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Learning from Past in the Commercial Air Transport Industry: A Bibliometric Analysis and Systematic Literature Review in the Safety Management Framework

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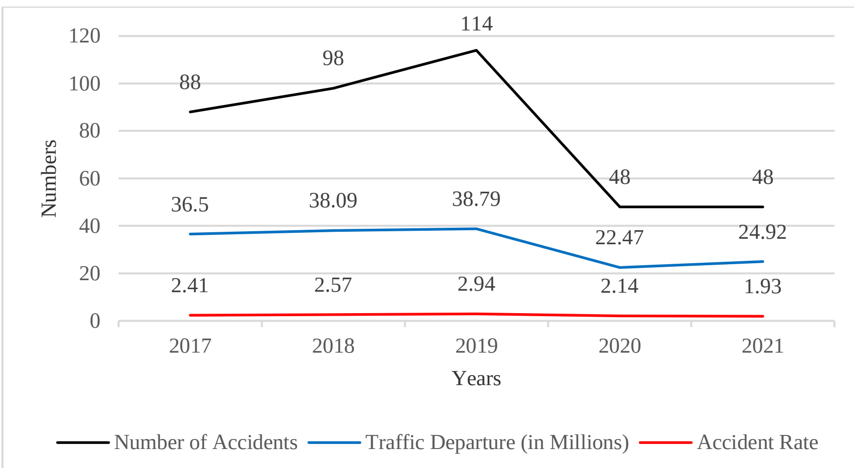
The sole purpose of investigating aircraft accidents and incidents is to avoid recurrence (ICAO, 2020). It is not only the aviation industry; usually, irrespective of the type of industry, the primary purpose of investigating any disaster is to learn lessons from it for safer practices. However, a study by Drupsteen et al. (2013) on various industries, including construction, chemical, energy, and transportation, reveals that “numerous accidents have occurred because organizations have failed to learn lessons from the past.” The commercial air transportation (CAT) industry also exhibits the same pattern; on 13 Apr 2015, at Khajuraho, India airport, flight 9W 2423 (Boeing 737 NG) of an Indian commercial aircraft operator soon after the landing met with an accident (AAIB, 2017a). During the touching-down phase of the landing roll, the left side main landing gear (MLG) collapsed, which resulted in the aircraft’s left engine rubbing the runway surface and veering to the left from the runway centerline before stopping. The aircraft sustained extensive damage and blocked the runway for several hours. The failure of the left side MLG aft trunnion pin (a critical load-bearing member of the MLG assembly) was identified as the immediate cause of the accident.

Almost a year later, on 03 March 2016, another flight, 9W 354 (Boeing 737 NG) of the same operator, was involved in an accident during the landing roll at Mumbai, India airport (AAIB, 2017b). This time, the right MLG collapsed after touching down, and the aircraft deviated to the right from the centerline of the runway, and the same load-bearing member; this time, the right side MLG aft trunnion pin was found sheared off. Both accidents occurred with the same airline within less than a year, and the same maintenance agency overhauled both failed parts. The safety investigation reports of both occurrences are available in the open domain to get more insights. In addition to this, the Aviation Safety Network (ASN) database contains multiple accident records indexed under the same contributory or causal factors. Therefore, it is reasonable to infer that the recurrence of past accidents continues, and the potential of past safety occurrences is still not fully utilized to improve safety performance. The cited mishaps and the ASN database underscore the need to investigate learning from the past and the complexities of the aviation industry.

Current Safety State

CAT is one of the safest means of transportation, and now, the real challenge to the stakeholders is to improve the safety of an already ultra-safe industry (Shappell et al., 2007; Wiegmann & Shappell, 2017). One of the reflections of the safety performance of the CAT sector is the ICAO annual safety report (ICAO, 2022), which exhibits the number of accidents, accident rate, and traffic departures (Figure 1). The data between 2019 and 2021 does not indicate the usual trend of the industry, as the pandemic drastically reduced aircraft operations. The critical aspects of aviation safety are its societal perception and the growth rate. The general public and passengers perceive aviation safety in absolute numbers of accidents, not the accident rate, and increased commercial aviation accidents might be unacceptable to societies (Gerede, 2015; Martins, 2016). On the other hand, the growth in CAT predicted by the leading aircraft manufacturers (Airbus, 2022) and (Boeing, 2022) poses severe challenges in keeping the number of accidents constant. This aspect is evident in the pre-pandemic period (Figure 1) when the rise in departures has significantly increased the number of accidents, whereas the accident rate is marginally augmented. Further, the impact global aerospace and aviation communities and societies have suffered in the aftermath of two Boeing 737 Max accidents in late 2018 and early 2019 is challenging to realize in terms of the accident rate. Therefore, the present state of global CAT safety is to be further enhanced to accommodate the predicted growth and acceptability of societies.

Figure 1
CAT Accident Statistics (ICAO, 2022)



