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A Ranking Method to Prioritize VFR Airports to be Provided Instrument Approach Procedures

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The primary purpose of this work is to investigate the necessity of a more comprehensive and systematic method to prioritize airports to be provided with instrument approaches and landing procedures in the Brazilian air transportation landscape. First, an overview of the main contributors to risks associated with the approach and landing phases is provided, covering the most critical aspects of unstable approaches and controlled flight into terrain (CFIT) events. Second, considering the emergence of Terrain Awareness and Alerting Systems (TAWS), the role of its contribution to safety is discussed and the certification context related to the design, installation, and operation of those systems. A ranking method is developed based on the analysis of TAWS alert events in several Brazilian airports. The technique results in a ranking list of airports eligible for instrument procedures and points to objective means to improve safety, accessibility, and efficiency on the flight operations to those locations.

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Introduction

Several airports across Brazil, including those operated by regional and leading commercial airlines, are not certificated to operate Instrument Flight Rules (IFR). These airports run with only visual approach procedures or instrument approach procedures to a point in the airspace where the approach continues under visual meteorological conditions (VMC). That is a substantial concern for the growth of regional and commercial air transport. Weather conditions increased approach, and landing minimums in altitude and required ceiling, causing flight cancellations and diversions to alternate airports to influence accessibility to those airports.

Table 1
Frequent Contributing Factors for Flight Cancellations in Top 15 VFR-only Airports, per traffic volume (2016 – 2019).

Contributing Factors	Percentage
Adverse weather	79 %
Airport infrastructure	2 %
The airline, Aircraft maintenance	13 %
Airline, Operations	5 %
Other	1 %

Note: Adapted from (ANAC, 2020).

Adverse weather has accounted for the contributing factor of 79 % of total flight cancellations in high traffic volume visual flight rule (VFR) only airports, as illustrated in Table 1.

The Commercial Aviation Safety Team (CAST) is an industry-wide multidisciplinary, international working group encompassing airlines, manufacturers, labor, and government institutions to develop and implement comprehensive safety enhancement plans. According to CAST, as visual approaches have been commonly associated with a higher number of unstable approaches and potentially higher ground proximity warning alerts, safety concerns must always be addressed (CAST, 2018).

Unstable approaches have been notably present in most safety events associated with approach and landing phases (IATA, 2020). Furthermore, the highly irregular approach event rate observed in the first months of 2020 has been connected with the overall flight downturn effects triggered by the covid-19 pandemic. The drops in operations, followed by a slow recovery, may have impacted the flight crew's proficiency (IATA, 2020).

IATA's Flight Data eXchange (FDX), from the Global Aviation Data Management (GADM) program, similarly describes the most significant contributing factors to unstable approaches. Airspeed, thrust, and ground proximity warning systems (GPWS) are the most relevant to maintaining stable methods, including a constant descent flight path angle (IATA, 2020).

Also, IATA (2017) significantly correlated unstable approaches with safety events as the following:

- Hard landing;
- Runway excursion;
- Short landing;
- Loss of Control In-Flight (LOC-I);
- Controlled Flight Into Terrain (CFIT).

The International Civil Aviation Organization (ICAO) also has identified high-risk accident categories as safety priorities in its latest edition of the Global Aviation Safety Plan (GASP) (ICAO, 2019): runway safety-related events, LOC_I, and CFIT. CFIT events have been a significant historical component of accidents in the 1960s. Conversely, technological milestones achieved during the 1980s with the development of aircraft glass cockpit, satellite-based navigation systems, procedures, and warning systems have contributed to reducing CFIT accident rates, becoming a significant risk mitigation factor (ICAO, 2019).

Problem Statement

The Brazilian airspace management is under the Brazilian Air Force Department of Airspace Control (DECEA). The Institute of Aeronautical Cartography (ICA) handles the analysis, development, and certification of visual and instrument navigation flight procedures, with departure, approach, and landing (Brasil, 2010). There is a long-term perspective of growth in air traffic in Brazil, associated with the increasing quantity of airports planned to be operated by companies under RBAC 121 and RBAC 135 (*Regulamento Brasileiro de Aviação Civil*, Brazilian operational regulations, like the United States Code of Federal Regulations Part 121 and Part 135, respectively).

Thus, that scenario suggests an increase in the demand for the development of instrument approach procedures for VFR-only airports, providing equivalent levels of safety associated with the approach and landing operations and higher operational efficiency levels. Table 2 lists regional airports in Brazil with relevant commercial traffic volume and their current operations certification status.

Table 2
Regional Airports with Relevant Traffic Volume.

