THE CONSTRUCTION NON-COMPLIANCES OF THE RUNWAY SYSTEMS IN BRAZILIAN AIRPORTS REGARDING SAFETY RULES

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ABSTRACT

This work presents a study aiming to show alternatives for the elimination or management of construction non-compliances in the runway systems of Brazilian airports. Taking into consideration that the solution to such non-compliances involves, in some cases, the implementation of actions of technical and financial complexity, this work endeavors to approach the following issue: “How to reach acceptable levels of safety while eliminating or managing -non-compliances related to construction risks in the Brazilian airport runway systems?”

Among the several conclusions reached through this research, one is worth highlighting: the Brazilian airport system’s overrun, undershoot and veer-off rates are equivalent to those in the developed world. This does not mean that civil aviation in Brazil is more or less safe, but it suggests that, considering the size and type of aviation operation, as well as the period selected for this study, the rates for the events in focus are equivalent to those in the European study used as a reference in this work.

INTRODUCTION

The majority of Brazil's civilian airports were built, as a rule, several decades ago, when operational safety demands were significantly lower. Besides, a significant number of these airports were originally military aerodromes, which do not comply with the same operational safety principles as those followed by civilian airports.

However, the demands in safety have evolved markedly over the last decades, in an attempt to keep up with the increasing complexity of the challenges presented by the growth in the use of civil aviation. This resulted in the development of a large number of construction non-compliances in the Brazilian airports' runway systems.

It should be noted, also, that many of the rules that define non-compliances in the Brazilian airports did not exist or were not required when these airports were built. In addition, the safety requirements were much less strong, because movement was much lower and the aircrafts were smaller, carried fewer passengers and their specifications required less landing and takeoff runway.

Today, the existence of such non-compliances makes the operations at those airports less safe and, consequently, exposes Brazilian civil aviation to the following risks:

1) a higher likelihood of accidents involving aircraft and airports
2) a higher likelihood that, should accidents happen, they cause more severe damage to people, installations and equipments;
3) accountability of the airport operator (or its agents) in case of accidents;
4) accountability of the regulatory authority (or its agents) in case of accidents;
5) a negative image of the country;
6) loss of credibility for the aviation system;
7) economic, political and operational impacts (due to the likelihood of restrictions being applied to these airport by international organizations);
8) more expensive insurance premiums for aircraft operations and airport operations in Brazil;
9) possible size limitation of the aircrafts that operate in these airports;

10) possible autonomy limitation of the aircrafts that operate in these airports;

The International Civil Aviation Organization - ICAO, of whose convention Brazil is a signatory member, adopted Annex 14 (Convention on International Civil Aviation) as an international standard for the design of aerodromes. The rules and construction standards adopted by ICAO are the result of careful risk assessment of airfield operations and aim to ensure a high level of safety for aprons, runways and taxiways.

In Brazil, Annex 14 standards and practices were progressively added to the national standardization policy through the following instruments:
- Portaria /GM5 (Dec 8th 1987)
- Portaria 398/GM5 (Jun 4th 1999)
- Regulamento Brasileiro de Aviação Civil 154 (May 12th 2009)

Albeit not fully compliant with the standards of Annex 14, such Brazilian airports, i.e. those airports in which non-compliances can be found, are particularly important for the national economy inasmuch as they allow for the connection between cities in Brazil and abroad and the moving of large numbers of passengers and cargo. The necessity is therefore obviated to study the problem and propose solutions that aim at solving these non-compliances and that may bring the safety level of Brazilian airports to a state of conformity with international standards.

The growth of the air transportation market in Brazil has resulted in an increase of aircraft movements, which, in turn, increases the risk of operations being performed with non-compliances in the same proportion.

OUTLINE OF THE MAIN NON-COMPLIANCES

Table 1 shows the non-compliances found in a sample of eight airports collected from the airport updating certification files (2007-2008) of the Brazilian National Civil Aviation Agency (ANAC). This sample was withdrawn from the universe of the twenty largest Brazilian airports in passenger traffic, whose passenger movements amount to more than two million passengers per year. The name of these airports is not quoted by request of the source.

All eight airports presented non-compliances, the highest incidence occurring in the following cases: absence of Runway End Safety Area- RESA and obstacles in the runway strip.