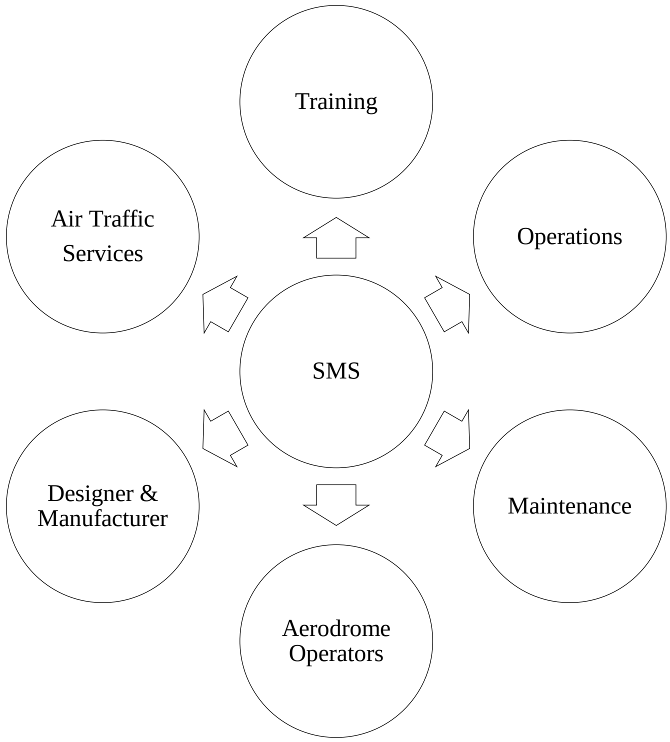
Current Regulatory Framework

The aviation industry's current safety management system (SMS) framework is an all-inclusive systemic approach to managing safety. The standards and recommendations of ICAO Annex 19 "Safety Management" second edition mandate that with effect from November 2019, all the stakeholders, for instance, airlines, freighter carriers, training organizations, aircraft designers and manufacturers, engine designers and manufacturers, propeller and aircraft components designers and manufacturers, air traffic service providers, aerodrome service providers are to integrate SMS framework into their business processes (Figure 2). In compliance with the regulations, all the industry stakeholders have attained a varied maturity level in implementing a safety management framework in their business processes. In the aviation context, safety is “The state in which risks associated with aviation activities, related to, or in direct support of the operation of aircraft, are reduced and controlled to an acceptable level” (ICAO, 2016). The intent and practicalities of this definition are amplified with the description of the hazard and operation-centric aviation activities. Hazards are omnipresent and dynamic and can be in different forms, such as unsafe acts, unsafe conditions, and unsafe objects having the potential to contribute to or cause an aircraft accident or incident. On the other hand, countless activities directly or indirectly support aircraft flying operations; for instance, air traffic management, aerodrome operations, aircrew, air traffic controllers and maintenance engineers training, and aircraft maintenance have a direct bearing on aviation safety. Thus, by combining all the aspects, safety management in aviation simplistically is a three-step process: first, identifying the omnipresent hazards in various aviation-related activities in the stakeholder’s business processes, assessing the associated risk, and finally, controlling or mitigating the risk linked to the hazard. One critical aspect of the SMS framework is “hazard identification and risk management” (HIRM).

The concept of HIRM essentially translates into identifying unsafe acts, unsafe conditions, and unsafe objects by the front-line personnel in day-to-day work and mitigating the associated risks before they lead to accidents. In the SMS framework, two methodologies are broadly used for hazard identification: reactive and proactive. While reactive hazard identification relies on the safety data and information drawn from past accidents and incidents, or in other words, on learning from the past, the proactive is an ongoing process-centric method. This literature review deals with the aviation industry's first step of safety management, i.e., hazard identification by reactive methodology.

Figure 2

SMS Framework Applicability to Aviation Industry Stakeholders (ICAO, 2016)



Aim and Applicability of the Literature Review

The literature review aims to investigate scholarly literature on "learning from the past" in the aviation industry while attempting to answer the following research questions:

RQ1: How has academic literature progressed on "learning from the past" with time since 2000, and the contribution of the journals, educational institutions, and countries to the progress?

RQ2: What are the prominent words and themes in scholarly literature related to "learning from the past?"

RQ3: How many studies are related to "learning from the past" in the SMS framework?

RQ4: What are the gaps in the scholarly approach and regulatory SMS framework on the "learning from the past" process?

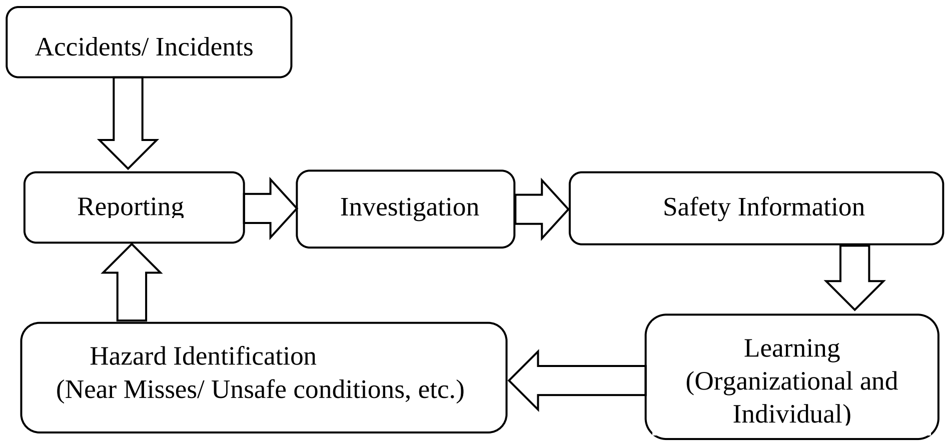
This review is novel on two counts; firstly, the scholarly literature is viewed through the prism of the current regulatory framework to include the aspects practiced in the global aviation industry. Secondly, it also identifies the gaps in the current regulatory guidelines-driven learning framework that may dilute the impact of the reactive methodology on overall safety management. In this study, the standard terms, such as “serious incident,” “incident,” “accident,” “safety data,” “safety information,” “causes,” and “contributory factors” are used as outlined in ICAO Annex 13, twelfth edition (ICAO, 2020). The review’s outcome sets the agenda to bridge the gaps in the reviewed literature for research scholars and an understanding of reactive methodology-based safety management to state regulators, safety practitioners, safety managers, and higher management, including Accountable Managers (usually CEOs) of the aviation industry.

Methodology

This review follows a mixed approach to achieve its aim. Usually, when the objective is broad, a bibliometric analysis is preferred, whereas for addressing the specificities, a systematic literature review is an appropriate method (Donthu et al., 2021). Therefore, a bibliometric review is suitable for the first two research questions using an R-tool, software version R 4.3.1, R studio, and biblioshiny packages, as it consists of multiple descriptive analysis functions in the bibliographic data frame (Aria & Cuccurullo, 2017). Additionally, the ‘word cloud’ and ‘thematic’ data analysis will likely assist in the inclusion /exclusion of studies for the other research questions. To address the third and fourth research questions, a systematic literature review is conducted in the framework derived from the reactive methodology-based hazard identification strategies of the SMS (Figure 3), complying with Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) updated version guidelines (Page et al., 2021). The regulatory ‘learning from past accidents’ framework comprises multiple safety management-centric stages. In an organizational setup, in the event of an accident/incident or near-miss, the process is initiated with ‘reporting’ followed by investigating to generate safety information for individual and organizational learning from the past.