IATA / ICAO Code	Condition
GVR / SBGV	IFR
OPS / SBSI	IFR
TXF / SNTF	VFR
JPR / SBJI	VFR
PGZ / SBPG	IFR
OAL / SSKW	VFR
TJL / SBTG	VFR
BYO / SBDB	IFR
ROO / SBRD	IFR
LEC / SBLE	VFR
VAL / SNVB	VFR
DIQ / SNDV	VFR
FEC / SBFE	VFR
BRA / SNBR	VFR
PAV / SBUF	VFR
PIN / SWPI	VFR
RVD / SWLC	VFR

Note. Adapted from (DECEA, 2020).

This research highlights the need for a ranking method to implement the IFR approach and landing procedures, mitigating risks associated with unstable approaches on VFR-only airports. This research is the condensed version of a thesis (Leão, et. al, 2021).

The development process of instrument procedures is a complicated and time-consuming undertaking (Ashford, 2013). It requires detailed analyses of the topographic characteristics of the airport's regions, the estimation of aircraft flight path within regulation-based terrain separation criteria, aircraft flight performance simulations, and flight tests to provide adequate compliance with certification regulation (Bezerra & Gomes, 2016).

Therefore, adequate prioritization of those airports is a critical aspect to the safe and efficient development of Brazilian air transportation and is an essential topic in discussions held with significant stakeholders, including airline companies, airport authorities, and DECEA, in industry-level forums as the BCAST (Brazilian Commercial Aviation Safety Team), and the Brazilian Chapter of CAST (BCAST, 2019).

Several new potential flight network expansion VFR-only airports have observed flight diversions and cancellations, unstable approaches, and alert terrain proximity. Therefore, the research question to be addressed is: What prioritization methods could be proposed and applied to effectively contribute to ranking current VFR-only airports to be provided with instrument approach procedures, including non-precision, RNAV approach procedures, for instance?

As expected, TAWS events during take-off and climb are commonly rare. Therefore, applying the Index criteria refines the rank of airports to be further analyzed by DECEA and ICA as its institute in charge of developing and implementing navigation procedures. Once the guidelines are designed and certified, accessibility to those airports is expected to increase over time, with significant improvements on operations' efficiency and reduced costs to airlines associated with fewer flight cancellations and diversions to alternate airports due to adverse meteorologic conditions. Also, a decrease in unstable approach events and ground proximity alerts is expected. As a result, they contribute to higher safety levels in operations to those airports (Ziółkowski & Skłodowski, 2018). The proposed approach contains an analysis of Terrain Awareness and Warning Systems (TAWS), or Ground Proximity Warning Systems (GPWS) alerts as possible adequate metrics. The study of TAWS alerts data related to landing procedures is provided by airlines, collected in local industry committees, as the Brazilian Commercial Aviation Safety Team (BCAST). Combined with current, historical, and forecast traffic volume information over regional, VFR-only airports, a set of indicators and a ranking methodology are proposed to determine high-priority airports to receive instrument procedures.

TAWS and GPWS alerts

The Terrain Awareness and Warning System (TAWS) is a generic term that describes an alerting system designed to provide information to the flight crew to detect a potentially hazardous terrain proximity situation and avoid a CFIT accident (FAA, 2000). The primary function of the TAWS system is gathering and processing data on flight parameters of an aircraft to create alerts to preclude catastrophic air accidents. Tooley and Wyatt in Ref. (12, chapter 17) offer a brief but at the same time very explanatory explanation of TAWS system operation, its underlying principles, and capabilities.

Specific systems currently in use include the GPWS and the Enhanced Ground Proximity Warning System (EGPWS) (Administration, 2017; FAA, 2000). In addition, TAWS design, installation, and operation requirements are covered by several regulations applicable to avionics manufacturers to which TSO-C151c is applicable (FAA, 2012), Operating under Title 14 of the Code of Federal Regulations (14 CFR) Parts 91,121, 125, and 135. The operations specifications (OpSpecs), standard operating procedures (SOPs), and other FAA-approved documents. Brazilian regulations also address manufacturers and operators in a similar context for Brazil's cases (ANAC, 2005).

CFIT fatal and non-fatal accidents

In IATA (2018), CFIT accidents have accounted for 6 % of total accidents in commercial aviation between 2008 and 2017. Although CFIT accidents have shown fewer absolute numbers in the past decades, the outcomes are almost catastrophic and involve fatalities to passengers or flight crews (IATA, 2018). As a result, IATA and industry representatives have assessed CFIT as one of the highest priority topics for safety intervention in the face of fatality risk.

