AIRPORT SAFETY MANAGEMENT: A PROACTIVE MODEL BASED ON RISK ASSESSMENT AND BENCHMARKING

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Abstract

This study presents a practical, context-sensitive approach to managing airport safety that combines the PDCA cycle with benchmarking techniques within a structured risk assessment framework. Given that ensuring operational safety in airports requires precisely recognizing, classifying, and successfully mitigating specific hazards, this study addresses this issue by creating a tailored risk assessment table. This tool, designed specifically for airport environments, clearly categorizes hazards based on their likelihood and severity and uses a novel equation developed in this study to correctly determine Safety Performance Indicators (SPI) and Safety Performance Targets (SPT). These indicators allow safety managers to effectively track performance trends, compare outcomes to other airports, and align safety policies with ICAO regulations. The cyclical nature of repetitive improvement in PDCA is assured, and value is added through benchmarking by applying tested best practices, enhancing the quality of decisions. A case study with airport safety practitioners establishes the practical applicability and value of this methodology in risk prioritization and pushing forward the drivers of corrective action. Collectively, the results demonstrate how this strategy supports proactive risk control and operational safety, and develops a sustainable culture of continuous improvement—a key component of effective airport safety management.

Keywords: Airport Safety; Risk Assessment; PDCA Cycle; Benchmarking; Risk Management; Safety Performance Indicators.

I. Introduction

Airport safety is a critical concern for both aviation authorities and airport operators. With increasing air traffic, the attendant increase in exposure to safety risks requires orderly and systematic measures. Although fatal aviation accidents are relatively infrequent compared to other modes of transport, the significant increase in the number of commercial flights requires that safety management practices be implemented effectively [1]. To ensure effective safety management, the International Civil Aviation Organization (ICAO) has developed a Safety Management System (SMS). This system includes procedures, documentation, knowledge systems, and organizational processes designed to manage and develop safety performance [2]. A safety reporting system is one of the key components of SMS, and it facilitates proper identification and monitoring of safety issues [3]. The ICAO framework defines SMS as a proactive approach to managing safety risks before they result in incidents or accidents. This includes developing an internal structure adapted to the specific needs of the organization and aligned with international requirements [4].

The implementation of SMS allows States to approach their safety responsibilities using a performance-based model [5]. Since the early 2000s, ICAO has revised several annexes—such as Annexes 6, 11, and 14 in 2006, and Annexes 1 and 8 in 2008—to require States to establish safety programs and ensure the oversight of service providers [6], [7]. According to these requirements, nations must create an ICAO-compliant safety supervision system.

The consistent application of ICAO criteria ensures that all aviation actors within a State operate at the same level of safety. Senior management is responsible for supporting safety efforts through policies, oversight, and audits [8], [9]. In addition, States are expected to promote a safety culture through regulatory frameworks and stakeholder engagement [10]. International coordination is supported by harmonizing procedures and facilitating cooperation among States. Systems used for airport safety integrate multiple components such as risk analysis, data management, and stakeholder communication [11].

Airport risk management is based on three components: risk identification, risk assessment, and risk control. Risk assessment has played an important role in the creation of airport safety management systems [7]. Despite the widespread use of SMS, there has been little academic research on how risk assessment and safety indicators are operationalized and evaluated in airport settings, particularly through dynamic and comparative frameworks. Most prior studies have concentrated on general SMS components or airline-centric safety models, leaving a gap in structured evaluation models specifically tailored for airports.

This study focuses on two components of SMS: risk assessment and the use of safety performance indicators. Risk assessment provides a methodical examination of potential risks, whereas safety indicators enable the monitoring of risk trends and the adjustment of mitigation strategies. While ICAO recognizes these factors as vital, there is still a need to incorporate them into a continuous improvement approach that can drive long-term airport safety performance review.

This paper uses a methodology that combines benchmarking and the PDCA (Plan–Do–Check–Act) cycle. While benchmarking helps compare safety standards between the investigated airport and reference airports, the PDCA cycle guarantees continuous performance monitoring.

This comprehensive approach makes it possible to identify best practices and strengthen airport safety, both in terms of infrastructure and for staff and passengers. This study aims to propose a practical, scalable, and adaptable assessment tool intended to support strategic decision-making on safety within airport operations.

II. Literature review

Assessing airport safety is a major challenge, particularly in contexts where operations are exposed to multiple and dynamic risks. Numerous researchers have examined the tools and methods for effectively measuring the performance of safety systems, in direct relation to the realities on the ground. This literature review presents a synthesis of the most relevant approaches, recontextualizing them on the scale of an airport's internal assessment.

The implementation of a Safety Management System (SMS) remains at the heart of continuous improvement measures at airports. It relies on active support from management, a clear division of responsibilities, regular identification of hazards, implementation of risk control measures, safety audits and performance monitoring over time. To measure their effectiveness, Evaluation scales have been proposed in [12] based on criteria such as document quality, safety training, management involvement, emergency management and clarity of internal policies. However, more recent work highlights certain limitations of SMS, notably their tendency to become overly bureaucratic and focused on procedural compliance, to the detriment of their operational adaptability. These findings are confirmed in [13], where the value of integrating employee perceptions to assess actual system performance is emphasized. These elements converge towards the need to design SMS that are compliant, flexible and focused on the specificities of each airport environment.