Figure 3

Learning from Past Framework in the Aviation Industry (ICAO, 2016)



Search Strategy

Xiao and Watson (2019) illustrated that a systematic review's quality is a function of the collected literature and suggested electronic databases and forward and backward searching methods to find suitable literature. Of these three, electronic databases are the most prevalent source of academic literature (Popay et al., 2006). Therefore, this review used the electronic databases Scopus and Web of Science to search for peer-reviewed scholarly literature aligned with the review's objectives. The search was restricted to the year 2000 and onwards as the safety management concept in aviation safety has been prevalent since the beginning of the 21st century; more precisely, the first edition of ICAO Annex 19 on safety management was published in 2013. The keywords and Boolean operators used in the search string are derived from the intent of “learning from the past” in the aviation industry, including learning from accidents, incidents, unsafe conditions, unsafe acts, and near misses. Accordingly, the filters are applied to search only published research articles in peer-reviewed journals in English until July 2023. The search syntax used for Scopus and Web of Science databases is exhibited in Table 1.

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Table 1
Database Search Syntax

Databases	Search Syntax
Scopus	TITLE-ABS-KEY (("learning ") AND ((past) OR (accident*) OR (incident*) OR ("unsafe condition*")OR("unsafe act*")OR("near-miss*")AND("aviation*"))) AND (LIMIT-TO (SRCTYPE,"j")) AND (LIMIT-TO (PUBSTAGE,"final")) AND (LIMIT-TO (DOCTYPE,"ar")) AND (LIMIT-TO (LANGUAGE,"English"))
Web of Science	All=((("learning ") AND ((past) OR (accident*) OR (incident*) OR ("unsafe condition*")OR("unsafe act*")OR("near miss*"))AND("aviation*"))) [limited to research articles published in English]

Inclusion and Exclusion Criteria

The inclusion and exclusion criteria are meant to select appropriate literature for the third and fourth research questions. Following the PRISMA protocol, the inclusion and exclusion criteria are defined, considering its implementation in two stages. First, based on the title and abstract screening, and second, after downloading the complete article and assessing their eligibility.

The scope of the literature review is limited to the commercial air transportation sector as it represents the lion's share of the aviation sector (EASA, 2017). The studies on general aviation, military aviation, and unmanned aerial vehicles are excluded from the scope of the review. Another criterion to include or exclude a study is based on the methodology adopted. The quantitative research studies aimed to describe the utility of past accident data by machine learning, neural and deep learning, and other artificial intelligence tools are excluded as these studies do not represent the post-accident learning framework. Globally, the aviation industry complies with the standards and recommended practices of ICAO Annex 13, which mandates that each aircraft accident, serious incident, and incident be reported and investigated. An investigation includes collecting information about the accidents/incidents, determining causes and contributory factors, drawing conclusions, and making recommendations to the stakeholders to prevent recurrence (ICAO, 2020). The learning contents from past accidents and incidents are the safety data/information and the recommendations derived from the investigation. Therefore, this review includes research articles conducted using qualitative or mixed methodology and related to the procedural stages of learning from accidents and incidents in the industrial setting.

In the context of safety, the 'learning from past accidents and incidents' concept is broadly followed in all industrial and nonindustrial sectors. The studies conducted in the industries, for instance, sports and adventures, fire and rescue, academic, medical and health care, etc., that are not aligned with the review's objectives are excluded from this review. A consolidated summary of inclusion and exclusion criteria (Table 2) is presented.

Table 2
Inclusion and Exclusion Criteria

Included	Excluded
Research articles focused on the SMS or structured approach to learning from accidents or incidents in the aviation industry setting.	Quantitative studies focused on applying various artificial intelligence and machine learning tools.
Research articles describing and related to any stages of learning from accidents and incidents in the organizational setting.	Studies related to applying learning from past concepts in health, medical & patient care sectors.
Peer-reviewed research articles published in the Scopus and Web of Science-indexed Journals from 2000 onwards in English.	Studies centered on aviation training, emergency rescue, simulations, virtual reality, sports & adventures, fire, etc.
Research articles that followed the qualitative or mixed approach.	Review articles and conference papers.

Quality Assessment

This review has extracted research studies from Scopus and Web of Science databases. Some Journals are indexed in both databases and searched studies may likely be duplicated. This review considers a unique research study by excluding all duplicate entries.

Results

Scholarly literature was searched on 12 Aug 2023, and the defined search strings in the Scopus database yielded 222 results, whereas Web of Science searched 192 studies. The records from both databases were exported with the complete information/full records in comma-separated values (CSV) and plaintext format, respectively. Subsequently, using the biblioshiny package, both files were converted to Excel format and loaded into the R studio environment. Using the simple R commands in the R Studio, both the files were merged, duplicate records (131) were removed, and 283 unique studies with 30 variables were obtained for further analysis.

Evaluating the completeness of bibliographic metadata is essential as it is related to the quality of results. A database of 283 unique studies with 30 variables was loaded into the biblioshiny package, and the acceptable metadata description

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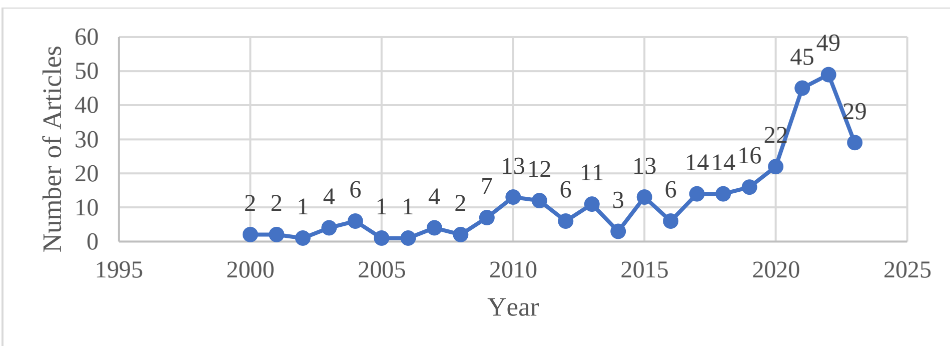
with the corresponding degree of available counts was evaluated. While the metadata for variables, publication year, corresponding author country, source, and affiliation ranged from excellent to acceptable, the available counts for ‘keywords’ and ‘keyword plus’ were around 65% and were observed in the ‘poor range.’ Therefore, this review's ‘word cloud’ and ‘thematic mapping’ are based on the ‘Abstract’ field variable.