Several contributing factors may occur individually and more frequently in combination to result in CFIT accidents. The analysis and assignment of contributing factors, classified as latent conditions, environmental, and airline threats, may help foresee the problem from a broader perspective and develop risk mitigation strategies. Table 3 lists some significant contributing factors related to CFIT accidents.

Table 3
Frequent Contributing Factors for CFIT (2008 – 2017).

Latent Conditions	**Percentage**
Regulatory oversight	72 %
Technology and equipment	54 %
Safety management	46 %
Flight operations	31 %
Environmental Threats	**Percentage**
Meteorology	51 %
Navigation aids	51 %
Ground-based navigation aid malfunction or not available	49 %
Poor visibility, IMC	46 %
The undesired Aircraft States	**Percentage**
Flight towards terrain	56 %
Vertical, Lateral, Speed Deviation	49 %
Unnecessary weather penetration	18 %
Unstable approach	10 %
Continued landing after an unstable approach	5 %

Note: Adapted from "IATA Controlled Flight Into Terrain Accident Analysis Report," 2018, p. 22. Copyright by International Air Transport Association.

A CFIT event definition is in its nature associated with descent scenarios, as approach, final approach, and landing. Even though unfavorable or adverse meteorological conditions may be present during a given flight's approach and landing phases, there is no indication (nor is it necessary to) that the same prevailing conditions existed during the previous flight phases. Poor visibility, deteriorating meteorological conditions, or accidental entrance into IMC may impair the pilot's ability to maintain adequate orientation and control of the aircraft flight path during the visual traffic pattern in a VFR procedure. It is crucial to interpret the taxonomy outlined in Table 3, considering that the contributing factors do not occur in isolation.

The overall contributing factors indicated as latent conditions and environmental threats, in the form of low visibility, IMC, and lack of visual references, point to the need to implement instrument, precision approach procedures, or Performance-Based Navigation (PBN) approaches as an essential method to reduce the risk of CFIT accidents (Ashford, 2013). ICAO sets out VFR minimum for the various classes of airspace, which countries, by and large, have adopted with some slight variations to suit their circumstances (Ashford, 2013).

As a combination of several factors is usually the case to build up a potential CFIT event, one or more of the environmental threats, coupled with inadequate training, may contribute to inappropriate adjustments and corrections on the aircraft's flight path to an unstable approach.

Likewise, unstable approaches are also crucial components of CFIT accidents. They may influence the flight crew's attention and divert it away from the approach procedure to maintain better aircraft control in that flight phase. The most common definition of a stabilized approach, based on recommendations from ICAO and IATA's body of requirements under IATA Operational Safety Audit (IOSA) provisions, states that a safe approach requires the aircraft's flight path angle, landing gear and flaps configuration, and airspeed to be stabilized before a certain altitude threshold is reached.

Unless all the mentioned flight parameters are complied with, the approach becomes unstable and requires flight crew action. A go-around is then initiated. Therefore, evaluating airports with TAWS events history based on Flight Operations Quality Assurance (FOQA) or other means provided by air transport carriers may prove an essential metric of risks related to unstable approaches and CFIT that affect candidate airports eligible for instrument procedures.

The implementation of PBN procedures has been considered an essential means to address unstable approaches in VFR-only airports. It may prevent the need to rely solely on the visual approach procedure (Brasil, 2020). Also, adequate obstacle separation areas corresponding to IFR procedures must comply with any PBN procedure designed for a given airport, per ICAO Doc 8168 recommendations and DECEA regulations about instrument design approach procedures (DECEA, 2018; ICAO regulations, 2007).

A report published by IATA about unstable approaches also addresses the benefits of PBN procedures as an effective technological measure to reduce inconsistent practices, as PBN provides flight crews with vertical and lateral guidance from the initial descent phase to the aircraft's touchdown on the runway, with defined descent profile and adequate terrain separation (IATA, 2017).

Instrument approach procedures are essential to provide higher safety levels in the landing operations in specific locations with VFR-only airports. No vertical or lateral flight path guidance chart or navigation database is published to the flight crew (ICAO, 2019).

Moreover, cost-effectiveness can be attained by analyzing possible locations that can receive "RNAV Visual" procedures or the v-RNP (RNP APCH procedures for Visual Runways). Positive flight path guidance to the flight crew may offer safer operations than no guidance at all.