The risks to airport safety cover a wide spectrum: human error, foreign object debris (FOD), runway incursions, bird strikes, extreme weather conditions, technical failures or even terrorist threats [5], [14]. To better model and analyze this complexity, An evaluation framework has been developed in [15] integrating standardized management criteria into traditional processes. Their model highlights the fundamental role of managerial practices in risk reduction. In the same vein, a two-stage method was designed in [16] based on the Analytic Network Process (ANP) and the Technique of Order of Preference by Similarity with the Ideal Solution (TOPSIS), to structure the assessment of SMS components at airports. A conceptual framework is proposed in [17] combining quality management principles, key performance indicators (KPIs), and Lean Six Sigma approaches. This integrated approach aims for continuous improvement, based on specific performance measures and a clear distinction between proactive (preventive) and reactive (post-event) indicators.

However, the use of KPIs at airports faces significant challenges due to differences in operational context and site-specific safety standards. The need to adapt performance indicators to the particularities of each airport is emphasized in [18], due to the difficulties inherent in standardizing them. Pursuing this approach, A robust safety assessment model has been developed in [19], applicable to air navigation aids (NAVAIDs), based on the safety maturity framework proposed by Eurocontrol. Their model, validated by on-site audits and expert reviews, includes 18 major factors and 49 descriptive and measurable indicators. In addition, the strategic importance of Safety Performance Indicators SPI and Acceptable Levels of Safety Performance ALoSP was underlined in [20], as defined by ICAO. This proactive approach relies on the analysis of past trends to set safety targets and establish alert thresholds, helping to anticipate risks and guide decision-making. At the same time, recent advances in data-driven safety intelligence are paving the way for new assessment tools. With this in mind, a model based on LSTM neural networks was proposed in [21] to predict and rank potential risks in real time. This model demonstrated high accuracy and promising robustness for early detection.

Taken as a whole, these contributions provide a solid basis for thinking about safety assessment on the scale of a real airport. They show that such an approach requires a combination of adapted indicators, contextualized managerial practices, and advanced technological tools to proactively and reactively anticipate, monitor and correct safety failures.

III. Methodology

This section describes the methodological approach adopted for proactive and continuous risk assessment in airport safety. Our method relies on both quantitative and qualitative data to identify and classify potential hazards, following ICAO recommendations [5], [22] and established risk management principles [23]. A particular focus is placed on safety indicators, which help refine risk assessment and adjust prevention strategies in response to evolving threats.

Risk assessment follows a structured, multi-step process, as outlined by [24] and [25]:

1. Threat identification: Identifying human-induced hazards (errors, malicious acts) and natural hazards (weather conditions, infrastructure weaknesses).
2. Risk assessment and prioritization: Evaluating the likelihood and severity of identified threats to determine priorities for action.
3. Development of mitigation measures: Implementing targeted strategies, including enhanced safety protocols, technological upgrades, and specialized staff training.
4. Monitoring and continuous improvement: Using risk indicators for ongoing monitoring, enabling early detection of trends and timely adjustments to safety measures.

Following these steps, we have developed an approach based on a combination of benchmarking methods and the PDCA (Plan-Do-Check-Act) cycle. This approach ensures a continuous improvement process, aligned with industry best practices, enabling dynamic and adapted airport risk management. The integration of benchmarking enables airport safety levels to be compared with those of other establishments, thus encouraging the adoption of the highest safety standards. The PDCA cycle, meanwhile, ensures a constant re-evaluation of the actions implemented, guaranteeing that safety strategies are always in step with developments and challenges in the sector. This combined approach makes it possible to cross-reference quantitative data (such as statistics and performance indicators) with qualitative analyses (incident reports, safety audits), thus providing a global and accurate view of airport risks. The results obtained are based on safety reports published by ICAO [26], past incidents, as well as field observations and interviews with experts.

3.1.Airport Risk Identification and Assessment

3.1.1. Risk Identification and Predictive Management

Risk identification is a fundamental step in airport safety management. It is based on a systematic approach combining three complementary methodologies: reactive, proactive and predictive, enabling potential hazards to be detected, analyzed and dealt with comprehensively.
Reactive management involves analyzing incidents after they have occurred, in order to determine the underlying causes and implement corrective measures to avoid their recurrence [27]. This approach relies primarily on the exploitation of incident reports, safety audits and post-event investigations.

In addition, proactive management aims to prevent risks before they occur. It is based on the identification of emerging hazards through systematic observations, regular inspections and in-depth analysis of safety trends [28]. This approach makes it possible to anticipate organizational and operational vulnerabilities in order to reinforce preventive measures.

Finally, predictive management exploits advanced analytical tools, such as historical data processing and statistical forecasting models, to anticipate future risks and implement appropriate mitigation strategies [29]. The integration of techniques such as Flight Data Analysis (FDA) makes it possible to identify weak signals and take preventive decisions before an incident occurs [30].