Academic literature progress on ‘learning from the past’ since 2000 (Figure 4), the contribution of the countries based on the corresponding author (Figure 5), leading contributory Journals (Figure 6), and the educational institutions where authors have published ten or more articles are shown in Figure 7.

Figure 4

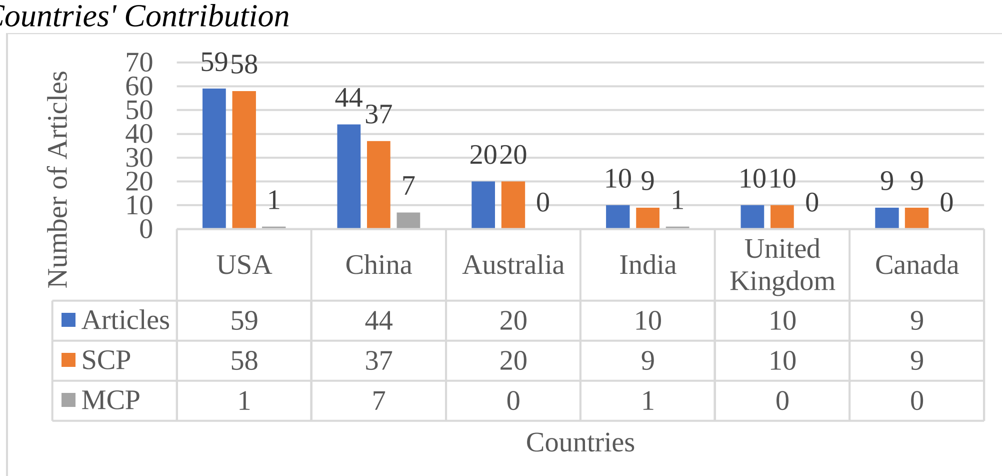
Academic Literature Progress



Note. Source: Biblioshiny Package Annual Scientific Production

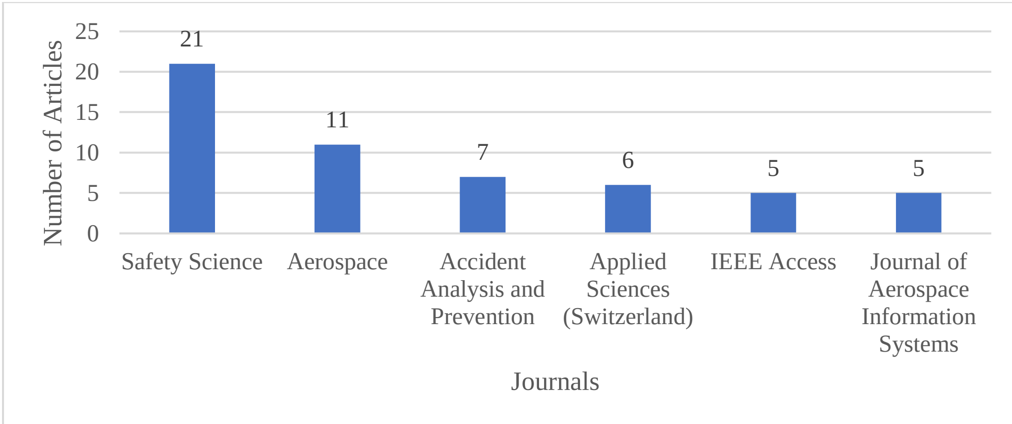
Figure 5

Countries' Contribution



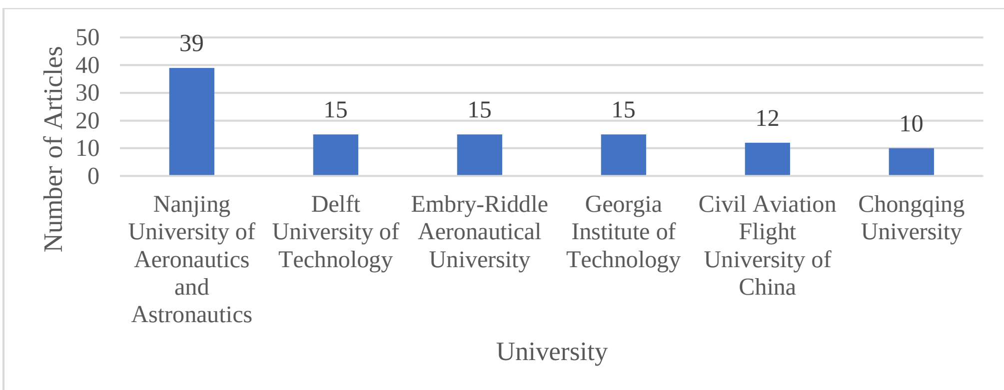
Note. Source: Biblioshiny Package Author Countries

Figure 6
Journals' Contribution



Note. Source: Biblioshiny Package Most Relevant Sources

Figure 7
Academia Contribution



Note. Source: Biblioshiny Package Most Relevant Affiliations

Word Cloud and Thematic Mapping

In this review, the variable 'Abstract' of the 283 records is scanned in R environment in bigram and trigram settings, and the results are exhibited in Figure 8 and Figure 9, respectively.

Figure 8
Word Cloud (Bigrams)

Figure 9
Word Cloud (Trigrams)

Thematic clustering of the "Abstract" variable using bigrams with no word stemming is shown in Figure 10. Out of the total 20 clusters, the prominent clusters (frequency of more than 50) with respective density and centrality are exhibited in Table 3.