Methodology

This research involves basic and applied research, as fundamental air navigation concepts are discussed and applied to VFR-only airports' operational environments. A quantitative approach analyzes TAWS alerts and traffic volume figures (number of flight operations) into airports in the Brazilian landscape. Analyses of the significance of TAWS alert data in VFR-only and IFR airports are provided, along with the historical data of flight cancellations or diversions caused by adverse meteorological conditions. In this study, technical research procedures cover the bibliography, applicable regulations, guidance material related to the topic, and experimental methods of collecting TAWS alerts data. This approach characterizes ex-post-facto, as data and other relevant information are based on past events.

CAST recommends that the evaluation of airports with the highest risks of unstable approaches, including those certified as VRF-only, be identified with a significant history of TAWS warnings from the Flight Data Monitoring database (CAST, 2018). A preliminary analysis of airports based on TAWS alerts clusters is conducted, and data visualization software with geolocation tool (Tableau®) is used to visualize the TAWS "hotspots". Graphic visualization of the identified "hotspots" may scale the problem's scope in the Brazilian scenario. Airports' population covers the traffic volume observed in Brazil's most relevant air carriers operating under RBAC / FAR 121. Sample delimitation considers TAWS alerts events time histories. Data is collected from the air carriers' FOQA database in a 1-year timeline, from January 2019 to October 2019.

The proposed method to analyze FOQA data to capture unstable approaches is proper. It may provide precise means to break down essential flight parameters related to a "stable approach window" and the flight path along with the descent profile. The parameters include descent slope, descent rate, airspeed, thrust setting and adjustments, terrain proximity warnings, and aircraft landing gear and flap configurations.

Current data related to 2020 may not be helpful due to the worldwide reductions in commercial flight operations caused by the covid-19 pandemic, causing air carriers to reduce or temporarily cease operations in several airports significantly. Data collected contains airport identification, geographic location coordinates of TAWS alert events, the nature of TAWS alerts by type (Caution or Warning), and arrival runway designations.

The determination of VFR-only airports with a higher number of TAWS alerts associated with a traffic volume history provides a list of ranked candidates to receive instrument approach procedures. Also, TAWS alerts observed in VFR procedures into IFR airports may even rank in the candidate airports list to receive a further analysis from implementing other instrument approach and landing procedures or revising existing policies. A list of the recorded TAWS parameters that compose the database is described in Table 4. This study parameters of primary focus are the geographic coordinates of the TAWS alerts, destination airport, flight phase during which the alert is detected, and the type of landing procedure performed (VFR or IFR). Using metric criteria (Index), we can indicate the number of TAWS alerts per number of flight operations. The appropriate ranking method considers that listing the absolute numbers of TAWS for the airports in the database shall be analyzed about traffic volume for adequate prioritization of the candidate airports. As a result, a metric criterion, namely Index, indicates a rate of TAWS alert events per number of flight operations at a given airport is an adequate parameter. The Index receives a dimensionless number as a correction factor (1000) to facilitate its interpretation in order of magnitude and comparison of candidate airports illustrated in Equation 1.

$$Index = \frac{number\ of\ TAWS\ alerts}{number\ of\ flight\ operations}\ x\ 1000$$

Table 4
TAWS: description of recorded parameters.

Parameter	Description
Event Date	Date of the year
Flight Phase	Flight phase during which the alert occurred
Alert Type	Warning or Caution
Departure Airport	(ICAO Code)
Departure Runway	(ICAO Code and RWY Code)
Destination Airport	(ICAO Code)
Flight Procedure	VFR or IFR
Landing Runway	(ICAO Code and RWY Code)
Latitude	Geographic coordinate
Longitude	Geographic coordinate
Altitude (QNH)	Altitude at which the alert occurred.

Note: It is extracted from the Brazilian Commercial Safety Team (BCAST), CFIT Working Group, confidentiality and study purposes.

Outcomes

TAWS events database is provided from the three currently most relevant Brazilian air carriers, considering the number of flight operations in one year from January 1st, 2019, to October 31st, 2019.

TAWS events

An overview of the number of TAWS events is described in Table 5, detailed by the flight phase. Most TAWS events are observed for the final approach, followed by landing and approach flight phases.

As expected, TAWS events during take-off and climb are commonly rare. Most initial climb and departure phases occur in normal conditions and are carried out in Standard Instrument Departure procedures.

Table 5
TAWS events per flight phase (January 2019 – October 2019).

Flight Phase	Number of Events	Percentage
Initial climb after take-off	2	0.17 %
Enroute climb after take-off	5	0.43 %
Descent	2	0.17 %
Approach	26	2.24 %
Final approach	1079	93.02 %
Landing	46	3.97 %
Total	1160	100 %

Note. It is extracted from the Brazilian Commercial Safety Team (BCAST), CFIT Working Group, for confidentiality and study purposes.