The possible consequences that may result from the non-compliances identified are, respectively:

- In cases of landings during which the touch of the aircraft occurs before the beginning of the runway (undershoot) or during which the aircraft accidentally exceeds the end of the runway (overrun), the likelihood of serious damage and injury to passengers and crew will be higher.
- If an aircraft accidentally exits to the side of the runway (veer-off) during a landing or takeoff, the probability of collision with an obstacle will be greater.

Table 1.– Occurrences verified in a sample of eight airports.

OCURRENCES VERIFIED IN ASAMPLE OF EIGHT AIRPORTS (Source: ANAC 2007-2008)		
NON-COMPLIANCES	N. OF AIRPORTS IN WHICH THE NON-COMPLIANCE WAS VERIFIED	TOTAL
Absence of Runway End Safety Area - RESA	8	26
Obstacles in the runway strip	8	13
Obstacles penetrating the transitional surface	6	8
Obstacles penetrating the approach and take-off surface	2	2
Runway strip (graded area) unevenness	4	6
Drainage ditch in the runway strip (graded area)	4	4
Service road on the runway	4	4
Wall and urban area within the range of runway strip	2	3
Taxiway in the runway strip	1	1
Insufficient distance between the axis of the runway and taxiway	1	1
Insufficient distance between axis of the runway and apron edge taxiway	1	1
Obstacles in the taxiway strip (graded area)	1	1
Vertical signs different from standards	1	1
Horizontal signs different from standards	2	2
Width of the runway different from standards	1	1
TOTAL OF CONSTRUCTION NON-COMPLIANCES OF THE RUNWAYS SYSTEMS		74

From the description of the risks involved in these non-compliances, it is possible to understand the importance of their elimination or management.

As the incidence of non-compliances found relate to construction standards established to protect aircrafts and passengers in the occurrences of overrun, undershoot and veer-off, this work will focus on the elimination and management of non-compliances relating to such standards and their associated risks

ACCIDENTS IN RUNWAY SYSTEMS

Design standards for airport runway systems exist in order to minimize the consequences of events such as undershoot, overrun and veer-off.

According to Ashford (1992), research conducted by the Airline Pilots Association from 1967 to 1992 indicated that five percent of accidents occur on route and fifteen percent occur near airports, usually within 15 miles (24km) of the airport. Eighty percent occur in runways or in their areas of excess and unobstructed areas (Clear Zones). A diagram with the points where these accidents occur (see Figure 1) shows that the majority of accidents occur at a distance of up to 500 feet (152.4 m) from the centerline of the runway and 3000 feet (914.4 m) from the threshold.

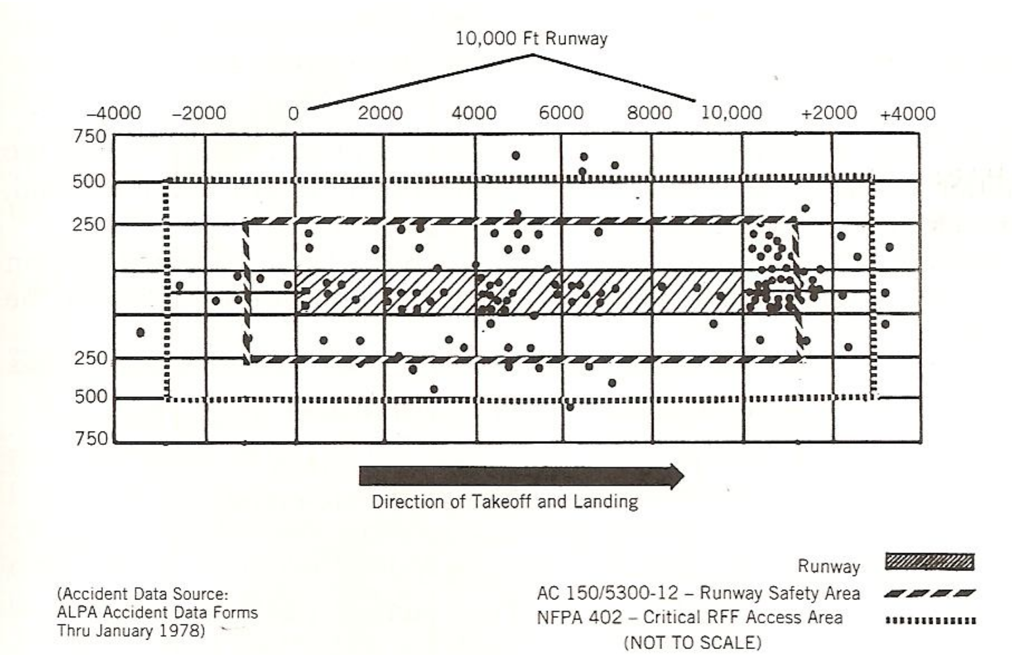

Figure1 – Distribution of accidents around the runways (ASHFORD -1992)