Figure 10
Thematic Map

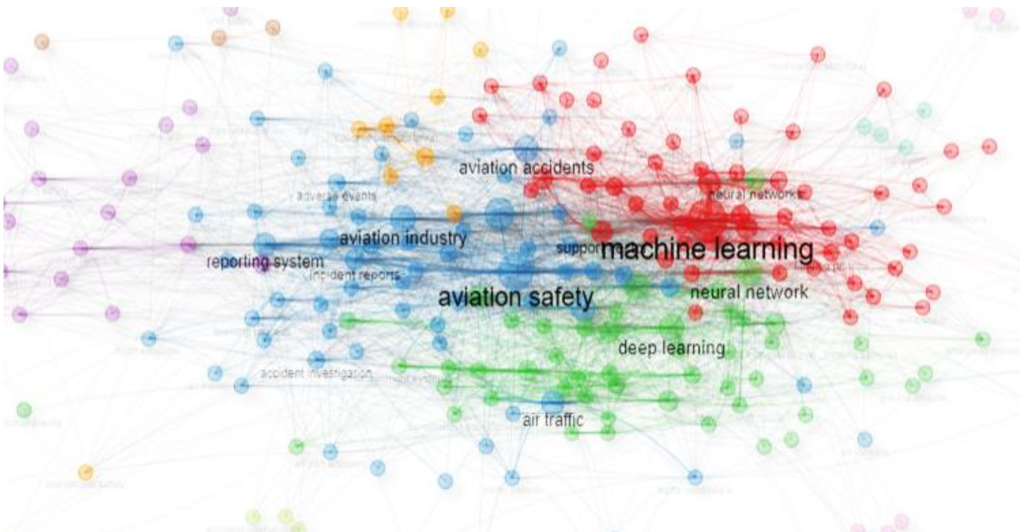


Table 3
Leading Theme Clusters (Biblioshiny Package Conceptual Structure)

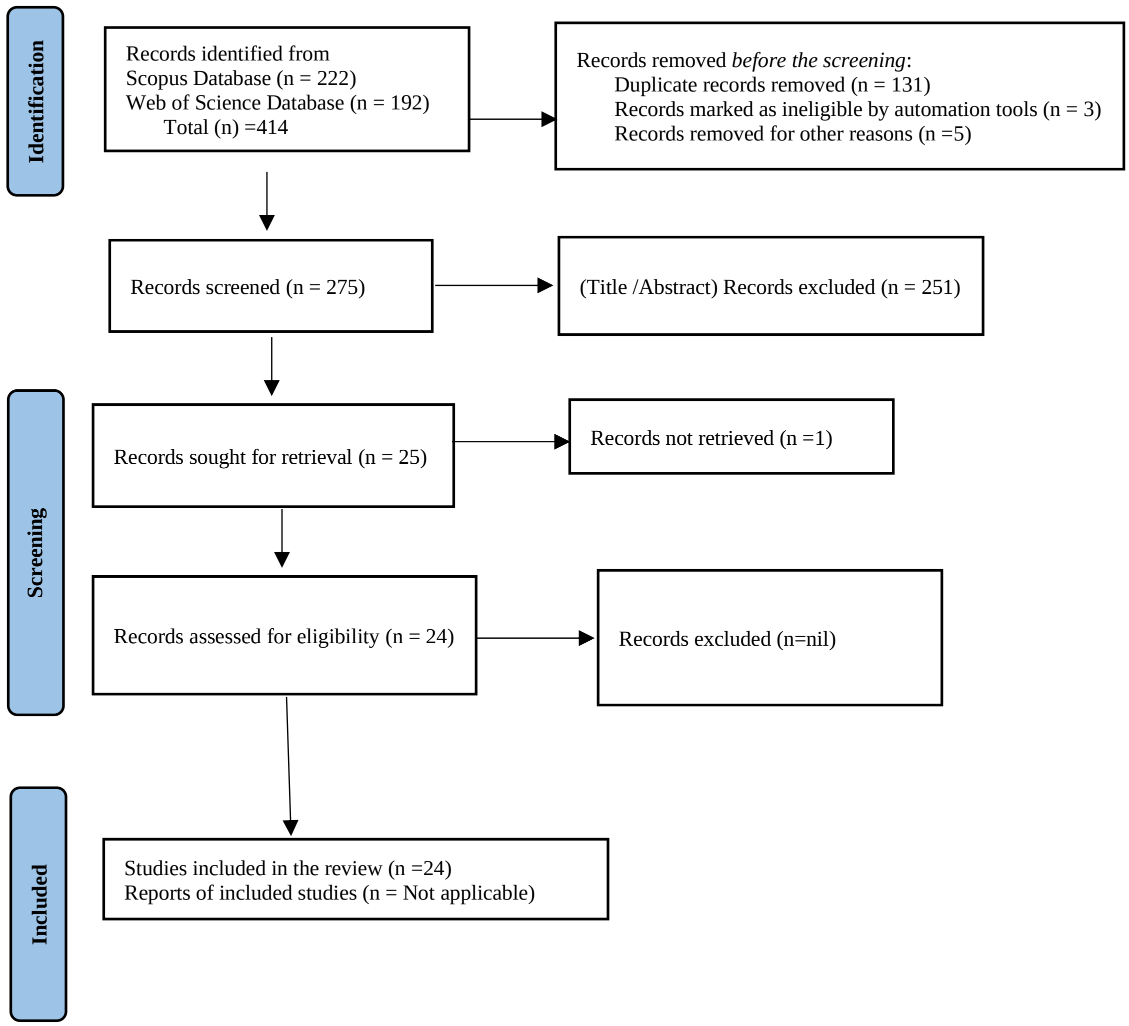
Cluster	Callon Centrality	Callon Density	Cluster Frequency
Risk Management	3.824770041	40.84399284	136
Safety Board	2.344748677	42.26041667	50
Aviation Safety	14.57035398	39.03936789	473
Machine Learning	10.57565842	76.50302407	335
Air Traffic	9.878986159	40.12692826	212

Study Selection

The selection of eligible studies is meant to address RQ3 and RQ4 by a systematic review complying with PRISMA Protocols. The Scopus and Web of Science merged file containing 283 unique records with 30 variables is the base document for the systematic review. Firstly, the number of variables in this file was reduced to four (authors' name, publishing year, title, and abstract) for easy handling. While screening, five studies were without 'Abstract,' and three more studies were still observed in duplicate because of republishing, differences in text, and articles in title/abstract fields. All eight records were removed, thus making the eligible study count 275 for the 'Title /Abstract' screening.

'Title/Abstract' screening is based on the inclusion and exclusion criteria defined in the methodology section. The first and third authors independently performed the 'Title/Abstract' based screening, which subsequently, the second author compared both authors' recommendations and finalized 31 studies for retrieval and further analysis. This approach was followed to reduce the bias in deciding the eligibility of the studies for the review. Eventually, 24 studies were observed as eligible for inclusion criteria and selected for analysis. The PRISMA flow diagram (Figure 11) exhibits the details of literature screening.