Therefore, further study of the approach and landing scenarios is highlighted as VFR and IFR approach procedures in the considered database may arise.

Table 6 details the contribution of TAWS alerts observed in VFR and IFR flight rules during the approach, final approach, and landing phases.

Table 6
TAWS events per flight rule: VFR and IFR (January 2019 – October 2019).

Flight Phase	Number of Events	VFR	IFR
Approach	26	0	26
Final approach	1079	976	103
Landing	46	46	0
Total	1151	1022	129

Note. Extracted from the Brazilian Commercial Safety Team (BCAST), CFIT Working Group, confidentiality and study purposes.

As indicated in Table 6, the most significant contribution to the total number of TAWS alert events in VFR procedures is observed for the final approach and landing phases. Thus, the suggestion is coherent with the expectation that, as the flight progresses to land under VFR rules, the exposition to terrain clearance risk may increase during the visual traffic pattern.

It is important to note that the total number of TAWS alerts observations in VFR procedures covers all airports in the analysis database, including IFR certified but received flights performing a VFR procedure to land. The analysis is then detailed further to consider and separate the VFR-only airports from the entire airport database, described in Table 7.

Table 7
Airports in the database for which VFR landing procedures were performed.

IATA / ICAO Code	Landing Certification
AFL / SBAT	IFR
BEL / SBBE	IFR
BSB / SBBR	IFR
CGB / SBCY	IFR
CGH / SBSP	IFR
CGR / SBCG	IFR
CKS / SBCJ	IFR
CNF / SBCF	IFR
CWB / SBCT	IFR
CXJ / SBCX	IFR
FLN / SBFL	IFR
FOR / SBFZ	IFR
GIG / SBGL	IFR
GRU / SBGR	IFR
GYN / SBGO	IFR
IOS / SBIL	VFR
MAO / SBEG	IFR
MCZ / SBMO	IFR
OAL / SSKW	VFR
POA / SBPA	IFR
PVH / SBPV	IFR
RAO / SBRP	IFR
REC / SBRF	IFR
ROO / SBRD	IFR
SDU / SBRJ	IFR
SLZ / SBSL	IFR
SSA / SBSV	IFR
VCP / SBKP	IFR
VDC / SBVC	IFR
VIX / SBVT	IFR
XAP / SBCH	IFR

Note: Adapted from (DECEA, 2020).

As Table 7 indicates, SBIL and SSKW are the first strong candidates to receive instrument procedures since they are VFR-only airports and contained in the detected TAWS alerts database.

The Tableau® visualization of geographic locations of TAWS alerts identified in the collected data is depicted in Figure 1. The "hotspots" indicate a scatterplot of TAWS alerts' geographic coordinates and may contain several superimposed points related to alert events detected in the database within the analysis timespan. The examples highlighted by the numbered circles detail further.

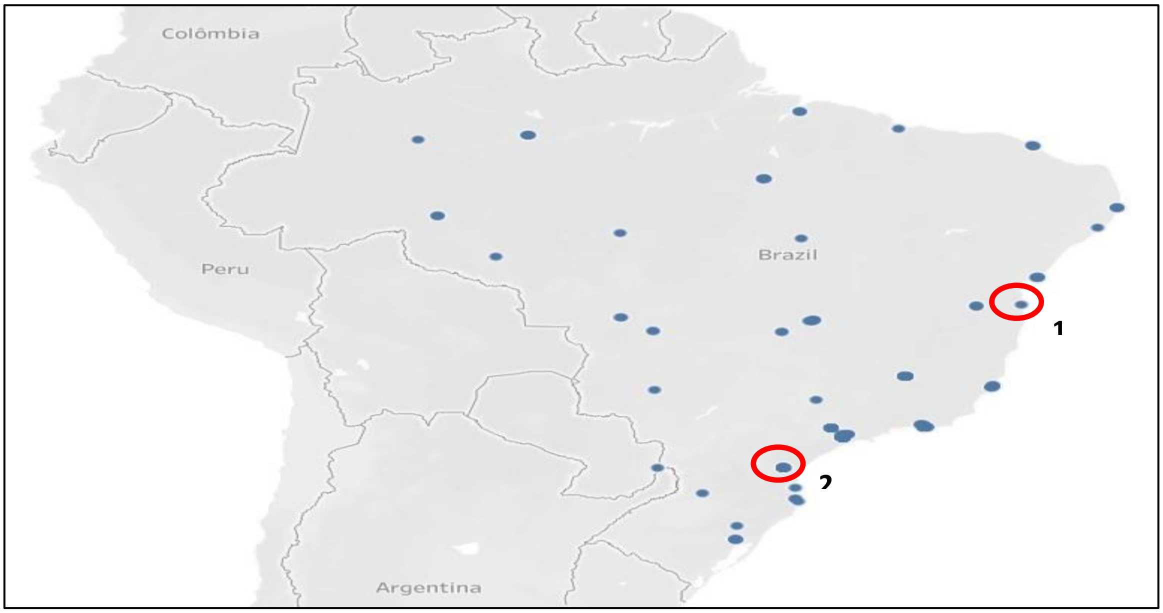

Figure 1. "Hotspots" of TAWS alerts collected from the study database.