The effectiveness of this approach relies on the coherent integration of these three approaches within Safety Management Systems (SMS), in line with the recommendations of aviation regulators, notably the Federal Aviation Administration (FAA) and the European Aviation Safety Agency (EASA). The use of databases derived from past incident reports, audits and field observations enables risk identification processes to be continually enriched and management strategies optimized [31].

This identification process is the starting point for the risk assessment cycle, which is based on a systematic analysis of the probability and severity of identified hazards.

3.1.2. Risk Assessment and Prioritization in Airport Safety Management

Once risks have been identified, assessing and prioritizing them is an important step towards effective safety management in the airport area. To ensure a thorough and objective analysis, our methodology is based on a combination of proven approaches: Deming's PDCA (Plan-Do-Check-Act) continuous improvement cycle, benchmarking of best practices in aviation safety, as well as the use of risk matrices according to [5], the International Civil Aviation Organization (ICAO), including Table 1 for risk severity, Table 2 for probability, and Figure 1 for risk matrix. This approach enables a rigorous classification of risks according to their severity and probability of occurrence.

Table 1: *Severity table - Incheon Airport [32]*

	Severity	Loss	Meaning
5	Very High	Human Loss	Casualties are more than 10 people
		Hardware Loss	More than 10 million dollars
		Operational Loss	Airport Close or airport operation suspension
4	High	Human Loss	Casualties are 1 to 9 people
		Hardware Loss	More than 1 million and less than 10 million dollars
		Operational Loss	Runway close: more than 24 H, taxiway and apron close: more than 72 h
3	Moderate	Human Loss	Serious Injuries to be hospitalized
		Hardware Loss	More than 100,000 and less than 1 million dollars
		Operational Loss	Runway close: more than 12 H, taxiway and apron close: less than 72 h
2	Low	Human Loss	Light injuries more than 4 weeks medical treatment
		Hardware Loss	More than 10,000 and less than 100,000 dollars
		Operational Loss	Aircraft Operational Delay 3 H or Aircraft operation cancel
1	Very Low	Human Loss	Light injuries less than 4 weeks medical treatment
		Hardware Loss	less than 10,000 dollars
		Operational Loss	No effect airport operation

Table 2: Probability table - Incheon Airport [32]

Number	Probability	Meaning
5	Very High	It is expected to happen in a month
4	High	It is expected to happen in a year
3	Moderate	It is expected to happen in 5 years
2	Low	It is expected to happen in 20 years
1	Very Low	It is expected don't happen in 20 years

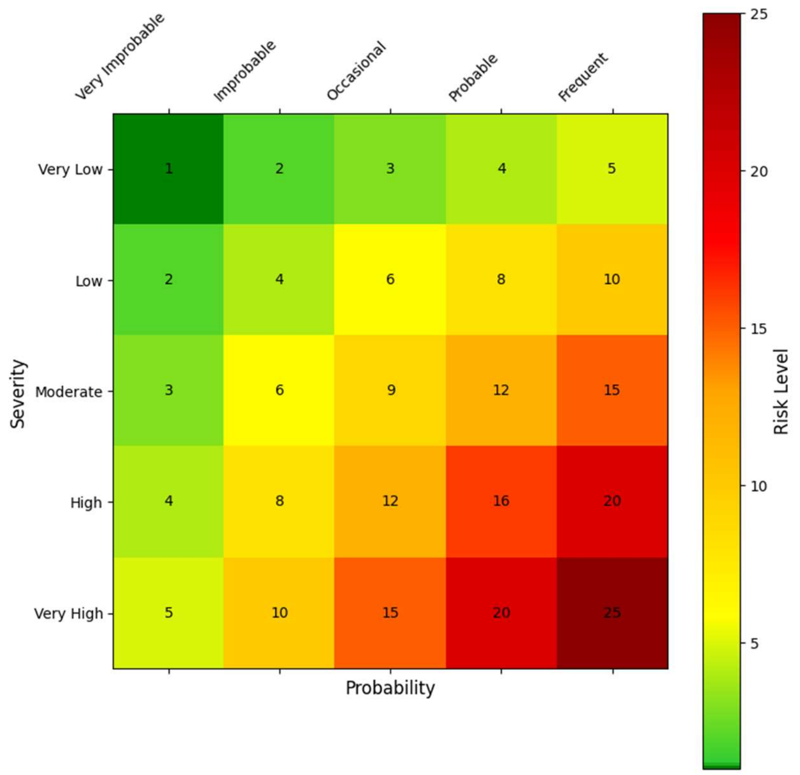

Figure 1: *Risk assessment matrix: severity vs probability [33]*

And for an accurate risk assessment, we have drawn on several models that have demonstrated their effectiveness. A formula based on ten factors to assess wildlife risks was developed in [34], while [35] applied fuzzy logic and FMECA analysis to prioritize 14 risk elements at Taiwan Taoyuan Airport, and [36] proposed an integrated approach combining risk identification and classification according to the effectiveness of mitigation measures. In the same vein, a method for assessing and improving aviation safety was introduced in [20], using Safety Performance Indicators (SPI) and Acceptable Levels of Safety Performance (ALoSP). using analysis of previous years' performance to define alert levels and targets, thus reinforcing proactive management of safety trends.