Figure 11
PRISMA flow diagram



Discussion

This section summarizes the studies on 'learning from the past' in two parts. Firstly, the bibliometric metadata-based overview of the studies followed by the characteristics of the included studies aligned with the regulatory framework.

Descriptive Analysis

Descriptive analysis provides an overall understanding of the research work and its evolution among researchers, academic institutions, and geographical areas. Academic literature progress on ‘learning from the past’ can be divided into three phases (Figure 4). Firstly, the period from 2000 to 2009; perhaps, during this phase, the subject could not attract the attention of researchers as manifested in the research papers count in a single digit. The second, from 2010 to 2018, the period of fluctuation, and finally, the last five years wherein the contribution of the researchers is on a consistent rise and the subject is gaining momentum. Another parameter is the contribution by countries. The USA and China have been the dominant contributors (Figure 5); however, China is emerging to work beyond national boundaries as having maximum multiple country publishing (MCP) research articles. The country of an article is decided based on the origin of the corresponding author. The mainstream of publications is in the Single Country Publication (SCP) category, which can potentially restrict the literature range to a specific environment rather than a broader spectrum of different past events' causal and contributory factors. Since the commercial air transportation sector is recognized as a global industry, a collaborative approach in research based on the safety data of different cultures and operating environments is likely to add more value to safety management. The attribute ‘source’ could indicate the societal need and researchers’ interest. Only six journals have published five or more research articles since 2000. The journal ‘Safety Science’ is the leading source of literature with 21 research articles (Figure 6), followed by ‘Aerospace’ with contributions in double digits; otherwise, the majority (90%) of journals have published either one or two articles on ‘learning from the past’ in the last 23 years. Authors' affiliations to publications indicate the prominent academic institutions contributing to ‘learning from the past’ in the aviation research field. This variable gains more significance as associations drive the productivity of authors and vice versa, and Chinese universities have a clear edge over others on this parameter.

Word Cloud and Thematic Mapping Analysis

A ‘word cloud’ is an analytical tool demonstrating the word frequency in the selected text proportionate to word image size. It has several limitations and does not accurately communicate the contents' meaning and context (Atenstaedt, 2021). However, the ‘word cloud’ guide to understanding information similarities in the specific text data (Kabir et al., 2020). Word clouds in bigram and trigram settings (Figure 8 and Figure 9) are consistent and indicate the domination of various machine learning techniques in research studies. On the other hand, thematic mapping analysis permits finding the center of interest of the collection corresponding to a given research topic (Aria et al., 2021). The variables, density and centrality, are the two important indicators of a cluster, where centrality demonstrates the degree of relations with other networks, and density indicates its internal strength (Cobo et al., 2018). Figure 10 and Table 3 show that using various 'machine learning' algorithms in aviation safety and other sectors is a leading theme in research studies.

Study Characteristics in the Reactive Methodology-Based Learning Framework

The characteristics of the included 24 studies are presented chronologically in ascending order of publishing year under the learning framework's different stages, i.e., reporting, investigation, safety information, and learning.

Reporting

In the context of ultra-safe and high-reliability organizations, Lofquist (2010) examined the effect of deliberate significant strategic organizational changes on the safety outcomes of an aviation service provider. The study suggests that there may be more appropriate methods to define safety performance in the aviation industry than conventional indicators (accidents/incidents). Reporting latent failures, particularly during system changes, may provide critical safety information for impending disasters. In the context of learning from past near-misses, (Madsen et al., 2016) examined large U.S. commercial airlines (having annual turnover of USD 20 Million or more) that operated from 1990 to 2007. The study finds that airlines improve their safety performance by learning from their past accidents as well as the accidents of other airlines. Also, the near misses with clear signs of danger that could have resulted in accidents, airlines are keen to learn. Contrary to this, the airlines do not fully utilize the learning potential from near misses with a lower magnitude of the threat and not obviously dangerous. Broadening the reporting of such events by the stakeholders, flight crews, air traffic controllers, ground crews, maintenance personnel, etc., and utilizing the data for safety improvement is essential.

Lawrenson and Braithwaite (2018) studied eleven commercial aviation accidents concerning individual and corporate criminal prosecution/conviction. The study analyzed the regulatory intent of organizational safety culture and safety reporting stage (one of the critical attributes of SMS) in light of the prevailing criminal justice system at national and global levels. The study concludes that regulatory efforts may be counterproductive if SMS regulations are not harmonized with the legal justice system. Wang (2018) evaluated a defense aviation audit system in a commercial SMS framework. The study subdivided safety culture into reporting, informed, just, and learning/adaptive cultures. Based on the participation of the crew members, it established relationships amongst the different cultures. Patriarca et al. (2019) examined the EUROCONTROL-developed Toolkit for Air Traffic Management (ATM) Occurrences, abbreviated as TOKAI, meant for unified and structured reporting for Air Navigation Service Providers (ANSPs). The study explores various features of TOKAI and suggests integrating with a common language and taxonomy for utilization as a safety management support tool based on past safety occurrences and near misses on day-to-day processes.

Cross (2022) argues for reporting positive human performance, especially in challenging circumstances (process surprises). The study conducted in a flying training setting suggests recording the certified flight instructor's (CFI) behavior for resilient performance is related to two stages; 'reporting' and 'investigation.' The study primarily emphasizes the enhancement of safety information. Instead of focusing only on safety information from the adverse outcomes for safety management, it advocates for safety information yielded from resilient performance under various challenging aviation activities. Both adverse and resilient outcomes are part of 'learning from the past' and have the potential to enhance safety performance if encouraged by the regulatory framework.

Investigation

A specially invited paper (Rose, 2004) highlights and differentiates the quality of investigations between the accidents (severe consequences) and incidents (minor effects), or, in other words, the investigation conducted by the State with multiple agencies and the organizational internal departments. The paper suggests that system barriers and redundancies must be strengthened instead of blaming an individual for failures. In pursuit of identifying the factors that contribute to and support learning at various levels, Hovden et al. (2011) analyzed the safety investigation reports of three Norwegian accidents, including one in the aviation sector. The study's findings include the conditions for the learning-centered investigation process, the investigation's recommendations and context, following the safety information, and the changes demonstrated in the organizational approach. Arnaldo Valdés and Gómez Comendador (2011) explored the reasons behind the revised regulation on the "investigation and prevention of accidents and incidents in civil aviation."