For example, in Figure 1, red circle #1 refers to Ilhéus Airport (IATA Code IOS) in Bahia State, and red circle #2 refers to Curitiba Airport (IATA Code CWB) Paraná State.

Enlarged pictures of those locations with further detail are illustrated in Figure 2 for IOS and Figure 8 for CWB. While IOS presents one TAWS alert point detected in the analysis timespan, IOS is a VFR-only airport. Its candidacy to receive instrument procedures, therefore, remains relevant within the scope of this study.

The blue dot in Figure 7 identifies the TAWS alert event location. It refers to an alert detected close to the runway in the short final approach phase to land.

Figure 2. TAWS alert identified for Ilhéus Airport (IOS), RWY 11.

The case for Curitiba shows in Figure 3 several TAWS alert events detected in various points along the final approach path, most of which for Runway 33. That characteristic indicates unstable approaches and suggests difficulties in maintaining the correct final approach glideslope to the runway.

Figure 3. TAWS alert identified for Curitiba Airport (CWB), RWY 15/33.

As discussed previously, the collected database contains TAWS alerts observed in VFR operations in destination airports that are IFR-certified. Figure 4 depicts the number of TAWS alerts during VFR operations, including IFR-certified airports, listed by IATA Codes.

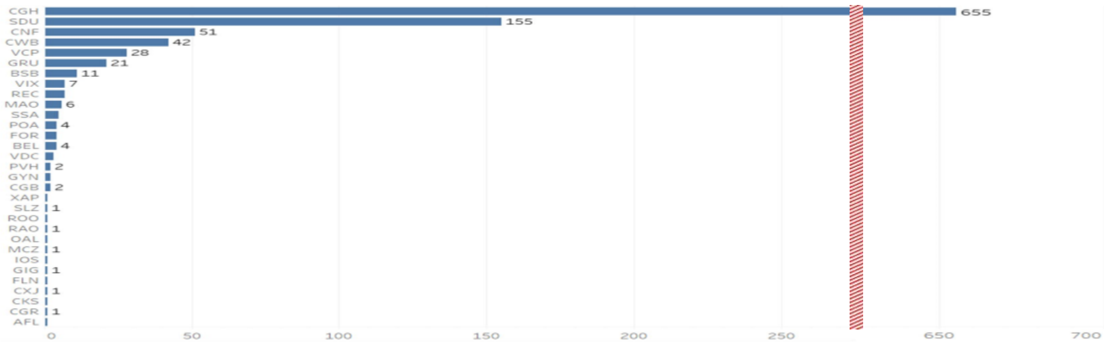

Figure 4. Quantity of TAWS alerts in VFR operations, including IFR-certified airports (January 2019 – October 2019).

The red marking in Figure 4 indicates the brake on the horizontal axis scale to accommodate the significantly higher number of TAWS alerts related to CGH airport than the other airports.

In this sense, based on the absolute numbers of TAWS alerts observed in this study's timespan, Figure 4 indicates the stronger candidate IFR-certified airports for detailed analysis to receive instrument approach and landing procedures.

The results indicated in Table 7 and Figure 4 are cross-checked with flight operations traffic volume related to those airports in the study period.

The total number of the Brazilian leading carriers' flight operations into those airports is described in Figure 5, considering VFR and IFR procedures.