In addition, Heinrich and Bird risk management models are used to analyze incident frequency and define tolerance thresholds. By studying trends in minor incidents, these models make it possible to anticipate serious events and adapt safety strategies accordingly [37], [38]. This study also incorporates a color-coded severity/probability risk matrix Figure 1, which visually represents risk levels from green to red. This graphical tool supports a clearer classification of hazards and facilitates strategic decision-making by safety managers based on the degree of risk severity.

Based on this research, we have designed an innovative table that brings together all airport risks in order to prioritize and assess them more accurately and comprehensively. More detailed than existing models, this table incorporates new equations for calculating key performance indicators, ensuring ongoing assessment and better comparison of results over time and with other airports.

The method we have proposed is based on a combination of the PDCA cycle and benchmarking, enabling continuous improvement and dynamic risk assessment. PDCA facilitates regular reassessment and adaptation of safety strategies in line with data collected and results obtained. In addition, benchmarking enables risk indicators to be compared with those of other airports, providing a valuable perspective for optimizing risk management.

Although the ICAO risk matrices and the methodology they propose are fundamental, our approach enriches them to provide a more detailed analysis, better adapted to the specificities of airport risks. This method guarantees proactive and continuous risk management, meeting the needs of airport safety managers.

A detailed example of the application of this methodology is presented in the "Case studies" section, where we analyze the results obtained to demonstrate the effectiveness of this approach.

3.2. Model for Airport Risk Assessment and Safety Improvement

The development of our model is based on a structured, multi-stage approach, combining proven methods to ensure accurate assessment and continuous improvement of airport safety.

3.2.1. Analysis of Existing Methods and Model Justification

In this section, we began by reviewing existing approaches to airport risk assessment to identify their strengths and limitations. Benchmarking, used in various sectors to improve risk management, has helped identify best practices and common weaknesses [39], [40], [41]. At the same time, the PDCA (Plan-Do-Check-Act) cycle has proven to be an effective tool for continuous improvement in management systems, particularly in safety and risk management [42].

3.2.2. Structuring Risk Assessment

Based on these approaches, we have developed a framework for rigorous airport risk assessment. This framework is based on two key elements:

a. Benchmarking: By comparing safety performance between different airports and over different time periods, we have identified gaps and opportunities for improvement. This method has also been used in other sectors to refine risk assessment, notably in the analysis of specific substances such as trichloroethene [43].

b. Application of the PDCA cycle: This cycle structured our risk management approach into four interconnected stages:

- Plan: Identification and prioritization of risks using ICAO risk matrices and performance indicators.
- Do: Implementation of mitigation measures and improvement strategies.
- Check: Monitoring and evaluation of safety indicators to measure the effectiveness of the system.
- Act: Continuous adjustment and optimization of strategies based on results obtained.

3.2.3. Development of an Innovative Risk Analysis Chart

Based on the analyses carried out, we designed a table to group and prioritize airport risks. This table, which is more detailed than existing ones, incorporates several elements:

- Specific equations: These allow for the calculation of key performance indicators (KPIs) and the establishment of alert thresholds based on observed trends [20].

- An ISO 31000:2019-compliant approach: This ensures proactive risk management, in line with international standards [44].

- Dynamic comparison with other airports and previous years' performance: This comparison provides an evolving view of risk management.

3.2.4. Validation and Prospects for Improvement

To validate our model, we carried out a series of case studies, which tested the effectiveness of the approach. These analyses showed that the combination of benchmarking and the PDCA cycle optimizes risk management. This approach guarantees not only continuous improvement but also reactive and predictive risk management, thanks to up-to-date data and adjustments based on benchmarking.

To illustrate the applicability of the proposed methodology, the model was tested using representative operational data from a real-world airport environment. This demonstration highlights the model's practical feasibility without disclosing sensitive or proprietary operational details.

We developed an integrated model Figure 2 for airport safety identification, assessment, and improvement, incorporating methods such as benchmarking and the PDCA cycle. This framework provides a systematic approach to identifying, assessing, and mitigating risks at the airport, thus fostering a continuous process of safety improvement.