The facts outlined above justify the runway safety areas established by design standards for the airports' runway systems, which are implemented with a view to mitigating the severity of accidents.

Accidents in the airports' runways systems can be divided into three categories: undershoots, veer-offs and overruns.

Undershoot

Undershoot is an event that occurs during an approach to landing that results in early landing, contact with the ground or obstacle near the runway or landing area. Typically, this type of event occurs due to poor assessment of distance, speed and / or altitude on final approach. The main causes of this type of accident are Windshear, loss of power on approach and decisions of the pilot. The distance of undershoot is described as the longitudinal distance from the point at which the aircraft touches the ground until the start point of the runway.

Windshear is a meteorological phenomenon, also known as wind gradient. It is the occurrence of violent air currents descending from CB cloud towards the ground by microburst. Windshear represents a serious threat to an aircraft in flight, especially in the stages of approach, landing and takeoff, when the airplane has less speed in relation to the ground. Due to windshear, the aircraft may have its support strength and stability altered. Windshear may have several sources: lightning, the presence of Cumulonimbus, virga (precipitation type that occurs in the base of some clouds and that does not reach the ground), frontal systems, jet streams of low levels, strong surface winds, sea and land breezes, mountain waves, squall lines and strong temperature inversions, among others.

Veer-off

Veer-off occurs when the pilot loses the directional control of the aircraft in a landing or in a takeoff due to problems with tires and/or brakes, skidding on wet or ice-covered runway, aquaplaning and low runway friction coefficient, especially in conditions of crosswinds. The distance of veer-off is described as the lateral distance between the lateral limit of the runway and the point where the aircraft stopped after exceeding this limit.

Overrun

Overrun is the most common accident in airports. It can happen on landing, due to hydroplaning on a wet runway, skidding on a runway with snow or ice, the spot of the runway where the aircraft touches the ground being too far from the optimal spot, speeding, or failure in the braking system. It results in overrunning the end of the runway. It can also happen in aborted takeoffs at high speeds, due to aircraft mechanical failures or tire problems. This last cause has been responsible for half of the accidents with fire. The range of overrun is described as the longitudinal distance between the edge of the runway and the point where the aircraft stopped after exceeding this limit.

ACCEPTABLE RISK LEVELS

Criteria for risk acceptability are widely used in human activities. Any form of activity involves some risk. Risk acceptability is directly linked to the benefit provided by the activity.

The level of acceptable risk for a society is associated with socio-economic and cultural reasons.

The assessment of the risks involved in an activity can take place in a quantitative or qualitative way. The use of the historical frequency of occurrence of an event to calculate the probability that it will occur again is an example of quantitative evaluation. The FHA (Functional Hazard Analysis) method, used by Eddowes et. al (2001) and Hall et. al (2008), based on the work of a multi-disciplinary team and the employment of a probability x severity matrix, is an example of qualitative evaluation.

The occurrence rates of overrun, undershoot and veer-off events may be obtained from historical data of accidents and incidents of this nature in relation to the number of movements (takeoffs or landings) within a given period of time. With such data, it is possible to estimate the probability that one
of these events occur again.

A study by Eddowes, M. *et. al* (2001) estimated the frequency of these events from North-American and European data:

- *Veer-off* during take-off: $1{,}9 \times 10^{-7}$;
- *Veer-off* during landing: $5{,}6 \times 10^{-7}$;
- *Overrun* during take-off: $4{,}7 \times 10^{-7}$;
- *Overrun* during landing: $15{,}7 \times 10^{-7}$;
- *Undershoot*: $2{,}5 \times 10^{-7}$;

The Medeiros (2009) study estimated the frequency of these events from Brazilians data:

- *Veer-off* during take-off: $1{,}2 \times 10^{-7}$;
- *Veer-off* during landing: $9{,}8 \times 10^{-7}$;
- *Overrun* during take-off: *
- *Overrun* during landing: $11{,}0 \times 10^{-7}$;
- *Undershoot*: **

Comparing the values obtained from Eddowes, et. al. (2001) and those obtained from Medeiros (2009), it can be inferred that the veer-off during landing, veer-off during takeoff and overrun during landing rates were equivalent. It was not possible to compare the undershoot (**) and overrun during take-off (*) rates due to the absence of these events in the sample period. However, according to Eddowes, M. et al (2001), there is a ratio between overruns during landing and overruns during take-off of about 20:6, and between veer-off during landing and veer-off during take-off of about 4:1, which would allow us to estimate the results for the items that did not occur in the sample period.

The data from Eddowes, M. *et. al* (2001) includes accidents / incidents involving air taxi. Because of the way that INFRAERO (Brazilian Airports Company) accounts for movements in Brazil, the data from Medeiros (2009) doesn't consider such events. However, such difference is not statistically significant for the purposes of this paper.

PROSPECTING DATA

The data source used by Medeiros (2009) is the investigation of aircraft accidents and incidents coordinated by CENIPA - Center for Research and Prevention of Aeronautical Accidents - in Brazil.

The purpose of an investigation of an aircraft accident / incident, according to CENIPA standards, is the prevention of aircraft accidents by the establishment of contributing factors (directly or indirectly present in the event) and the issuing of safety recommendations that enable the taking of direct action or the immediate making of decisions in order to eliminate those factors or to minimize their consequences.

Thus, primarily, , , the data collection for the purposes of study and assessment of runway safety areas, as well as of elements for the development of standards relating to this subject, is not, in any direct way, under the scope of investigation.

Nevertheless, the data and the history of accidents and incidents during landings and takeoffs are valuable elements for the risk analysis of operations in existing runways, as well as for the establishment of construction standards that are more appropriate to the national reality.

The studies of Hall, J. et all (2008) and Eddowes, M. et all (2001) show that it is possible to lay off models based on data of accidents and incidents that allow us to estimate the risk that an aircraft that operates within specific conditions of an airport will come to use the runway safety areas and stop beyond the available limits, or collide with existing obstacles in its interior.

For that, one would require the availability of a series of data about accidents and incidents, which are, in most cases, not yet available today in the investigation reports and in the accident information management systems, combined with other data that is already available. Example of data that are not avaible include: distances x and y, respectively, from the threshold and the axis of the runway to the spot where the aircraft stopped; distances x and y, respectively, from the threshold and the axis of the runway to the spot where the aircraft first reached the ground; the excursion path of the aircraft in the ground, the direction and speed of the wind, the speed of the crosswind, ceiling, visibility, temperature, presence of fog, presence of electric storm, presence of hailstorm, presence of snow, presence of ice and presence of rain, regardless of the fact that those factors were considered contributing factors to the accident or not.

Reading the CENIPA standards, it is observed that the investigation process does not require the acquisition of precise data regarding the place where the aircraft stopped and the excursion path taken by it during the events of overrun, undershoot and veer-off. The main concern expressed in these documents is the relative location of the wreckage, in a way to facilitate the search of the contributing factors to the accident/incident. Corroborating with these observations, there no precise data was found in the final reports of accidents/incidents examined regarding the place where the aircraft stop and the excursion path taken by it during the aforementioned events.

Just as the investigations are not focused on such purposes, the accident database (SIGIPAER), and even the accident data research system configuration (which uses the Business Object software) are not so as well. The events are classified by a determined taxonomy and always by the first occurred event, which makes the research even harder. For instance, if the first event was a 'burst tire', it won't be possible to find it through any other keyword but 'burst tire', even if the aircraft had left the runway resulting a veer-off event or a " loss of control in the ground". Thus, it is necessary to read the final report of the accident to know if there was the occurrence of veer-off after the burst of the tire or not.

On the other hand, the taxonomy used does not have a direct correlation with the events internationally called overrun, undershoot and veer-off. For example:

-overrun events can be classified as "long landing" (overrun during landing), or "loss of control in the ground" (overrun during takeoff), or "burst tire" (overrun during takeoff);

-undershoot events can be classified as "landing before the runway", or "landing on non-predicted location";

-veer-off events can be classified as "collision with obstacles on the ground", or "burst tire", or "control loss in the ground".