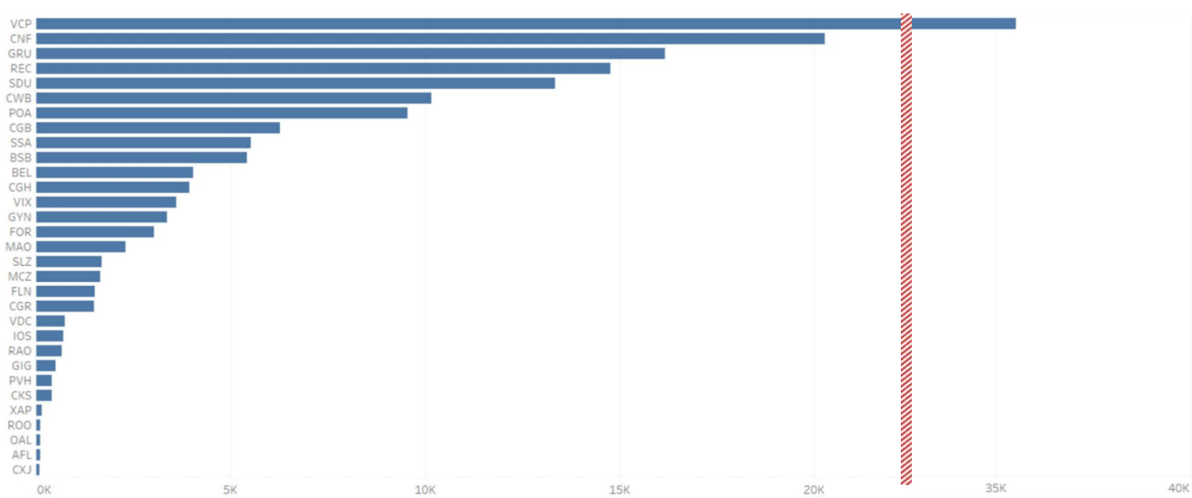

Figure 5. Traffic volume: quantity of flight operations - VFR and IFR - (January 2019 – October 2019).

A relation between the results presented in Figures 4 and 5 can be established using the application of metric criteria (Index) to indicate the number of TAWS alerts per number of flight operations based on the index formula.

The Index receives a dimensionless number as a correction factor (1000) to provide an exact comparison between airports to be ranked in the priority list to receive instrument approach and landing procedures.

Therefore, the index factor application (Figure 6) indicates that the airports showed higher TAWS alerts per thousand flight operations in the study period.

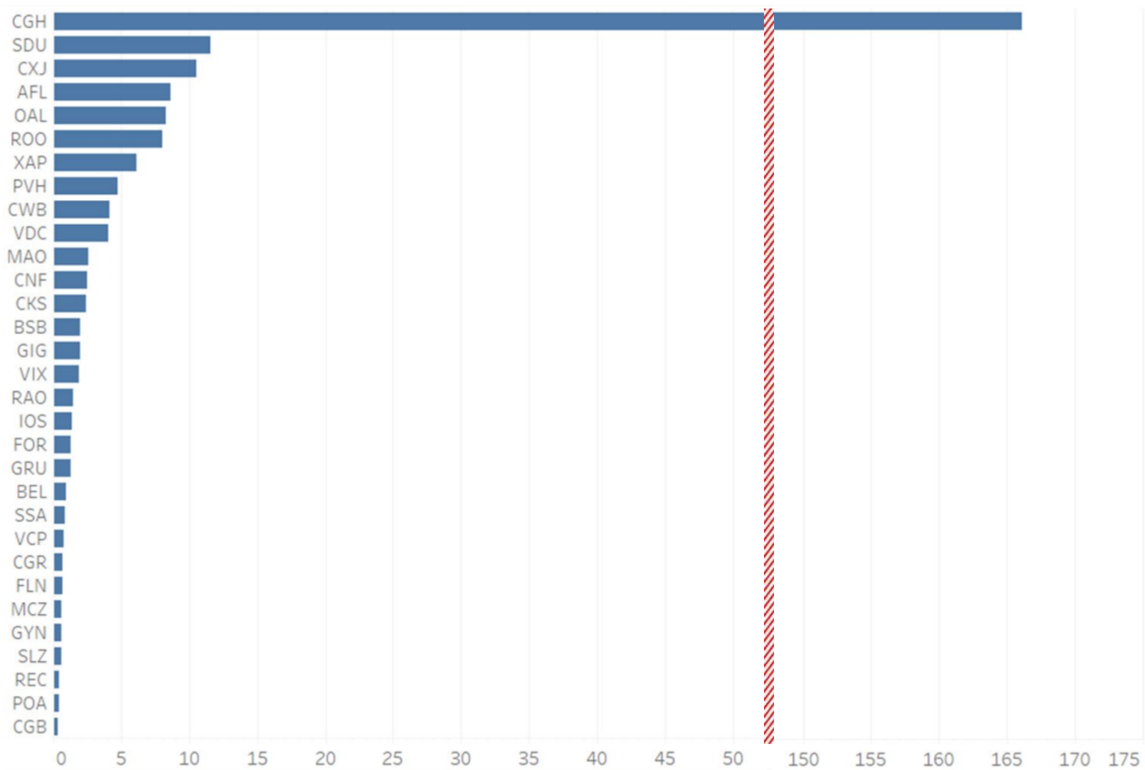

Figure 6. Index: Number of TAWS alerts per flight operation [x1000].