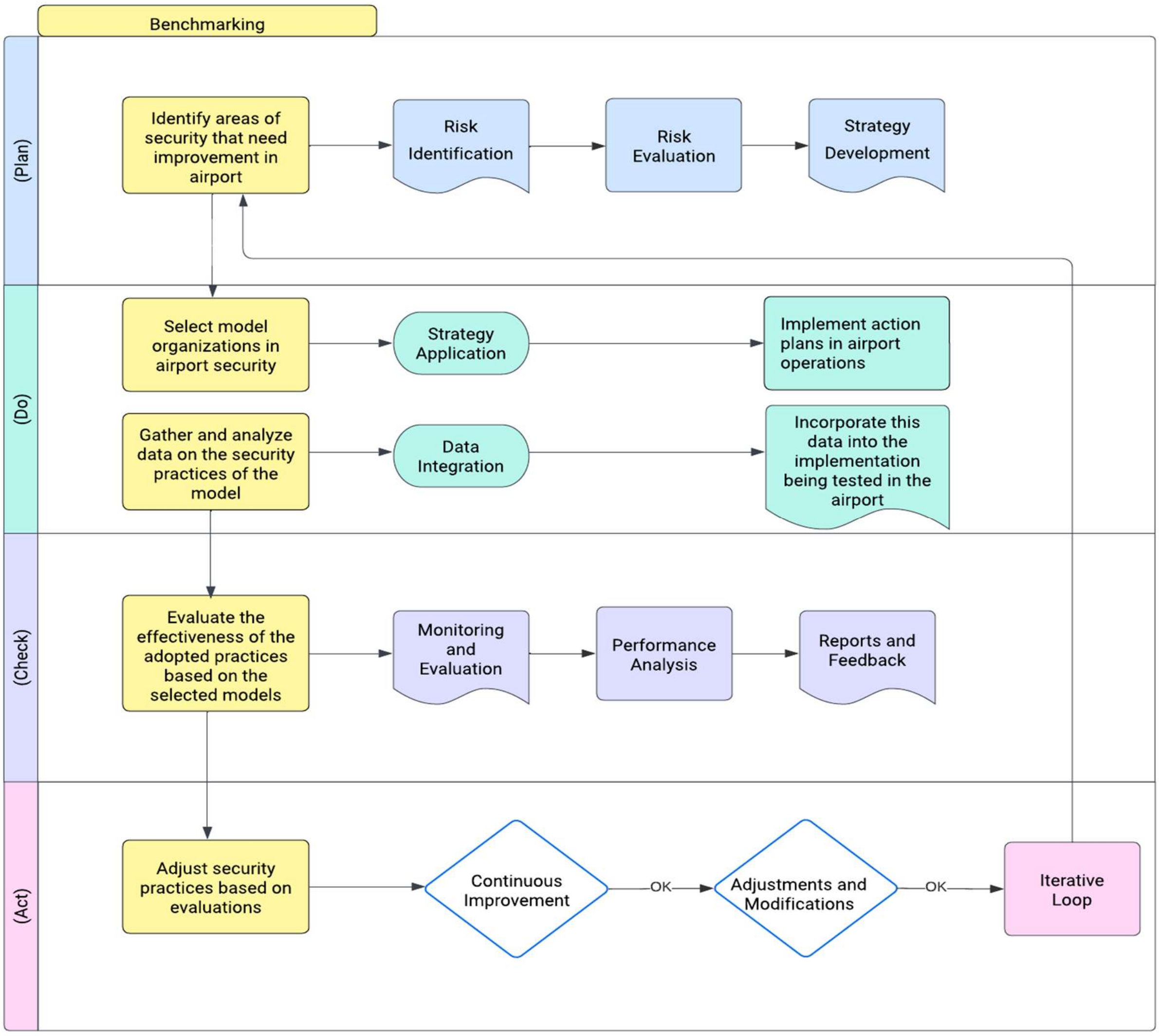

Figure 2 : *Integrated Model for Airport Safety Identification and Improvement*

The Airport Safety Identification, Assessment, and Improvement with Benchmarking and PDCA module offers a structured four-phase process for continuously improving safety in airport operations.

- In the Planning phase, risks are identified, assessed, and strategies are developed to mitigate them.
- The Implementation phase then puts these strategies into action.
- The Verification phase monitors and evaluates their effectiveness. The identification of potential risks specific to the airport plays a crucial role in this phase, helping to determine safety threats and vulnerabilities.
- The last phase is Action, to make improvements and repeat the process till the safety of the airport improves.

The new model could serve as a continuous mechanism to improve airport safety. This attracts benchmarking to keep up its superior standard of safety, while adaptability assures that it is able to respond to the latest airport safety issues in a more flexible operational milieu.

Furthermore, this dynamic integration enables continuous learning from both internal performance trends and external benchmarking results. It allows for the proactive identification of emerging risks and fosters a data-driven culture of improvement. The alignment with Safety Performance Indicators (SPI) and Acceptable Levels of Safety Performance (ALoSP) further strengthens its effectiveness. Ultimately, this model enhances the airport's capacity to anticipate and manage complex safety challenges in an evolving operational environment.

IV. Case Study: Risk Assessment And Performance Evaluation In Airport Safety

Following an in-depth study based on the results of a questionnaire sent out to a group of airport safety managers, as well as the previously cited research into the various safety assessment methods, we have developed a risk assessment table.

To demonstrate the applicability of the proposed method, the following example uses simulated operational data inspired by real-world airport contexts. These data were constructed for illustrative purposes and do not represent any specific airport's confidential records.

This tool brings together the data collected and, thanks to automated calculations, provides a clear picture of the level of risk at the airport.