Stoop and Dekker (2012) evaluated the potential of the 'safety investigation stage in the SMS context. The study identifies the characteristics of modern safety investigations, which essentially contain evidence and knowledge-based safety information with a systemic approach. A contemporary safety investigation of a safety occurrence provides a case-based learning opportunity assuming the role of an independent safety assessor. Thoroman et al. (2019) analyzed sixteen serious incident investigation reports applying Rasmussen's risk management framework from the database of *Bureau d'Equetes et d'Analyses* (BEA), a French air accident investigation agency. The study focuses on identifying the factors that limit the effect of an occurrence to an incident and prevent it from being an accident. Systemically identifying the factors responsible for keeping an event a 'near-miss' and contextualizing these into safety information for learning from the past can improve safety in the aviation industry. Carrera Arce and Baumler (2021), studied the human factors and just culture-related aspects in the aviation and maritime sectors of the EU-funded SAFEMODE project under the Horizon 2020 program. The study is related to two stages of learning from the past: the investigation and the reporting stage. The study underlines that 'human error' is identified as a causal or contributory factor in 60% to 80% of aviation accidents. It is not just about front-line workers and their characteristics; 'human error' is much beyond that, and if all the aspects are not included in the investigation reports, learning from the past is adversely affected. On the other hand, 'just culture' is a prerequisite for creating a trusting atmosphere between the management and the front-line workers in which they openly report safety-related issues without fear of blame.

Tusher et al. (2022) analyzed the major accidents from 2017 to 2022 of the European Union's "Major Accident Reporting System" (MARS) database and underscored the importance of Non-Technical Skills (NTS) in the investigation reports. The MARS database does not specify NTS deficiencies in the investigation reports and usually underlines the supervision, operator error, organizational attitude, procedures, and training as prevalent causes of accidents. The study illustrates that accident reports are generally superficial and that including non-technical aspects such as situational awareness, problem-solving, decision-making, communication, and time management of the frontline workers and the management may enhance the safety of the process. The quality of investigation is related to learning from the past, and a comprehensive investigation framework provides more opportunities for learning to organizations and individuals. (Stroeve et al., 2023) argue that human factors in aviation safety investigations need to be more safety management-centric. The study suggests a four-layered taxonomy to classify human factors while investigating accidents and incidents.

Safety Information

Walker (2017) explored the history of black boxes, i.e., flight data recorders (FDR) and cockpit voice recorders (CVR), and underscored the availability of safety data with stakeholders. It suggests that despite abundant data, opportunities to use it to 'learn from incidents' are vanishing because of improved safety standards. This aspect prompts a fundamental question on what incidents and learning from incidents mean and what it could look like in practice. Another study (Inan & Topal, 2020) compares two accident investigations and underscores the importance of FDR and CVR data in comprehensive analysis and learning from the past.

Learning

Carroll and Fahlbruch (2011) summarize the papers presented in a workshop on accidents and incidents as a ''gift of failure.' In other words, these safety occurrences offer learning potential to the stakeholders and possibilities to introduce beneficial changes to organizations, technologies, and mental models. All the papers were organized into three categories: "the process of event analysis, the relationship between event analysis and organizational learning, and learning at multiple system levels." A study conducted in a formal aviation education environment consisting of students and flight instructors with a wide range of experience (Grant Wofford et al., 2013) examined the informal learning of aviation instructors. Based on the incidental and informal learning model, the study describes the complexities of informal learning and relates to the prerequisites of such learning.

In the aircraft maintenance organizational setting, Cromie et al. (2015) evaluated the human factor continuation training mandated as a tool for hazard identification and risk management in the SMS framework. One of the study's assumptions is that while organizations invest considerable resources in demonstrating compliance with the training regulations, the same attention is not given to ensuring its impact on the organization. The study suggests that human factor training should be designed for the organizational context, need, and profile. Gerede (2015) studied the implementation of SMS in the aircraft maintenance industry of Turkey. The study focused on the barriers experienced while implementing SMS at different levels in the organizational setting. Following a qualitative data collection approach, SMS specialists, professionals from aircraft maintenance organizations, and representatives of regulatory authorities participated in the brainstorming session, and the barriers to implementing the SMS at the activity level were identified. The perception of front-line aircraft technicians and engineers about the 'Just Culture' is critical to SMS's success. Based on the response to a survey conducted with airline employees (Rawashdeh et al., 2021), the relationship between organizational learning, knowledge management, and organizational performance was measured. Although this study is not directly related to hazard identification by reactive methods framework, it underscores the importance of knowledge (potential outcome of accident investigations) management and organizational learning to an aviation organization's operational (safety) performance.

The National Transportation Safety Board (NTSB) commercial airline accident database was examined from 2008 to 2018 (Kim & Rhee, 2021). The study views learning from the past through the inter-organizational perspective as with enhanced safety standards; organizations on their own have insufficient opportunities to learn. Regarding the practical aspects of accident-related information sharing, the study's outcome shows that airlines are likelier to share safety information and learn in an alliance setting. Clare and Kourousis (2021a) analyzed the 15 Mandatory Occurrence Reports (MORs) from "The European Co-ordination Centre for Accident and Incident Reporting Systems (ECCAIRS)" against Dupont's 'dirty dozen' taxonomy of human factors related hazards in the aircraft maintenance industry. The study underlined the inadequacy of learning from past safety occurrences in aircraft maintenance organizations. To briefly summarize, learning from past safety occurrences, a reactive safety management

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method has the potential for formulating proactive safety management strategies provided organizations have a robust training mechanism, just culture, and regulatory oversight (Clare & Kourousis, 2021b). Semi-structured interviews based on qualitative research underscore the importance of just culture and continuity training programs in aircraft maintenance organizations and draw attention to shortcomings associated with investigations, the contents of training programs (learning from past contents), and regulatory guidelines applicable to the learning process.

Each included study has its objective and is not exclusively conducted within the settings of the learning framework. In this review, research articles are grouped under different stages based on the scope and leading theme; however, three studies are distinctly related to multiple stages and are therefore included in more than one group. A stagewise summary of the included studies is exhibited in Table 4.