The results are shown in Figure 6 already indicate the airports of more significant concern to receive instrument approach and landing procedures for prioritization purposes. Therefore, applying the Index criteria refines the rank of airports to be further analyzed by DECEA and ICA as its institute in charge of developing and implementing navigation procedures.

Regarding the frequency of diversions due to weather, for example, as discussed previously, the most significant causes for flight cancellations and diversions in VFR airports are adverse weather conditions at the destination. Therefore, the underlying condition may already be addressed in the TAWS alert analysis for those airports.

Nevertheless, an evolution of the ranking method may include a detailed analysis of possible correlations of TAWS alerts and weather diverts in a given set of VFR airports.

As for IFR airports that make up the ranking list, existing IFR procedures may have limited room for further improvements to address meteorological minimums, as RNP AR procedures, for example, would require additional certification to aircraft as well.

For the cases of VFR-only airports, RNP procedures for Visual Runways can be applicable. For IFR-certified airports, revisions of current instrument procedures or implementing the v-RNP type's additional procedures can also be applicable.

The 20 airports of primary concern, ranked by the Index criteria, are summarized in Table 8.

Table 8

Candidate Airports to receive a further analysis of instrument procedures.

# Rank	Airport (IATA Code)	# Rank	Airport (IATA Code)
1	CGH	11	MAO
2	SDU	12	CNF
3	CXJ	13	CKS
4	AFL	14	BSB
5	OAL	15	GIG
6	ROO	16	VIX
7	XAP	17	RAO
8	PVH	18	IOS
9	CWB	19	FOR
10	VDC	20	GRU

Finally, it is essential to notice that the ranking method also captured OAL and IOS airports. They were previously mentioned as potential candidates to receive instrument procedures since they are VFR-certified only.

Conclusions and Recommendations

This study investigated significant aspects of the safe and efficient landing procedures to airports in the Brazilian landscape by analyzing TAWS alert events gathered from the central Brazilian air carriers operating domestic flights.

A ranking method was developed to identify "hotspots" of TAWS alerts, evaluated for IFR and VFR-only airports. The prioritization of airports eligible to obtain instrument approach and landing procedures furthermore contemplates the history of traffic volume, in terms of the number of operations into those airports, to offer valuable metrics of comparison between candidate airports. Implementing instrument procedures successfully offers applicable separation with ground terrain and lateral and vertical guidance to preserve stable approaches, decreasing CFIT risk. As depicted in our results, PBN procedures enhance meteorological minimums, grant higher accessibility to those airports, and reduce flight cancellations and diversions to alternate airports caused by adverse meteorological conditions. That is too a significant economic benefit to amplified connectivity and growth of the national commercial air transportation network.

This study illustrates that a suitable prioritization method to rank current VFR-only airports to be provided with instrument approach procedures, or additional exploration in the case of IFR airports, entails analyzing TAWS events during approach and landing, combined with the traffic volumes at a given airport.

This study's limitation is the unavailability of traffic volume information detailed by type of operation (VFR or IFR). A leading-edge method may separately consider the number of VFR operations about the candidate airports identified by the TAWS alert events.

Recommendations

DECEA is currently reviewing the method as a systematic process to identify, analyze and rank airports, in terms of TAWS alerts by the number of operations, to be provided with PBN procedures for approach and landing and, more specifically, the viability of the application of v-RNP (RNP APCH for Visual Runways).

A detailed investigation of the nature of the TAWS alerts (whether they are "caution", "warning", related to aircraft configuration or the approach flight path) in the detected "hotspots" for IFR airports may provide a better understanding of the effectiveness of existing IFR procedures. Thus, future research may include a more detailed analysis of TAWS alerts for each runway at a given airport. In addition, since the TAWS "hotspots" are related to approach and landing procedures to a specific runway, the ranking method may be refined with the analysis to prioritize specific runways of interest.

Additional concerns to the TAWS alert event analysis also involve the flight crews' measures to behave correctly and rapidly a missed-approach procedure or evasive maneuver once a TAWS alert is uncovered throughout approach or landing. For airports with added complex surrounding terrain environments, assessing the viability of a go-around maneuver under VFR rules might develop into a significant contributor or impose a given airport's priority to receive an instrument approach procedure. Hence, additional research may also involve examining the complexity of existing missed approach procedures considered in the ranking method.

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