In this approach, safety managers first carry out a careful collection of relevant data, including past incidents and previous risk assessments. This information is then integrated into the table, which identifies, analyzes and evaluates risks in terms of probability and severity. Based on this analysis, the results obtained provide a better understanding of airport risk trends and identify deviations requiring corrective action. Finally, targeted mitigation measures are put in place to reduce or eliminate the most significant risks, thus ensuring the safety and reliability of airport operations.

Emphasizing that an SPI program is first and foremost a measure of management performance and that you can only manage what you measure [45], it is essential to effectively evaluate safety performance indicators. To illustrate the method used, we take the following example to explain risk assessment by measuring safety performance indicators SPI and SPT, in line with the methodology established by the ICAO [20].

Table 3: *Sample data sheet used to generate a high-consequence SSP safety indicator chart (with alert and target-setting criteria)*

Preceding Year				
Mth	All Operators Total FH	All Operators Mandatory Incidents	Incident Rate*	Ave (line)
Jan	29854	4	0,13	0,21
Feb	28725	5	0,17	0,21
Mar	28904	5	0,17	0,21
Apr	27460	8	0,29	0,21
May	28986	6	0,21	0,21
Jun	32344	4	0,12	0,21
Jul	33678	6	0,18	0,21
Aug	30904	5	0,16	0,21
Sep	29866	7	0,23	0,21
Oct	29974	4	0,13	0,21
Nov	29955	2	0,07	0,21
Dec	30744	6	0,20	0,21
		Ave	0,17	
		SD	0,06	

Current year				Current Year Alert Levels			
Mth	All Operators Total FH	All Operators Mandatory Incidents	Incident Rate*	Preceding Year Ave +1SD (line)	Preceding Year Ave +2SD (line)	Preceding Year Ave +3SD (line)	Current Year Target (line)
Dec	30744	6	0,20	0,23	0,29	0,35	0,20
Jan	29674	3	0,10	0,23	0,29	0,35	0,20
Feb	29316	4	0,14	0,23	0,29	0,35	0,20
Mar	28482	7	0,25	0,23	0,29	0,35	0,20
Apr	29 549	4	0,14	0,23	0,29	0,35	0,20
May	30786	5	0,16	0,23	0,29	0,35	0,20
Jun				0,23	0,29	0,35	0,20
Jul				0,23	0,29	0,35	0,20
Aug				0,23	0,29	0,35	0,20
Sep				0,23	0,29	0,35	0,20
Oct				0,23	0,29	0,35	0,20
Nov				0,23	0,29	0,35	0,20
Dec				0,23	0,29	0,35	0,20
		Ave	0,16				
		SD	0,05				

AVE+1SD	AVE+2SD	AVE+3SD
0,23	0,29	0,35

Current Year Target is ,say, 5% Ave rate improvement over the Ave rate for the preceding year, which is SPT: **16**

Current Year Alert Level setting criteria is: Preceding Year Ave + 1/2/3 SD

Table 3 shows the recorded data on the number of movements versus the number of incidents for each month of the previous and current year. This information enables a detailed analysis of monthly trends and potential correlations between movements and incidents. On the basis of this table, the SPT is calculated for comparison with the SPI, determined in the next step.

The data in Table 3 corresponds to the graph in Figure 3 and can also be used to generate additional graphs displaying alert and target lines. These graphs are automatically generated using predefined parameters, as specified in ICAO Document [46]

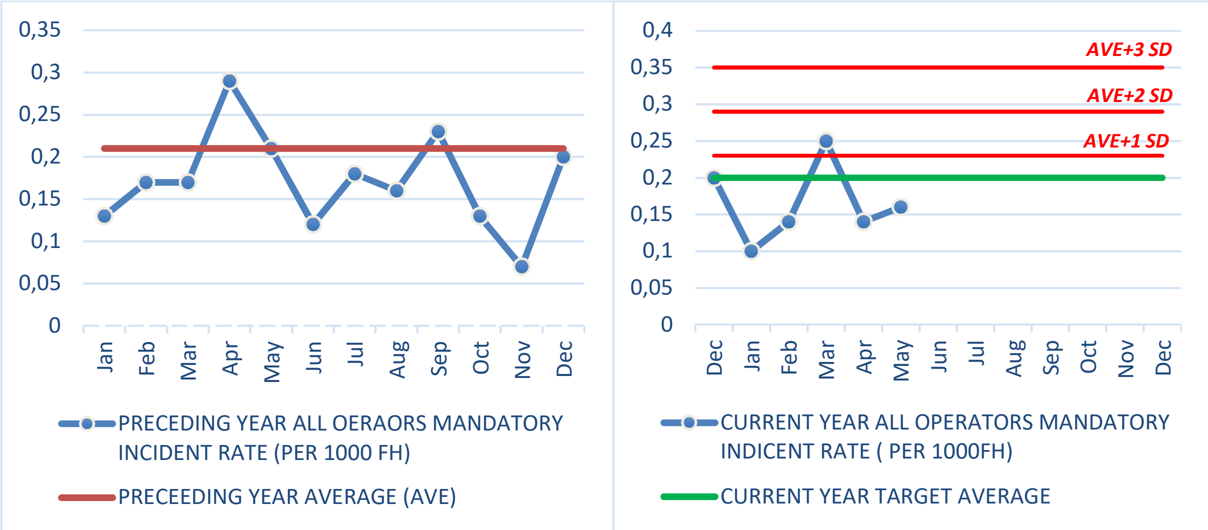

Figure 3 :*Example of an SSP safety performance indicator chart (with alert and target level settings)*

Figure 3 graphically presents an example of a high-consequence safety performance indicator, in this case, the aggregated incident rates reported by all operators. The graphs display the previous year's performance alongside expected trends for the current year. The alert level is determined based on standard safety deviation criteria and is calculated using either the Excel formula “=STDEVP” or through manual computation [46].