ALTERNATIVES TO REACH AN ACCEPTABLE SAFETY LEVEL

The Brazilian legislation for civil aviation establishes that, when the identified non-compliance is somehow related to physical aspects and its resolution is unfeasible, the development of an aeronautic study to define if the associated risk is acceptable or not becomes necessary. If the risk is acceptable, the Civil Aviation Authority can authorize a sort of “circumvention”. If the risk is not acceptable, it will be necessary to establish an operational agreement of permanent character, even if this agreement reduces the hourly capacity of the airport, in order to ensure an acceptable safety level. If the concession of the “detour” is bound to a permanent operational agreement, risk management practices become necessary, also permanently, in order to ensure that the risk will always remain lower or equal to the acceptable safety level.

Two other alternatives could be applied, according to each case: the threshold retreat, with a consequent reduction of declared distances, and the restriction of types of aircrafts authorized to operate in the aerodrome. The objective of this last measure would be to make the aircrafts in operation compatible with the physical restrictions imposed by the runway’s non-compliances.

The flowchart presented in Figure 2 organizes and summarizes the alternatives presented in the two previous paragraphs. In this flowchart, "R" means risk resulted from the operation with non-compliance and "NAS" means acceptable level of safety.

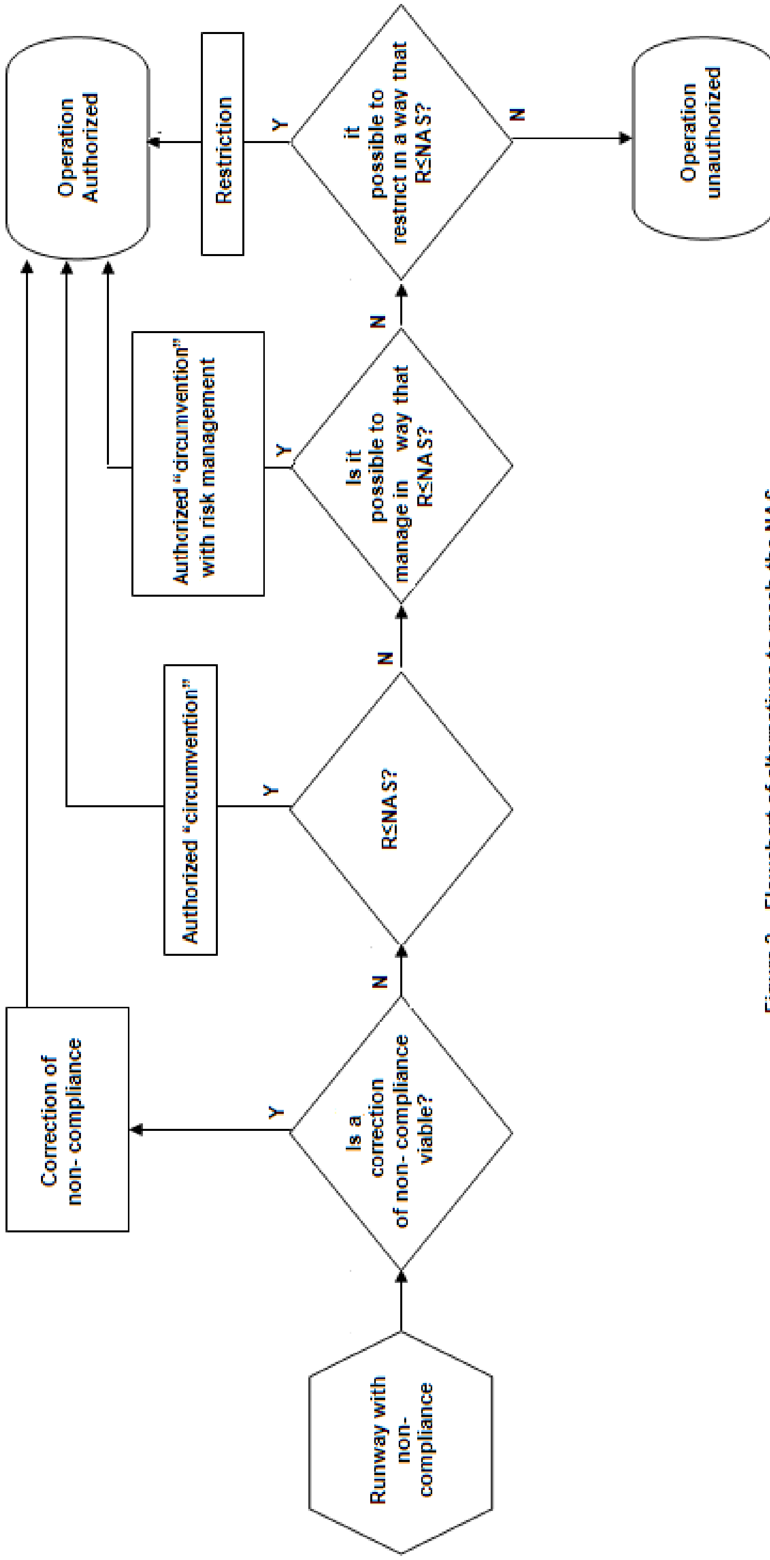

Figure 2 – Flowchart of alternatives to reach the NAS

CONCLUSIONS

According to the points exposed in this paper, it is possible to establish national models, based on the data collected from accidents and incidents, which allow us to estimate the risk that an aircraft which operates under the specific conditions of a given Brazilian airport will need to use its runway safety areas and stop beyond the limits available, or collide with the obstacles in its interior. But, for that, it is necessary that such data be obtained during investigations, and then made available on accident information management systems.

Such measure would allow the development of the cited risk analysis models, tools that would help on the risk analysis of the existing non-compliances, offering a larger number of viable risk management alternatives and, consequently, saving resources by the avoidance of corrective actions that would be very costly. Moreover, the information and data collected could also be utilized to support the studies of the improvement of Brazilian construction standards for runway systems, likely resulting in savings in design and construction of new airports.

On the other hand, the information gathered on CENIPA also allow us to conclude that, if the non-confidential informations concerning accidents and incidents cited were made available in a report or even directly in the accident information management system, thus avoiding the need for the investigation to be over and its final report to be avaible before such info is released as a research source, the unavailability of that information for research and study purposes would be avoided for a long period.