Table 4

Included Studies vis-à-vis Learning Stages

Stages of Learning Framework	Studies
Reporting	(Lofquist, 2010) (Madsen et al., 2016) (Lawrenson & Braithwaite, 2018) (Wang, 2018) (Thoroman et al., 2019) (Patriarca et al., 2019) (Carrera Arce & Baumler, 2021) (Cross & Kiernan, 2022)
Investigation	(Rose, 2004) (Hovden et al., 2011) (Arnaldo Valdés & Gómez Comendador, 2011) (Stoop & Dekker, 2012) (Thoroman et al., 2019) (Carrera Arce & Baumler, 2021) (Cross & Kiernan, 2022) (Tusher et al., 2022) (Stroeve et al., 2023)
Safety Information	(Walker, 2017) (Inan & Topal, 2020)
Learning	(Carroll & Fahlbruch, 2011) (Grant Wofford et al., 2013) (Cromie et al., 2015)

	(Gerede, 2015) (Rawashdeh et al., 2021), (Kim & Rhee, 2021) (Clare & Kourousis, 2021a) (Clare & Kourousis, 2021b)

The bibliographic review provides an overview of the 'learning from the past' regarding its progress with time, literature sources, and institutional and geographical contributions. In the all-inclusive systemic approach of SMS, the attribute 'contribution by countries' becomes significant as it has the potential for data sharing among diversified operating cultures and environments. However, most publications in this domain are in the SCP category. This trend is likely to restrict the flow of safety information. Since CAT is a global industry, a collaborative approach among different cultures and operating environments will likely add more value to safety management. The 'word cloud' and 'thematic map' are in unison and demonstrate the dominance of various 'machine learning' algorithms in research studies. On the other hand, a systematic review adds to the present understanding of the subject in the commercial transport industry. The researchers adequately explored each intermediatory stage of the learning framework except the safety information stage, with only two studies on FDR and CVR data.

Related to the 'reporting' stage, almost all the studies have underlined the necessity for reporting events of lower consequences and drawing learning value from it, which is in unison with the regulatory SMS framework. However, there are two approaches: firstly, reporting positive actions that restrict an event at lower consequences instead of becoming an accident, and secondly, harmonizing SMS regulations with the criminal justice system. While the regulatory framework supports reporting negative outcomes, its inadequacy is underscored in reporting positive actions in the challenging environment for learning from the past. Similarly, the SMS regulations of the aviation industry vis-à-vis the criminal justice system is an area that needs attention for a productive and effective SMS. The 'investigation' is the learning content generation stage. The regulatory guidelines on 'investigation' have been regularly amended and revised since their adoption in April 1951. Annex 13 (ICAO, 2020), the 12th edition, is currently applicable for investigating aircraft accidents and incidents. The dynamic nature of this regulatory document is likely to create inconsistencies in the investigation reports, which in turn introduce gaps in the learning process. Therefore, contextualizing safety information generated by old investigating reports becomes substantial before learning contents are included in training/learning programs. The industry stakeholders with a business-centric approach may not devote resources to this seemingly insignificant activity until recommended by regulations and accordingly audited.

Another aspect of the investigation stage is related to quality, and scholarly research suggests that the ‘human factors’ and ‘non-technical skills’ of front-line workers need more comprehensive analysis during the investigation. The two researchers explored the ‘safety information’ stage, focusing on CVR and FDR data to ascertain causal and contributory factors. The scholarly views on the ‘learning’ stage indicate that organizations invest considerable resources in demonstrating compliance with regulatory agencies instead of achieving the objectives of training/learning. This area needs to be explored to underline the factors related to organizational safety and learning cultures. The systematic review could recognize studies about different stages of learning from the past. However, no study has been conducted on ‘learning from the past’ in the aviation industry by combining all the stages in which each stage's impediments and catalysts are underscored and measured.

Conclusion and Future Research

Studies indexed in the Scopus and Web of Science databases had their precise aim and were not intended to be aligned with the objectives of this review. Nevertheless, a well-defined literature search and inclusion/exclusion criteria could identify 24 studies to achieve its goal. This review was conducted following a novel approach wherein scholarly literature was evaluated in the regulatory framework to address the practicalities of the aviation industry. The review's findings possess the potential to contribute and add value to the existing knowledge base. The key findings, along with trends and gaps identified in the academic research, are listed below:

- The descriptive analysis highlights the need for collaboration among countries to include the diversified safety and work cultures prevailing in different geographies and organizations. The ‘word cloud’ and ‘thematic mapping’ demonstrate the extensive application of artificial intelligence and related concepts in data handling and modeling of different sectors of aviation safety. However, the current regulatory framework has yet to embrace these technological advancements' potential.
- In the context of this review, ‘learning from the past’ is essentially a data-driven decision-making process for hazard identification. Thus, attempting to learn only from the adverse outcomes may not suffice for learning from the past. Safety information yielded from resilient performance under various challenging aviation activities is equally valuable, and the researchers may further explore this aspect to enable regulators to provide supporting guidelines.
- While ‘reporting’ events with minor consequences (near-misses) is a weak area, the quality of ‘investigation’ also has inherent shortcomings. Both

attributes are related to learning from the past and can adversely affect individual and organizational learning.

- Study characteristics also underline the organizational outlook on learning from the past. Organizations are more inclined to demonstrate regulatory framework compliance instead of evaluating the impact of various learning/training programs mandated by the regulations. This aspect is equally important for the regulators as merely auditing the organizations on compliance may be counterproductive.
- The trend of the included studies reveals that 'learning from the past' has not been explored holistically following the SMS intent, i.e., as a reactive hazard identification tool. A clear research gap is associated with understanding this reactive methodology-based hazard identification process. One of the methods is to identify each stagewise barrier and catalyst for learning and quantify the learning from the past by evaluating the variations in reporting unsafe acts/unsafe conditions /near misses, etc.

This review is based on assumptions (specified in the methods section) and restricted to only two databases, so it is not comprehensive. This review attempts to set an agenda for the researchers to investigate the individual and organizational learning from the past process in the current regulatory environment and for regulators to evaluate the impact of various training/learning programs intended to facilitate learning.

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