The standard deviation (σ) is given by the formula:

$$\sigma = \sqrt{\frac{\sum(\mathrm{xi}-\mu)2}{N}} \qquad (1)$$

Where “X” is the value of each data point, “N” is the number of data points and “μ” is the mean value of all data points [46].

This figure provides an overview of the safety level, relying on the previous year’s average (Ave) and standard deviation (SD) to define alert thresholds. An alert is triggered when a single data point exceeds 3 SD, two consecutive data points exceed 2 SD, or three consecutive data points exceed 1 SD, indicating a significant deviation that requires corrective action [20].

To ensure continuous improvement, the target is to reduce the average incidence rate by at least 5% compared to the previous year. If this reduction is achieved by the end of the monitoring period, the target is considered met. Alert and target levels are reviewed annually and recalibrated if necessary, based on recent data and changing trends in operational safety, ensuring continuous safety improvement.

This method of assessing overall airport safety is widely used and considered practical. However, an in-depth study based on a questionnaire identified certain limitations. Our findings indicate that this method is both effective and practical for safety managers. However, it does have one important limitation: when a monitoring graph triggers an alert, it can be complex to determine precisely the origin of the problem and the specific risk to be mitigated.

To solve this problem, we have proposed a more precise and complementary method, based on the same principle as the one previously explained, but with an enhanced ability to detect exactly which risks require mitigation. Rather than replacing the existing approach, this method enhances its effectiveness by providing a more detailed risk identification process, allowing safety managers to take targeted actions.

As a first step, it is essential to identify and collect all the risks present at the airport, and then report them in the following table:

Table 4: *Table of existing risks in the airport and their acceptability level*

Risk	Description	Severity	Probability	Risk Level	Risk Acceptability
Runway foray	Unauthorized entry onto a track	5	1	5	Tolerable under control
Fire on the tarmac	Fire on the airport grounds	2	2	4	Acceptable
Act of terrorism	Terrorist attack in the airport	5	2	10	Tolerable with mitigation
Fuel leak	Fuel spill on tarmac	3	2	6	Tolerable under control
Lost or stolen baggage	Lost or stolen baggage	2	4	8	Tolerable under control
Air traffic control system failure	Faulty air traffic control system	4	2	8	Tolerable under control
Aircraft collision	Airplane accident in flight or on the ground	5	4	20	Unacceptable
Identity theft	Fraudulent use of identities	3	1	3	Acceptable
Infiltration of illicit substances	Introduction of illicit substances	4	2	8	Tolerable under control
Cybersecurity breach	Computer attack on the system	4	3	12	Tolerable with mitigation
Poor waste management	Improper waste disposal	1	3	3	Acceptable
Damage caused by personnel	Human errors or negligence	3	3	9	Tolerable under control
Failure of safety equipment	Equipment malfunction	4	2	8	Tolerable under control
Environmental pollution	Spill of harmful substances	1	2	2	Acceptable
Severe weather	Extreme weather conditions	4	3	12	Tolerable with mitigation
Signaling failure	Failure of traffic signs	3	3	9	Tolerable under control
Tentative d'intrusion	Perimeter intrusion attempt	4	2	8	Tolerable under control
Contamination of food	Food contamination	2	2	4	Acceptable
IT security incidents	Computer attacks on systems	4	3	12	Tolerable with mitigation
Traffic accidents	Accidents involving vehicles	3	4	12	Tolerable with mitigation
Bomb threat	Bomb threat or threat	5	1	5	Tolerable under control
TOTAL		71	51		

Based on the ICAO risk matrices Tables 1 and 2, a comprehensive Excel-based tool was developed to capture all potential hazards identified within the airport under evaluation. Each risk is assigned a severity and probability level, which are then multiplied to calculate a specific risk level. This result is visually translated using a color-coded matrix Figure 1, ranging from green to dark red, indicating the degree of severity and guiding the type of response required. This approach provides a clear visual interpretation of each individual risk.

Beyond individual assessment, the total severity and probability values are aggregated and incorporated into a custom-built equation, specifically developed, tested, and validated in this study. This original formula (2) enables airport safety managers, after completing the Excel-based assessment table with the severity and probability values, to automatically obtain key performance indicators and a global view of the overall risk level within the airport. These indicators can then be used to track performance over time and benchmark safety status against previous years or other comparable airports.

