
stage_2 end	3
Sum	**15**

2) Ability of PP to fulfill ATCO's instruction to avoid conflict

In EMG_1 the crew (PP) was able to perform the requested go-around in 8 out of 8 cases. In EMG_2, in 2 out of 7 cases, the crew was not able to cancel the take-off according to the instruction. However, no collision has happened throughout the evaluation. The distance between the conflicting traffic was adequate in all cases.

3) System Reaction

Mean system reaction time to clearance infringement is shown in Table II below.

TABLE II. SYSTEM REACTION TIME

	Mean value
EMG_1	**0:00:05**
RWY entered from HP on TWY A	0:00:04
RWY entered from HP on TWY B	0:00:10
EMG_2	**0:00:03**
Take-off run using full length of the RWY	0:00:04
Take-off run from intersection F	0:00:03
Take-off run from intersection G	0:00:02
Mean value	**0:00:05**

4) Time to solve conflict

It was only possible to obtain the exact data about the change in trend of movement of the aircraft in EMG_1 in case of RWY incursion from TWY A.

Values for TWY B are not precise due to the source. Table III below shows mean value for time to solve the conflict.

TABLE III. TIME TO SOLVE THE CONFLICT

	Mean value
RWY entered from HP on TWY A	0:00:15
RWY entered from HP on TWY B	0:00:20
Mean value	**0:00:16**

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5) Height of the aircraft at the time when the alert disappears

Information about the height of the aircraft once the alert ceased to be displayed is available from the log. The values are considered adequate..

6) Time to Closest point of Aproach

It is a log derived value indicating the time to a possible collision at the time the alert for given conflict situation was first generated. This value was only available for the arrivals.

TABLE IV. TIME TO CLOSEST POINT OF APPROACH

	Mean value
RWY entered from HP on TWY A	0:00:31
RWY entered from HP on TWY B	0:00:37

The maximum calculated buffer values together with ATCO opinion on timing of alert generation are shown in Table V below.

TABLE V. BUFFER CALCULATION

TWY	**CPA limit 150m**	**Stage 1 TCPA limit 90 s**	**Stage 1 TTT limit 40 s**	**Stage 2 TCPA limit 50 s**	**Stage 2 TTT limit 20 s**	**Buffer [s]**	**Opinion of the ATCO**
	Time to solve conflict [s]	**Stage 1 TCPA [s]**	**Stage 1 TTT [s]**	**Stage 2 TCPA [s]**	**Stage 2 TTT [s]**		
A	14	33	33	22	20	19	On time
B	18	-	-	37	20	19	-
B	21	-	-	36	20	15	Late
A	14	24	25	19	20	10	Late
A	18	37	37	22	20	19	On time
A	16	30	30	21	20	14	On time
A	12	34	34	22	20	22	On time
A	15	29	29	021	20	14	On time

The buffer ranges from 10 to 22 seconds. For RWY incursion from TWY A, an alert providing 10 seconds buffer is regarded as issued too late, alert with 14 second buffer is considered as on time.

For RWY incursion from TWY B it must be noted that alert stage 2 is issued straight-away. For this alert TCPA value is higher than the one in case of TWY A but the aircraft is just 20 seconds from the threshold this time (TTT).

Another conclusion is that alert stage 2 for the arrivals is for both types of RWY incursion situation generated once the aircraft is 20 seconds from threshold.

7) Other information about the conflict situation

a) ATCO transmission

Length and content of ATCO transmissions was further analyzed.

b) PP reaction time

c) ATCO reaction time

Reaction times of the ATCO were intended to be measured but due to problems with synchronization of audio and video tracks (VCS exported randomly compressed audio tracks) it was not possible to achieve acceptable level of accuracy.

C. Values from the questionnaire

The questionnaire provides following output. First, it was found out by which means the ATCOs noticed the conflict situation. See Figure 3 below.

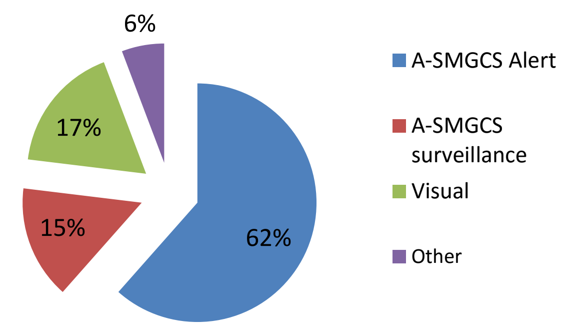

Figure 3. Means of notifitation of the conflict situation

The ATCOs also provide subjective information about the timing of alerts which was used in the analysis. Even though all conflict situations were successfully solved, the ATCOs reported that 15% of the alerts did not provide enough time to solve the situation. Moreover, 19% of the alerts were reported to be generated late.

Roughly 65% of the ATCOs rated the performance of conflict alert function above average (rating 4/5 or 5/5), 23% as average (rating 3/5) and 11% below average (rating 1/5 or 2/5). 67% of the ATCOs would appreciate an audible alarm to sound once alert stage 2 arises.

VII. CONCLUSION

In total, 15 exercises of TWR ATCO continuation training on a 3D TWR simulator were analyzed. A conflict situation in form of RWY incursions were implemented in the exercises.