The comparison between the results of the Medeiros (2009) and Eddowes, M. et al (2001) studies points at a surprising result: the frequency of the occurrence of overrun, undershoot and veer-off events in Brazil is equivalent to its frequency in Europe and North America. It doesn't imply that Brazilian civil aviation is more or less safe, but that, for its dimension, kind of aviation operation and period selected in this study, the rates for the focused events are equivalent to the ones of the developed world. It is necessary to highlight that some of the national factors may be contributing positively for this fact, for example: a newer aircraft fleet, less adverse meteorological conditions and the runway length, in most airports, superior to the required by most aircrafts operating in it.

RECOMMENDATIONS

From the conclusions of this paper, the following recommendations and suggestions may be subtracted:

- a review of the CENIPA standards, with the following purpose:
    - to explicitly mention the acquisition of data as one of goals of the investigation, in order to improve the study and the evaluation of runway safety areas, as well as elements to the improvement of rules referring this theme;
    - to include instructions for the acquisition of data about the localization of overrun, undershoot and veer-off events regarding the threshold and the runway axis;
    - to provide non classified information cited in this study as rapidly as possible after the accident either in a report or directly in the accident information management ;
- the recording of accidents and incidents on the CENIPA database “SIGIPAER” should be made not only by the taxonomy of the first occurred event, but it should also include the taxonomy of further events, and the possibility of their use as keywords for search;
- fomentation by the Brazilian National Civil Aviation Agency of research in this field in order to obtain more aids to the elaboration of standards to risk analysis and aeronautic studies.
- fomentation by the Brazilian National Civil Aviation Agency of capacity building of specialists in this field in order for it to be well-structured for the further challenges and demands that the process eventually presents.

SUGGESTIONS FOR FURTHER RESEARCH

From the information obtained in this paper, new matters have arisen for the deepening as much as for the increase of the study’s scope. For instance:

- the study of the location of overrun, undershoot and veer-off events regarding the threshold and the runway axis occurring in Brazilian airports;
- the study of the severity (fatality and aircraft damage) distribution of the overrun, undershoot and veer-off events occurred in Brazilian airports;
- the modeling for the risk analyses of overrun, undershoot and veer-off events in Brazilian airports.

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