The aggregated values are then used in the following equation to calculate the Safety Performance Indicator (SPI).

$$SPI' = \frac{S\mu}{5} \times \frac{P\mu}{5} \qquad (2)$$

Where: $S\mu = \frac{\sum S}{N}$ (3) and $P\mu = \frac{\sum P}{N}$ (4)

With Sμ representing the overall average severity and Pμ representing the overall average probability, and N representing the total number of existing risks in the airport.

Consider the provided example:

$$S\mu = \frac{71}{21} = 3{,}38 \quad (5) \qquad P\mu = \frac{51}{21} = 2{,}42 \quad (6)$$

Therefore: $SPI' = \frac{3{,}38}{5} \times \frac{2{,}42}{5} = 0{,}32$ (7)

As part of the airport safety assessment, we compare the SPI' safety performance index (7) with the SPT performance target, which is calculated based on the data in Table 3, to determine whether the airport meets the required thresholds, and compare it with the SPI' calculated from the data in Table 4.

- If SPI' is less than or equal to SPT, the airport's safety level is considered acceptable.
- If SPI' exceeds SPT, this indicates that the airport does not meet minimum safety standards, requiring immediate corrective action.

The airport safety manager focuses on the dark red and red-colored risks in Table 4 above and implements suitable controls immediately. Then, they address the orange-colored risks, before progressively mitigating those identified in yellow, in order to reduce the SPI below the SPT threshold.

This approach helps detect major risks at the airport and take appropriate measures to ensure the highest level of safety. The reassessment must be conducted every six months or annually, depending on the airport's category, following the outlined steps to ensure continuous improvement in airport safety.

V. Discussion And Evaluation Of The Proposed Safety Assessment Approach

This is one of a number of studies aiming at improving airport safety management systems (SMS). It proposes a novel approach that integrates the PDCA (Plan-Do-Check-Act) cycle with benchmarking technique to proactively identify and manage risks. Airport safety management have evaluated and confirmed this approach, which uses a risk table to categorize dangers based on their frequency and severity.

Method Effectiveness

The method developed proved significantly more effective than traditional approaches. By systematically collecting and evaluating risk data, it enables targeted prioritization of corrective actions. The SPI (Safety Performance Indicator) and SPT (Safety Performance Target) indicators, derived from the data collected, provide a global frame of reference. They allow both the comparison of performance between airports and the deployment of improvement strategies according to the standards of ICAO (International Civil Aviation Organization).

The Excel table is the key to being able to clearly visualize critical risks, especially with red zones highlighting the priorities. This strengthens the safety measures as it allows the risks once identified to be managed efficiently and effectively.

Alignment With Recent Advances In Predictive Safety Modeling

This method adds a dynamic aspect through the PDCA cycle, unlike static methods that rely on past data, like probabilistic models or risk contour maps [23], [47]. It ensures continuous evaluation and progressive performance improvement.

Recent research has investigated novel approaches in [21] and [48], such as structured models for identifying risks based on safety data trends and entropy-based frameworks to handle the increased complexity of airport settings. While [21] focused on forecasting risks using historical safety logs, our method expands on this work by incorporating an iterative improvement process through benchmarking and the PDCA cycle, which could be further improved by incorporating data-driven techniques such as the LSTM algorithm for real-time monitoring and predictive analysis.

Identified Challenges And Proposed Solutions

One of the major challenges encountered is the heterogeneity of risk assessment by different managers, leading to variations in results. For example, a similar risk may be classified differently depending on the experience or interpretation of the assessors. To remedy this problem, it is essential to introduce standardized training aimed at harmonizing risk assessment criteria.

Practical Application And Benchmarking

Benchmarking is a key component of this approach, making it possible not only to place an airport's performance in a global context but also to identify opportunities for improvement by drawing on industry best practices. Comparative analysis of SPI and SPT data has helped to assess performance gaps and justify immediate corrective action, particularly where SPI exceeds SPT.

This structured approach maintains airport operations within acceptable limits while ensuring adherence to international standards. It also contributes to a robust safety culture, essential in a complex airport environment.

Global Impact On Airport Safety

By combining the PDCA cycle with benchmarking, this method promotes continuous improvement in airport safety. Each step—from planning to action—is designed to iteratively identify, assess, and mitigate risks. By integrating advanced technologies and drawing on international standards, it transforms SMS into predictive and adaptive systems capable of meeting future challenges.

The obtained results show that this method not only contributes to risk management but also to a more rigorous safety discipline. In this sense, it represents a major step forward in guaranteeing the safety and reliability of airport operations.

VI. Conclusion

This study presents a dynamic and forward-looking approach to managing airport safety by combining the PDCA cycle with benchmarking in the risk assessment process. At the core of this method is a risk evaluation table that allows for clear classification of hazards and consistent monitoring of key safety performance indicators (SPI and SPT), contributing to continuous improvement in line with ICAO recommendations. In practice, this approach makes risk management more structured, scalable, and responsive, allowing for more informed decisions and improved foresight of safety hazards. While the results are encouraging, the approach can yet be improved and tailored to other airport scenarios. In the future, it could be used with modern technology to improve both safety oversight and operational performance.

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