The data were gathered from video recording of A-SMGCS CWP, a recording of ATCO and PP RTF communication and a RIMCAS log. 26 ATCO provided their point of view on the conflict alert function through a questionnaire. Following findings are issued:

Above all, no collisions occurred during the exercises. Together with the fact that the ATCOs were notified about the conflict situation mainly by an A-SMGCS alert, it is possible to say that the conflict alert function is a preventive measure to avoid the impact of RWY incursions.

Monitoring of Approaching Aircraft

In this case, the crew was able to act as instructed by the ATCO in all cases. The analysis of measured data proved the correct timing of alert generation for RWY incursions from the TWY A.

Alert stage 1 is issued followed by alert stage 2; the alerts fulfil the preventive aspect and they offer enough time to solve the conflict.

Only 2 RWY incursions from TWY B were observed. In this case alert stage 2 is generated about 36 seconds prior to a possible collision but the aircraft on final approach is only 20 seconds from the threshold. Moreover the ATCOs reported the alert is issued too late. It would be vital to consider increasing the value of stage 2 TTT limit parameter.

Furthermore, stage 2 alerts were generated every time when the aircraft on final approach was 20 seconds from the RWY threshold. All other limits for stage 2 alert have been already breached at that time.

Monitoring of Departing Aircraft

In this case, 2 times out of 7, the crew was not able to act as instructed by the ATCO, the aircraft continued rolling and took off passing the obstacle on the RWY at an adequate distance.

The RIMCAS log does not contain any information about the limits breached to issue an alert (e.g. TPCA and CPA). Logged value of *Stage 1/2 speed selector* does not provide enough information for full conflict analysis. Even though, for departures, the conflict alert function provides important notification to the ATCO; the alerts were issued once the mobile breached the departure alert area.

Preventive role of the A-SMGCS conflict alert function has been verified despite several issues with access to necessary data and limits of the measurement technology.

For a full analysis of the conflict alert function a more sophisticated tool to record behaviour of the system needs to be implemented on site. Also, 100% synchronization of audio and video recording would be necessary.

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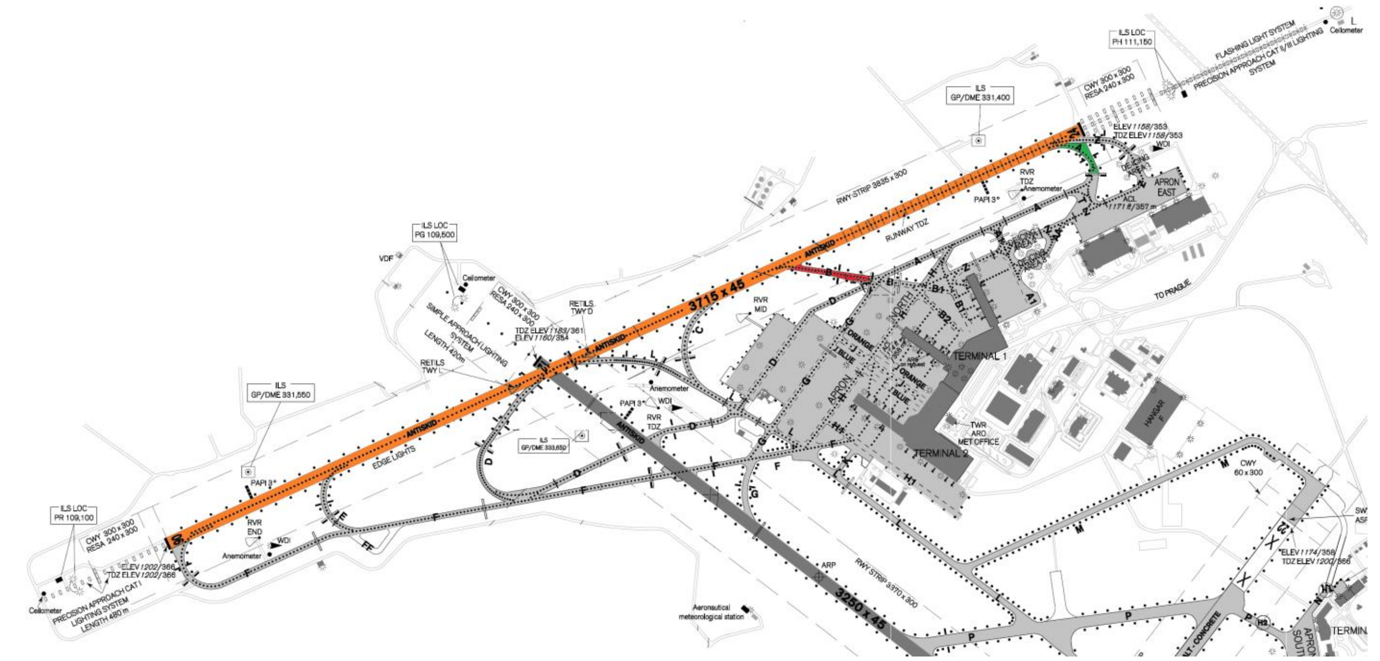

Figure 4. Part of ICAO Aerodrome chart of LKPR showing RWY 24 in orange, TWY B in red and TWY A in green [5]